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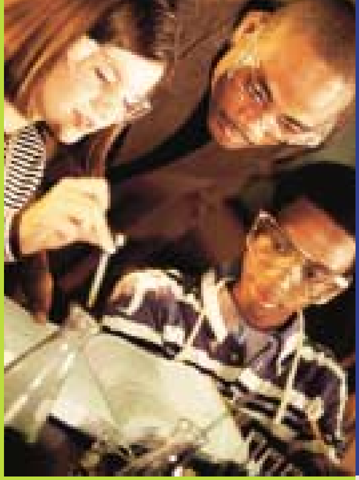

2005

The State of State SCIENCE Standards

by Paul R. Gross

WITH

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TABLE OF CONTENTS

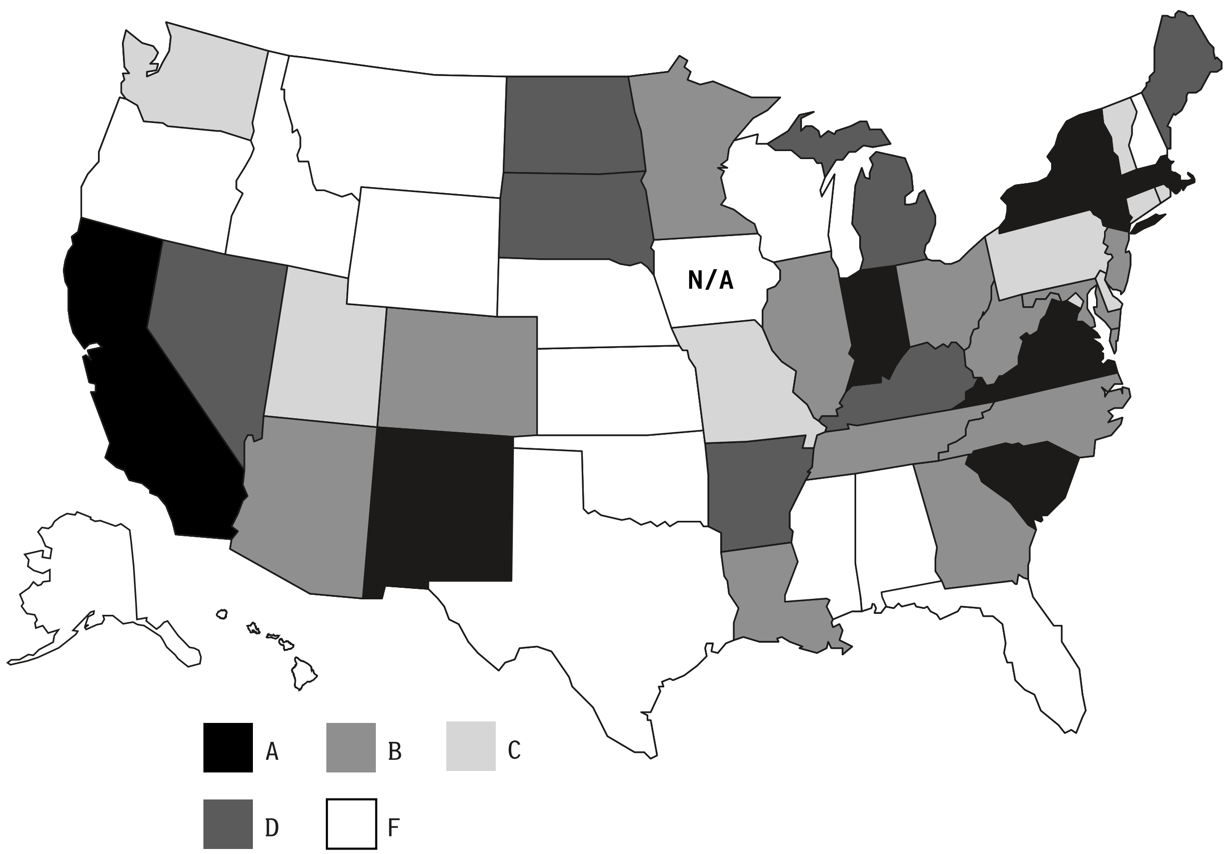
EXECUTIVE SUMMARY

The nation's policy and business leaders are increasingly and understandably anxious about maintaining America's scientific and technological leadership in a competitive world. Naturally they look to the education system, where they issue urgent calls for higher standards and greater rigor. But are states heeding the calls? In setting standards for their K-12 science programs, are they expecting enough of their students? As they prepare to implement the No Child Left Behind Act's science testing mandate, are states seizing the opportunity to raise the bar to a level that will ensure the nation's scientific prowess in years to come?

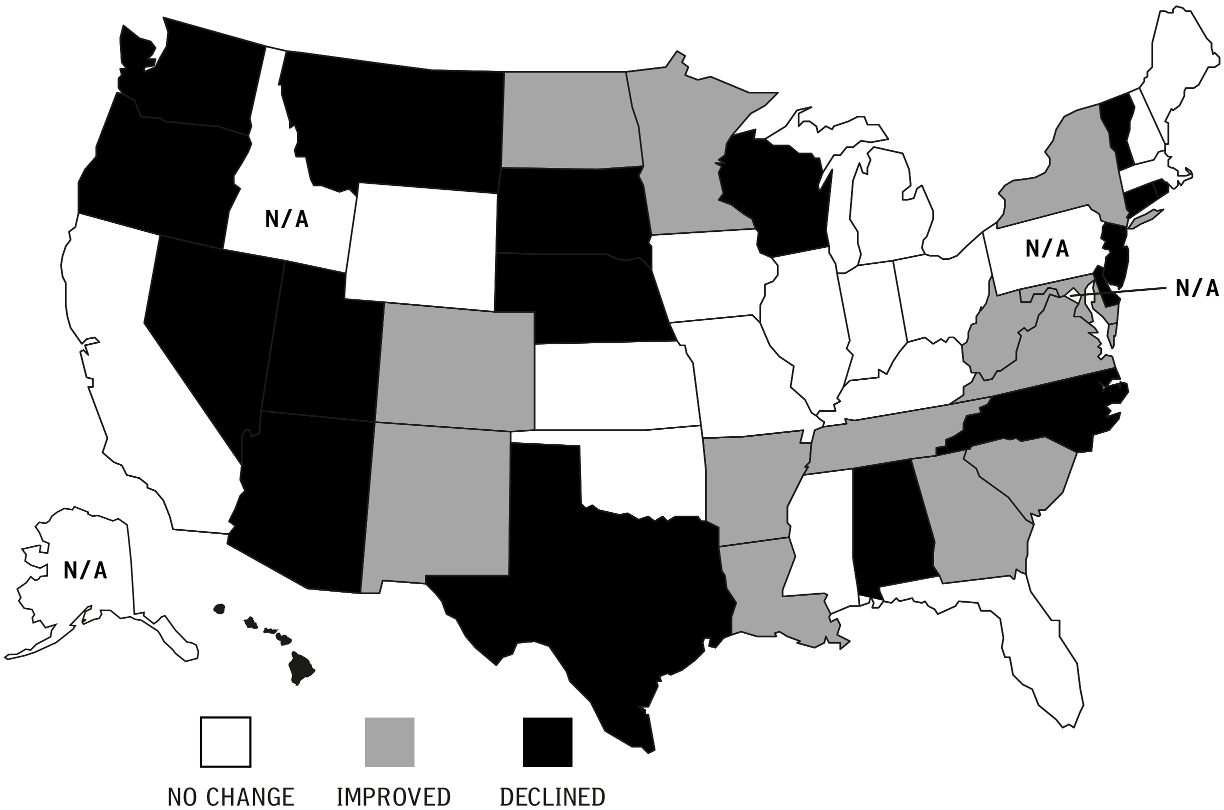
The answer—provided in this, the first comprehensive review of state science standards since 2000—is mixed. The good news is that 19 states have put in place standards clear and rigorous enough to earn them an "honors" grade of "A" or "B." Over half of U.S. children attend school in these states. Unfortunately, 15 states deserve failing grades, signifying either that they have no real standards for their science program, or that their standards are so vague and weak as to be meaningless. The remaining 16 jurisdictions get "C" or "D" marks. (Iowa is not included because it does not publish science standards.)

Have the states raised their expectations over the last half-decade? As is apparent on page 6, most states received a different grade in 2005 for their science standards than in 2000. However, while state standards are very much in flux, the nation, in its entirety, is neither making progress nor losing ground when it comes to expectations for what students should learn in science during the K-12 years. The same number of states received "honors" grades this year as in 2000, while the percentage of failing grades inched up just slightly from 26 percent to 30 percent. This flat trend line at the national level is worrisome, especially as America's world competitors make their own countries' science education a major focus.

Assigned letter grades for 49 states and the District of Columbia



Trends in grades from 2000 to 2005 for 49 states and the District of Columbia.

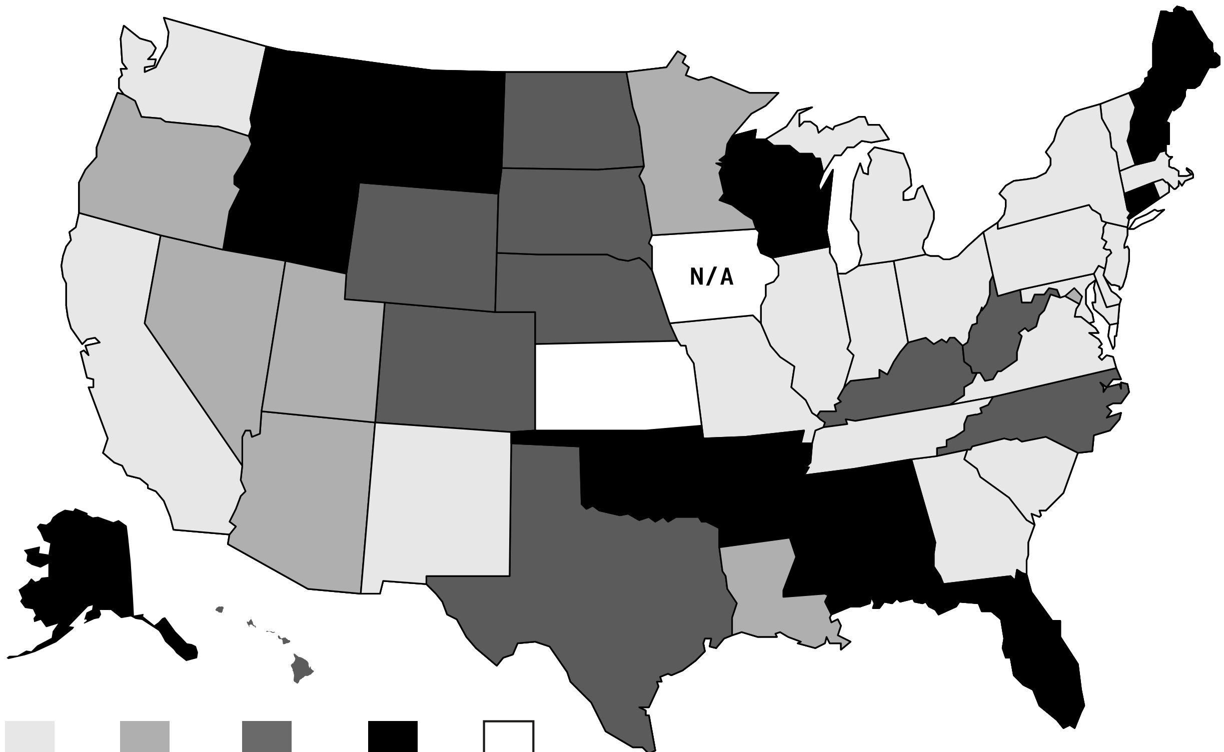


Common Problems

Some states—notably A-rated California, Indiana, Massachusetts, New York, New Mexico, South Carolina, and Virginia—produced exceptional academic standards documents that, if followed in the classroom, would result in excellent science programs. But most state standards have serious problems. These include:

1. **Excessive Length and Poor Navigability.** Sprawling, almost impenetrable documents, uncontrolled in size and poorly organized, are too common a result of a push to cover everything.
2. **Thin Disciplinary Content.** States' zealous embrace of "inquiry-based learning" has squeezed real science content (astronomy, biology, chemistry, ecology, physics, etc.) out of the curriculum to make room for "process." Of course, without content, there is little for science students to process.
3. **Do-It-Yourself Learning.** Many state standards documents take a very good idea—*Whenever practical, science learners should find things out for themselves*—and take it to an absurd level, declaring that all knowledge should be "discovered" by the student rather than passed along by the teacher. In many areas of science—e.g., atomic structure, plate tectonics, population genetics, thermodynamics—this is simply not possible.
4. **Good Ideas Gone Bad.** Too many state standards documents create a false dichotomy between "rote" and "hands-on" learning. Of course students should engage science in the laboratory or field, but they also must learn and memorize some things—facts, words and definitions, and problem-solving techniques, for example. Yet many states minimize the importance of the latter. At the same time, several states promote the fallacious idea that "all cultures" have made similar contributions to science. Alas, that's simply not true.
5. **Shunning Evolution.** A disturbing and dangerous trend over the past five years, in response to religious and political pressures, is the effort to water down the treatment of evolution, as shown by the map on page 7.

Treatment of Evolution in 49 States and the District of Columbia



Evolution

The attack on evolution is unabated, and Darwin's critics have evolved a more-subtle, more dangerous approach. A decade ago, the anti-evolution movement, which acquired a command post and funding source in the Discovery Institute of Seattle, Washington, argued vigorously for explicit teaching of the evidence for intelligent design—for the role of external, conscious agency in the history of life on Earth. When examined by qualified scientists and mathematicians, however, that evidence turned out not to be evidence, and so it remains—no evidence—at the time of writing. The promoters of intelligent design creationism have perforce retreated to arguments that invoke the popular and conveniently vague educationist formula, "critical thinking." 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.

Still, even under relentless attack, defenders of the teaching of evolution are holding their ground. In fact, comparing this year's scores of how states are handling evolution with the scores assigned in 2000, when Dr. Lawrence Lerner did a similar survey for Fordham (See table 6 on page 25), we find that the teaching of evolution hasn't changed much. Twenty states earned a "sound" grade this year for their treatment of evolution, down slightly from 24 in 2000. The number of states earning "passing" grades held steady at 7, while those earning "marginal" grades rose from 6 to 10. Failing grades (or worse, as in Kansas) held steady at 13

FOREWORD

Science education in America is under assault, with "discovery learning" attacking on one flank and the Discovery Institute on the other. That's the core finding of the first comprehensive review of state science standards since 2000.

Academic standards are the keystone in the arch of American K-12 education in the 21st century. They make it possible for a sturdy structure to be erected, though they don't guarantee its strength (much less its beauty). But if a state's standards are flabby, vague, or otherwise useless, the odds of delivering a good education to that state's children are worse than the odds of getting rich at the roulette tables of Reno.

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. When joined to a workable assessment-and-accountability system, they become far more than a blueprint. They become benchmarks by which to determine whether a child is promoted to the next grade or receives a diploma at the end of high school. They become the criteria for judging whether a school is effective, whether it warrants accolades or interventions, and whether, in a regimen of options and choice, it's worth selecting for one's daughter or son.

Until now, the No Child Left Behind Act of 2001 (NCLB) has focused everyone's attention on reading and math—and on whether schools are making "adequate yearly progress" in those two core subjects. Although some states incorporate additional subjects into their own accountability systems, reading and math have dominated most discussions of state standards, student achievement, and school performance.

That's about to change, with the addition of science to the NCLB regimen. Federal law requires that, beginning in 2007-2008, states must test students in science at least once in grades 3-5, once in grades 6-9, and once in grades 10-12. While the science results don't (yet) influence whether a school makes "adequate yearly progress," they must be reported at state and district levels. Formal consequences are avoided, but not sunlight, praise, and shame.

Thus the NCLB accountability spotlight will soon start illuminating states' and schools' and students' performance in science as well as reading and math. (Some of us wish it would do the same for history, but I'll defer that discussion for a later time.)

But the importance of sound science education doesn't hinge on NCLB. Its real significance has to do with the scientific literacy of the American people and the future economic competitiveness—and national security—of the United States. A recent National Academy of Sciences report concludes that "Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living." In his best-selling book *The World is Flat*, Thomas Friedman hammers the point: "The truth is, we are in a crisis now.... And this quiet crisis involves the steady erosion of America's scientific and engineering base, which has always been the source of American innovation and our rising standard of living."

Solving those problems and safeguarding our children's future means paying serious attention to science education in today's public schools.

There's plenty of evidence that it needs work. Long-term trend results on the National Assessment of Educational Progress (NAEP) show essentially no change in students' science prowess over the past 30 years. According to TIMSS—the Trends in International Math and Science Study that measures the math and science acumen of students across the globe—American youngsters' grasp of science is actually slipping. In 1995, U.S. 4th graders were outperformed by their peers in four countries; eight years later, seven other lands had 4th graders that bested ours in science.

Which brings us back to state academic standards. Sure, one *can* get a solid education in science (as in other subjects) even where the state's standards are iffy—so long as all the other stars align and one is fortunate enough to attend the right schools and benefit from terrific, knowledgeable teachers. It's also possible, alas, to get a shoddy education even in a state with superb standards, if there's no real delivery-and-accountability system tied to those standards.

But standards remain the keystone of standards-based reform as well as an indispensable feature of choice-based reform. And so, with states revising their standards and tests in time for the new NCLB mandate, we resolved to appraise the science standards of the 49 states that have them and the District of Columbia.

We had done this in 1998 and 2000, and one important question was whether the situation had improved. Five years ago, it was unacceptable. In 2000, reviewer Lawrence Lerner conferred "honors" (A and B) grades on the standards of just 19 states, Cs on 6, Ds on 9, and failing marks on a full dozen. (Iowa and four other jurisdictions had no reviewable science standards at the time.)

Science education in America is under assault, with "discovery learning" on one flank and the Discovery Institute on the other.

Since then, most states have revised or replaced (or launched) their K-12 science standards. So it was time to evaluate them again, not just because of the added weight that NCLB will place upon them but also because of the additional pressure that science education has come under from the forces of anti-science, particularly (though not solely) the neo-creationists flying the banner of intelligent design creationism.

To lead this appraisal, we turned to the most distinguished scientist we know who has a keen interest in K-12 education as well, biologist Paul Gross, former head of the Marine Biological Laboratory at Woods Hole and former provost of the University of Virginia.

Paul graciously assented to take on this immense task and recruited a terrific panel of experts (including Dr. Lerner) to join him. All but one member of the panel are experienced science teachers; one teaches, among other things, philosophy of science. Their combined expertise covers elementary-secondary science, university science education through the postdoctoral level, scientific research, and the management of large research enterprises. Their disciplinary coverage spans biology, chemistry, geology, and physics, as well as environmental science, epistemology, and logic. (Biographical sketches of Dr. Gross and his team are in Appendix B.)

The results of this review are now in, and we're pleased to present them—but none too pleased with what they show.

Bottom line: same as five years ago. Though a number of states did better (the criteria were similar but not identical this time), an equivalent number did worse. The revisions made in the science standards didn't always yield improvement. As you will see in the text and charts that follow, 19 states again deserve honors grades—but now there are 9 Cs, 7 Ds, and 15 Fs.

If there's good news, it's that 55 percent of U.S. children attend school in the "honors" states.

But 45 percent do not.

The seven states with "A" grades demonstrate, once again, that it's possible to craft outstanding standards despite all the pushing and pulling and hollering. That being the case, we find ourselves, once again, wondering why other states don't use *those* standards as models for their own. And yes, we also find ourselves speculating that America might be better off with high-quality national standards for science, instead of leaving every state to craft its own. How much difference is there, after all, between what kids in Jacksonville should learn about science and what those in Worcester or Terre Haute should learn? (For that matter, how much difference is there between Jacksonville and Seoul, Prague, or Cape Town?)

Five other conclusions also leap out from the pages that follow.

First, evolution is still a flashpoint and the intelligent design folks (led by the Discovery Institute) are relentless. (They've even recruited President Bush and Senate Majority Leader Bill Frist to urge "equal time" for intelligent design creationism and Darwin, which is not unlike recommending that mustard plasters and bleeding be taken as seriously as antibiotics and heart-bypass surgery.) A number of states have resisted this madness in their science standards, but too many are fudging or obfuscating the entire basis on which biology rests. Kansas is the most notorious instance of this, but far from the only one. (Other observers have reached the same conclusion. A new analysis by *Education Week* says "many … standards … fail to address the fundamental evidence supporting the theory, which explains how life on Earth developed.")

Second, "discovery learning" is getting more weight than it can support in science. This is largely due to states' over-eager, oversimplified, and misguided application of some pedagogical advice enshrined in the so-called "national standards" propounded by the American Association for the Advancement of Science (AAAS) and the National Research Council. If schools taught nothing but science, the school day *might* be long enough to contain a full measure of lab work and student-directed learning as *well* as teacher-led instruction in fundamental scientific knowledge, skills, and procedures. Given the tight limits within which science education typically occurs, however, and given many educators' proclivity to choose constructivist pedagogy over old-fashioned instruction, American students run a grave risk of being expected to replicate for themselves the work of Newton, Einstein, Watson, and Crick. That's both absurd and dysfunctional.

Third, the follies in today's "national" science standards need to be kept in mind not just by states reworking their own standards but also in any future effort to substitute national for state standards. The swarming panels of science educators that drafted a new science "framework" for the National Assessment of Educational Progress (NAEP) delivered a weak product. (See Fordham's recent report, *Less Than Proficient: A Review of the Draft Science Framework for the 2009 National Assessment of Educational Progress.*) The National Assessment Governing Board wisely adjusted their draft—but this bears close scrutiny as NAEP moves from framework to actual science test (slated to start being used in 2009).

Fourth, many of the shortcomings in states' science standards are easily fixed. What they mainly need (apart from the simple remedy of substituting the outstanding versions already crafted by other states) is deeper involvement by bench scientists and better editing!

Fifth, and finally, it bears repeating that terrific standards are no guarantor of a terrific education being delivered or absorbed. Science may be the subject that U.S. teachers are least able to teach well—and the subject where traditional personnel practices for teachers (e.g., ed-school preparation, state certification, uniform salary schedules) are least apt to yield the teachers we need in 2005.

Based on the avalanche of recent commission reports, high-profile speeches, and calls for action, it appears that the nation's policy and business elite is ready to raise the bar on U.S. science education. State science standards are the right point of leverage. It's past time to get these right.

We are indebted to many individuals and organizations for making this study possible. Allow me, in particular, to thank the Carnegie Corporation of New York and the Ewing Marion Kauffman Foundation for their financial assistance and wise counsel. At the Fordham Institute, Michael Connolly and Justin Torres gave birth to the project and saw it through its toughest days. Martin Davis, Jr., Liam Julian, and Michael O'Keefe helped it across the finish line. Anne Elliott corrected our many errors and omissions. And the layout and design talents of Holli Rathman are evident throughout this report; we appreciate her hard work and endless patience. Most importantly, we thank Paul Gross and his colleagues (Ursula Goodenough, Susan Haack, Lawrence S. Lerner, Martha Schwartz, and Richard Schwartz) for their tireless commitment and sound judgment. This was no easy undertaking and they gave it their all.

States' science standards are easily fixed. What they need is deeper involvement by bench scientists and better editing!

• • •

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— Chester E. Finn, Jr., December 2005

Members of the evaluation team were at times, in the course of this review of K-12 science standards, greatly encouraged. A few of the best documents we examined could serve as models for other states. They are worthy of the positive things we say about them. But we have some general and serious concerns about the universe of these documents. In the order of the discussion that follows, these are about problems of: excessive length, poor organization, and careless writing; inadequate disciplinary content; vaguely, often empty, constructivist sentiments; mere catchwords signifying a strong empirical base for the design of standards, which base is in fact weak; and, (in some cases) a politically motivated avoidance or minimizing of evolutionary biology.

More about these problems later in the report.

We start by describing in detail the criteria upon which we based our judgments of the standards. These criteria are somewhat altered from the set used in the Fordham Foundation reports of 1998 and 2000. Explanatory comment is therefore interspersed. Such comment covers changes in the criteria, especially the addition of two new ones necessitated by recent trends. They are concerned with scientific inquiry and the handling of evolutionary biology. Methods employed in applying the criteria to the objects of study are described next. Then we present quantitative results of the evaluation, including tabular and graphical displays of scores, ranks, and grades, and we consider the progress (or lack thereof) made since 2000. Next, we discuss common problems found in many of the standards. A final section offers brief, but considered, summary observations on each state's standards documents, as they stood when we were able to study them. This was in most cases the late spring and early summer of 2005.

Criteria & Methods

Our criteria for evaluation of the standards fall into five categories. There are 21 main criteria, derived from and closely related to those used to evaluate K-12 science standards in earlier Fordham reviews (1998 and 2000). This relationship allows the new findings to be considered in light of, and compared with, previous studies.

Sustained public demand, as one response to the need to report progress in science education, has spurred rapid evolution of form and detail in the documentation of standards. A recent headline in *Education Week* is representative: "As Test Date Looms, Educators Renewing Emphasis on Science." This article refers to "the approaching mandates of the No Child left Behind Act…." Most states have revised or expanded their science standards documents since the last Fordham review in 2000.

Thus, what we appraise here as the offering of a particular state is most often not what was evaluated half a decade ago. Moreover, in a number of cases, what we review here will be changed again in coming months. Comparison of our reported grades with their predecessors is therefore possible, and is of interest for a number of states. But consistency is not necessarily or realistically to be expected. Our emphasis here must be on the time-slice of K-12 science standards as they were in mid-2005, and on the auguries for revisions to come, rather than on the situation in 1998 or 2000.

For some of the criteria used in the present study, we have inserted additional comments—not included in the working texts of the criteria—as an aid to the reader. Such comments are enclosed in editorial brackets—[]—immediately below the relevant text, to separate them from the criteria actually used by the reviewers.

There are a few instances of overlap between criteria in different groups. This is not accidental; the different groups represent broadly different kinds of quality judgment; so the overlap is not redundant.

Group A: Expectations, Purpose, and Audience

1. The expectation is unambiguous that throughout the primary and secondary grades all students will become scientifically literate, at levels appropriate to grade.

   [This and all the following criteria, taken together, provide an effective definition of science literacy. So defined, the condition "literate" is understood to be a minimum achievement. This is a point we must emphasize. There is no implication in criterion A1 that all students can and must become equally accomplished in science, or, conversely, that a good standard describes all that the best students know or can do.]

2. The standards can be used in designing effective assessments of student learning, theoretical and practical, appropriate to grade.

3. The presentation is as free as possible of jargon; it is lucid and comprehensible to all its audiences: educators, subject matter experts, policy makers and legislators, parents, and the general public.

   [This is very important, and for more than curriculum making and assessment design. Many of those audiences are not K-12 education professionals but are deeply, and justifiably, concerned about the quality of standards, and about the consequences of their application. Standards documents that are not *readable and lucid, not of reasonable length,* not *purged of redundancies, or not organized so that a committed and intelligent lay reader can understand them, have failed in one of their central purposes.]*

4. The standards call for student work written in good English and, where appropriate, in suitable mathematical language. They require student oral presentations that are clear, logical, and appropriate to grade.

Group B: Organization

1. Standards are organized by grade or by clusters of no more than four grades.

2. They are grouped in categories or themes that reflect the fundamental theoretical structures in modern science. Examples: Newtonian dynamics; conservation of mass and energy; cosmological evolution; plate tectonics; cells and organisms, inheritance, populations and ecosystems, and organic evolution.

   [Evolution—organic, planetary, cosmological, and formal (as in computer science)—is one of those fundamental theoretical structures of modern science. For the life sciences it is the central one. Thus it must not be ignored, nor hidden in obscure language, nor subjected to disclaimers, which arise, not from science but from political pressures. Because such pressures have increased greatly since the last review of state science standards, it has become necessary to provide a supplementary evaluation of the treatment of evolution in each state's documents, in addition to the attention it receives automatically in the general review of life science. More on this elsewhere in the report.]

3. Classroom instruction within each topic is devoted at each grade level to developing skills of observation and data gathering; to the planning, recording, and interpretation of observations; and ultimately to the design of experiments.

Group C: Science Content and Approach

1. The standards provide explicitly for substantial laboratory and (as appropriate) field experience. Replication of classical experiments is encouraged. The importance of empirical evidence and of sound criteria for the acceptance of data is emphasized.

A few of the state standards could serve as models. But we have serious concerns about the universe of these documents.

2. Unambiguous terminology and rigorous definition are stressed. Such terms as cell, continental drift, cosmic background radiation, energy, genotype, magnetic reversal, mass, metabolism, natural selection, pH, and valence are defined as carefully as possible for the grade level in which they are introduced.

3. At appropriate grade levels, data analysis, experimental error, reliability, and the practices needed to optimize the quality of raw information are taken up—as subject matter.

4. The standards call for mastery of tabular and graphical techniques for analysis and reporting, with increasing sophistication as grade succeeds grade.

5. The continuing interplay of data and theory, and well-justified modifications of theory, are stressed at all grade levels, in a manner commensurate with student maturity. Important conceptual shifts and innovations in the history of science are elements of the curriculum.

   [This body of content has come to be dealt with, almost universally, under the head of "Inquiry," a category now treated in most standards as separate from science content categories such as "Earth and Space Science" or "Life Science." The

formats, styles, and cogency of Inquiry treatments vary enormously. We have therefore found it necessary to appraise the handling of "Inquiry" in these documents independently. More below.]

6. The primary curriculum content is an adequately representative set of basic principles, explicit or contained within science themes. Examples (only) of basics: In physics, Newton's laws of motion, conservation laws, and the macroscopic - microscopic nexus; in astronomy, evolution of the universe and the structure of its parts (including the solar system); in geology, planetary structure, and plate tectonics; in chemistry, mass and energy conservation, atomic structure, and the nature of the chemical bond; in biology, cells, organisms, ecosystems, biochemical unities, history of life, and evolution.

Sustained public demand has spurred rapid evolution of form and detail in standards documents.

7. These principles are first introduced via facts and simple examples; they emerge as themes and theory in higher grades. Students' increasing ability to grasp generalizations and abstractions is taken into account. An adequate factual knowledge base, laid down in the early grades, is deepened systematically by means of increasingly refined theory.

8. The standards emphasize recognition of good inquiry as well as some of the distinctive methodologies of natural science; but they do not oversimplify these as "*the* scientific method." Common features of every kind of competent inquiry, including good science, as well as distinctions among different disciplines, are made clear.

   [As is argued later in the report and also indicated under criterion C5, emphasis upon Inquiry has become insistent since state academic standards began to be published. This has been a matter of pedagogic more than of philosophical (epistemological) or historical emphasis. The new emphasis is due in large part to a preoccupation with inquiry-as-learning in those influential national scientific and science-education organizations attempting to guide K-12 curriculum development. Thus we have found it appropriate in 2005 to provide additional evaluation of philosophy and history of science, treated in most of these state standards under Inquiry or an equivalent name.]

9. The standards provide for careful definition of technology and do not confuse it, or its social consequences, with the content of science. They do address relationships between science and technology and the way that science has shaped the modern world.

Group D: Quality

1. The standards are demanding as to science-disciplinary content; their expectations are neither so broad as to be vague nor so narrow as to be trivial. They are neither mere prosy encouragements nor simple lists of things to be memorized.

2. They cover many of the basic understandings of physical reality as the scientific community recognizes them; but the document makes no effort to be encyclopedic.

3. The standards, taken as a whole, define a core scientific literacy for all students in all public schools of the state. At the same time, they are sufficiently challenging to ensure that students who achieve proficiency by the final year will be ready for college work.

   [Please see the comment under Criterion A1.]

Group E: Seriousness

1. Nowhere do the standards offer or encourage—as though they were science—pseudo-scientific or discredited proposals such as medical doctrines not based on objective evidence, vaguely defined "energy fields," "auras," folk-cosmologies and mythologies, creationist or neo-creationist anti-evolution disguised as "critical thinking," UFO visits, astrology, or divination.

2. Nowhere do the standards suggest or imply that basic scientific principles are race-, ethnic-, or gender-specific; nor do they distort the history of science in an effort to inculcate particular social or political doctrines.

Assigning Scores
The degree to which a standard meets the requirement of a criterion was measured on a four-point scale:

0—The requirement is not met, or its treatment is useless
1—The requirement is addressed, but incompletely, erratically, or inconsistently
2—The requirement is addressed adequately but with no distinction
3—The requirement of the criterion is met and in a thoughtful manner

Additional Review and Scoring
Two additional scores, one for Inquiry and one for Evolution, joined the twenty-one above, employing the same 0—3 scale.

a. On Inquiry.
A separate grade for Inquiry—or for *process* ("*doing* science"), or history of science, or philosophy of science, or science-and-society, or some combination of these—has, as indicated, become necessary. As standards, or threads, or benchmarks, these subjects are now treated in most standards documents as independent content or even as skills the students are expected to acquire. Yet these meta-scientific issues, accompanied as they are by fulsome praise of hands-on learning, are sometimes little more than pedagogical advocacy. They are thus of no great help in accomplishing the proper purposes of standards. In most of the documents here reviewed, Inquiry is some combination of real and useful subject matter (usually distinct from basic science) with pedagogic theory. We felt it necessary to examine this element independently of the other content areas. The score (scale of 0 to 3) was added to the final score for science disciplinary content. To earn a "3," a state that gives the now-customary prominence to Inquiry had also to offer substantive, correct, and grade-appropriate material—subject matter—on the processes of scientific inquiry or on history or philosophy of science rather than empty encouragements toward good behavior.

b. On Evolution.
"It ill befits our great people, four generations after Darwin and Wallace published their epochal discovery of evolution by natural selection, to turn our backs on it, to pretend that it is unimportant or uncertain, to adopt euphemistic expressions to hide and soften its impact, to teach it only as one alternative theory, to leave it for advanced courses where the multitude cannot encounter it, or, if it is dealt with at all in a school or high school biology course, to present it as unobtrusively and near the end of the course as possible, so that the student will fail to appreciate how every other feature and principle found in living things is in reality an outgrowth of its universal operation."

—Hermann J. Muller, 1959,
(Nobel Prize for Physiology or Medicine, 1946)[3]

Criterion E1, the first of the two concerned with seriousness about science education, denies credit points to any standards that include, *inter alia*, "creationist anti-evolutionism disguised as critical thinking." The inclusion of such anti-evolution content is a goal of contemporary "intelligent design" creationism, now overtaking other, older forms of creationism in the perennial struggle to discredit "Darwinism."[4] A decade ago, this movement, which acquired a command post and funding source in the Discovery Institute of Seattle, Washington, argued vigorously for explicit teaching of the evidence *for* intelligent design—*for* the role of external, conscious agency in the history of life on Earth. When examined by qualified scientists and mathematicians, however, that evidence turned out not to be evidence,[5] and so it remains—no evidence—at the time of writing. The promoters of intelligent design creationism have perforce retreated to arguments that invoke the popular and conveniently vague educationist formula, "critical thinking." 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.

The claim is that evidence against "Darwinism" exists.… The hidden agenda is to introduce doubt at the critical early stage of science-learning.

However, political assertions and public relations escapades to the contrary, *no* sound evidence has so far been adduced against descent with modification. In the (at least) two-billion-year history of life on this planet, evolution has been a *fact*. For creationists of all varieties, this is a painful predicament. It leaves standards-writers or school committee members who may themselves be sympathetic to creationism, or who are pressured by creationist constituencies, only two means of response. One is to require disclaimers somewhere in the standards or in the curricular materials that flow from them, to the effect that evolution is "just a theory." The clear implication of this misuse of "theory" is that evolution may be, or is likely to be, false, and in any case has not been "proven." The other main technique is to insist in the standards that nothing in the documentation or in the classroom is intended to, or can, or will, have any effect upon anyone's conflicting beliefs. This is a conciliatory move, but it leads to the smart student's dangerous question: "Then why bother to learn it?"

Most of the state documents indulging in some downplaying of evolution were also weak in other ways.

Actually, there are more practical ways of getting the desired effect, visible in the standards documents of several states. One is simple: just ignore or ruthlessly scant the history of life on earth and avoid any discussion of descent and mechanisms. Set forth a few of the basics, even to the extent of mentioning the fossil record and some interpretation of it. But then simply avoid using the E-word or hide it somewhere in a mass of secondary verbiage. Some weasel words that don't mean the same thing, such as "change over time," may be substituted. Alternatively, however fully or scantily other biological and geological content is covered, the core science of evolution—physical as well as biological—can be passed over as though it were peripheral, or a curiosity. We have found it necessary to add, beyond Criterion E1, a grade (on the usual 0—3 scale) specifically for the handling of evolution in the life sciences and the other historical sciences.

A standards document that gives evolutionary science appropriate weight, at least within biology, that introduces the main lines of evidence, including findings in the fossil record, genetics, molecular biology, and development, and that connects all this with Earth history, merits a "3." The above, but with some big gaps, gets a "2." "1" is a marginally acceptable treatment. If the treatment is useless, disguised, or absent, the grade is "0."

It has turned out that most of the state documents indulging in some downplaying of evolution were also weak in other ways, so we have been largely—but not completely—spared the burden of lowering their letter grades because of their irresponsible treatment of evolution. Kansas is a special case, however, not so much of irresponsibility as of hardball politics, in aid of sectarian religion, substituting for science education. We explain this later.

Grading

In the very large body of files and text comprising the available standards documents for K-12 science, those for most states were read by all members of the reviewing group, each reader giving special but not exclusive attention to the subject matter of his or her professional expertise. All members of the reviewing group and the author of this report are veteran teachers of science and/or philosophy of science. Their combined expertise covers school science plus university programs through postdoctoral. Some of us have been deeply involved in standards-based reform. Professor Lerner is the author of earlier Fordham Foundation reports in this series. Five members of the reviewing group are scientists as well as science teachers. One has been the director of an international research institute and a senior science administrator. The reviewers' professional science disciplines include physics, chemistry, biology, geology, and environmental science. One is a philosopher of science and the author of important texts on epistemology and logic. Throughout the period of review, there was regular and detailed exchange of views among all the readers.

The maximum number of points available for award under the scoring system is 69 (23 criteria x 3 points). Each reviewer's actual score was rendered as a percentage of that maximum. The final score for each state is the mean of the final percentage scores provided by all readers of the documents for that state. These scores were then used as primary data in the assignment of letter grades. In general, there was unanimity among reviewers about the documents from a state. That testifies to the comprehensiveness of the criteria for evaluation and to the seriousness with which each reviewer employed them in reading and comparison.

Of course, there were some state documents in which one or another of the science disciplines was especially well, or poorly, handled. Where such differences were noteworthy, they are discussed in the comments that follow. However, the final scores reported here and employed in grading are the average scores for all criteria for all reviewers.

Finally: because a single number cannot reflect important but unquantifiable properties of documents (or, more accurately, multi-documents, as are these standards), we allowed for final adjustment. Each standards document was assigned an initial letter grade based on the numerical score; but we then considered additional factors that might justifiably change it. If group opinion based on all the evidence supported such a change, the grade could be adjusted one letter up or down. In the very few cases where they arose, such considerations are mentioned in the comments on the state's standards.

We did not assign pluses or minuses. For quality judgments as complex as those required for massive and complex documents, neither the criteria nor our judgments in applying them are fine enough to justify fifteen, rather than five, grade categories.

Disclaimers: Two members of the group were involved in production of the California K-12 science standards; they did not participate here in the assignment of a grade for California. One of us was consulted for editorial assistance in the preparation of the South Carolina standards, but was not a writer of the document. One of us offered comment at an early stage of preparation of the Massachusetts standards, but again, was not involved in their writing or presentation.

Results

Score spans for the award of letter grades are shown in Table 1. Letter grades A through C were awarded for numerical spans of 15 points: the point span for grade D is shorter—10 points. The reason for this is that, when the evaluations were complete, a clear break in mean numerical scores and in overall quality was evident on both sides of that 10-point span. Forty-five through 54 points was therefore a range appropriate to what we saw as "better than failing but by no means adequate." There are, however, fewer D grades than would have been dictated by the numerical score distribution in that range. Some otherwise D-worthy standards were downgraded for failure to treat evolution seriously.

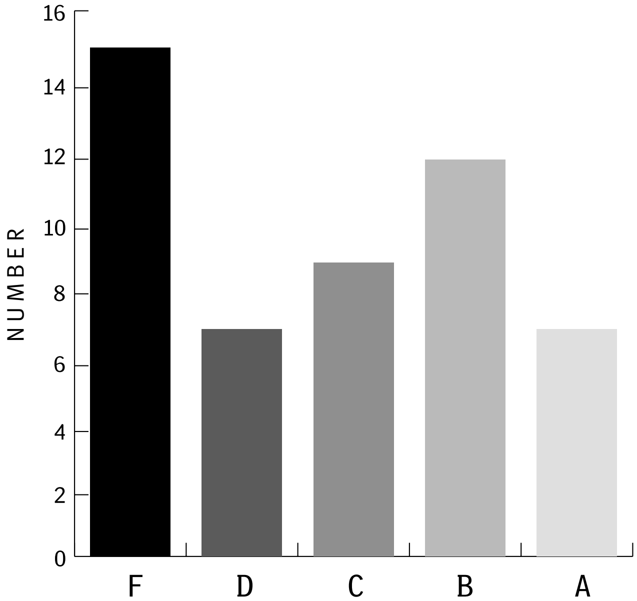
Table 1. *Initial score spans for the assignment of letter grades.*

Final Score (Percentage)	Grade
≥85	A
70 – 84	B
55 – 69	C
45 – 54	D
< 45	F

Table 2. *Final, adjusted letter grades.*

Grade	Number of States
A	7
B	12
C	9
D	7
F	15

Figure 1. *Distribution by counts (number) of final letter grades.*



The final distribution of letter grades, after adjustments, is displayed in Table 2, as well as in the bar graph of Figure 1. Average raw scores (from all reviewers of each document) by state, final percentage scores derived from them, and the assigned letter grades are displayed in Table 3 for 49 states and the District of Columbia. (Iowa does not publish academic standards.) The sort by state is alphabetic.

Distribution of all these final percentage scores by count is displayed in the histogram, Figure 2. The arithmetic mean score for N = 50 was 61 ± 20 (Std. Dev.), and the median was 63. It is disappointing that the average score was less than 70 percent of the possible maximum. One always hopes that in a fair test, with a motivated population of test-takers, it will be at least that. But the criteria were detailed and stringent, as was their application in these reviews. Attention to disciplinary content was very close. And, with exceptions to be discussed, the entire set of standards documents was disappointing.

On the other hand, the high proportion of "honor" grades indicates that the criteria applied were not unrealistic. More than a third of the states do fulfill them with honor. Within that group there is a small but significant subset of truly excellent documents. These were awarded the grade A. The population of good productions was thus quite large, so that all states whose standards documents are in the honors range (A or B) account for 38 percent of the total. That is both respectable and encouraging. The low-end tail of the distribution, sad to note, is long. On the descent toward the lowest scores, it indicates absence of serious or competent effort—so far—in many states. There are far too many "D" and "F" grades. We have seen distributions like this, on occasion, for final examinations in certain challenging, populous, introductory college courses, where a subset of the enrollees has essentially given up or has never really gotten started. It is not at all encouraging to find it, as in Figures 1 and 2, among the results of this survey.

Quality by Discipline

We observed some differences of quality in the presentation of science content for the subdivisions: Earth/space science; chemistry and environmental science; physics and physical sciences; and biological sciences. Note that the apparent separation here of chemistry from physical sciences, and the coupling of chemistry with environmental science, reflects additional expertise in the reviewing group, *not* a rejection of the now-standard subdivision of K-12 science into physical, life, and earth/space sciences.

Figure 2. *Distribution: Final Average Scores by Number of States*

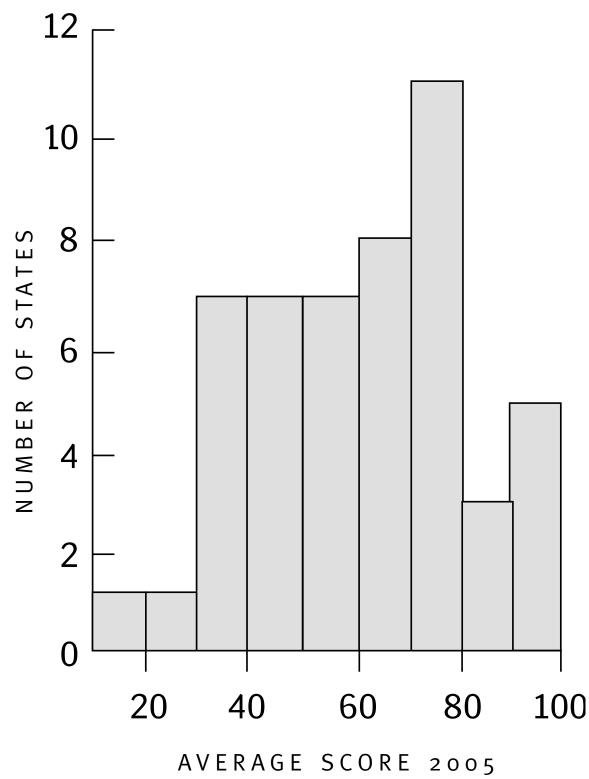


Table 3. *Average raw scores, derived final percentage scores, and assigned letter grades for 49 states and the District of Columbia.*

STATE	AVERAGE RAW SCORE	FINAL SCORE (PERCENTAGE)	LETTER GRADE
Alabama	28.8	42	F
Alaska	13.3	19	F
Arizona	49.6	72	B
Arkansas	30.8	45	D
California	66.7	97	A
Colorado	52.1	76	B
Connecticut	40.6	59	C
Delaware	46.8	68	C
District of Columbia	43.3	63	C
Florida	32.9	48	F
Georgia	51.6	75	B
Hawaii	26.9	39	F
Idaho	23.7	34	F
Illinois	48.6	70	B
Indiana	62.8	91	A
Kansas	44.7	65	F*
Kentucky	35.3	51	D
Louisiana	51.3	74	B
Maine	35.0	51	D
Maryland	49.6	72	B
Massachusetts	64.7	94	A
Michigan	32.9	48	D
Minnesota	48.8	71	B
Mississippi	32.4	47	F
Missouri	45.8	66	C
Montana	26.8	39	F
Nebraska	26.1	38	F
Nevada	35.1	51	D
New Hampshire	24.9	36	F
New Jersey	53.1	77	B
New Mexico	59.4	86	A
New York	60.5	88	A
North Carolina	54.6	79	B
North Dakota	33.2	48	D
Ohio	51.1	74	B
Oklahoma	34.8	50	F
Oregon	27.6	40	F
Pennsylvania	44.6	65	C
Rhode Island	39.9	58	C
South Carolina	64.1	93	A
South Dakota	35.7	52	D
Tennessee	57.1	83	B
Texas	23.6	34	F
Utah	42.6	62	C
Vermont	41.6	60	C
Virginia	66.0	96	A
Washington	44.8	65	C
West Virginia	48.4	70	B
Wisconsin	20.1	29	F
Wyoming	25.3	37	F

**Just before going to press, the grade for Kansas was reduced from "C" to "F," as explained in the comments on Kansas standards to follow.*

Percentage scores for the subject areas are indicated in Table 4, where the numbers are the average final scores by specific content emphasis. The average quality of handling of Inquiry, broadly understood, was about the same as the treatment of evolutionary biology (recon-

State standards are in flux, but the nation, in its entirety, is neither making progress nor losing ground when it comes to its expectations for students' science-learning.

sidered independently): just passing—57 percent of the maximum score of 3 in each case. Chemistry seems to cause more trouble for standards writers than do the other sciences. Yet its basic content is just as important for science literacy as that of any of the other disciplines. Indeed, the natural sciences have today become so interdependent that many of the traditional demarcations within the body of "basic" science have become arbitrary and are being abandoned at the research level. We might speculate that the quality differences among disciplines in the state documents speak to the science backgrounds of the K-12 standards writers, rather than to the relative difficulty of the subjects or to our biases as a reviewing body.

The tabulated results are averages, not applicable to individual standards documents. In a few cases, sound handling of content in one of these broad categories helped to pull up the mean score for a standards document in which others were weak. And vice versa. The relatively high "68" for biology does *not* represent the average quality of treatment of evolution alone.

As is apparent in Table 5, most states received a different grade in 2005 than in 2000. Of the 46 states with standards reviewed in both years, 13 earned higher grades in 2005, 14 received the same grade, and 19 earned lower grades. Does that mean that state science standards are, on the whole, getting worse? No. The same number of states received "honors" grades (A or B) this year (19) as in 2000, and the percentage of failing grades inched up just slightly from 26 percent to 30 percent. What's the lesson? While state standards are very much in flux, the nation, in its entirety, is neither making progress nor losing ground when it comes to its expectations for what students should learn in science. Unfortunately, that's hardly news worth celebrating.

Comparisons, 2000 and 2005

Table 5 compares the states' final percentage scores and letter grades from this evaluation with those reported in *The State of State Standards 2000*.[7] The sort is by 2005 final score. There is some consistency and matching, especially at the high and low ends of the grade distribution. However, there are some surprising mismatches, too. Some of these are happy. Georgia, New York, New Mexico, Tennessee, Virginia, and West Virginia, for example, have moved sharply and unequivocally upward into the honors range. A few others have moved, just as unequivocally, in the opposite direction (Nebraska, Oregon, Rhode Island, Texas, and Wisconsin). For all such cases, up or down, the dominant cause is changes in the state documents during the half-decade elapsed since they were last reviewed. Much less significant are changes in form and application of the criteria from 2000 to 2005, and in our broad but very close scrutiny of science content. The standards reviewed in 2005 are for the most part major or total revisions of their predecessors in 2000, responding to guidance, mandates, and pressures already different from those obtaining during the late 1990s.

Table 4. *Mean percentage score for all states by discipline.*

Discipline or Issue	Mean Percentage Score
Earth/Space Science	61
Chemistry, Environmental Science	50
Physical Science	64
Biological Sciences	68
Inquiry	57
Evolution	57

Common Problems

1. Excessive Length, Poor Navigability

For the entire complement of a state's science standard papers to add up to a bulky document is not unexpected. There is a lot to be covered. But sprawling, almost impenetrable documents, uncontrolled in size and poorly organized, are unfortunately too common a result of the push toward comprehensiveness. One gets the impression, after reading a dozen standards documents chosen at random from the 50, that they have grown by accretion rather than by plan. They seem to have been written by large committees whose members could not communicate with one another. In some cases (Ohio's and Vermont's massive undertakings come

Table 5. *Final scores and letter grades by state, sorted on the 2005 scores.*

STATE	SCORE 2005 %	GRADE 2005	GRADE 2000	TREND
California	97	A	A	↔
Virginia	96	A	D	↑
Massachusetts	94	A	A	↔
South Carolina	93	A	B	↑
Indiana	91	A	A	↔
New York	88	A	C	↑
New Mexico	86	A	F	↑
Tennessee	83	B	F	↑
North Carolina	79	B	A	↓
New Jersey	77	B	A	↓
Colorado	76	B	D	↑
Georgia	75	B	F	↑
Louisiana	74	B	C	↑
Ohio	74	B	B	↔
Arizona	72	B	A	↓
Maryland	72	B	D	↑
Minnesota	71	B	A	↓
Illinois	70	B	B	↔
West Virginia	70	B	F	↑
Delaware	68	C	A	↓
Missouri	66	C	C	↔
Kansas	65	F	F	↔
Pennsylvania	65	C	NA	NA
Washington	65	C	B	↓
District of Columbia	63	C	NA	NA
Utah	62	C	B	↓
Vermont	60	C	B	↓
Connecticut	59	C	B	↓
Rhode Island	58	C	A	↓
South Dakota	52	D	B	↓
Kentucky	51	D	D	↔
Maine	51	D	D	↔
Nevada	51	D	C	↓
Oklahoma	50	F	F	↔
Michigan	48	D	D	↔
North Dakota	48	D	F	↑
Florida	48	F	F	↔
Mississippi	47	F	F	↔
Arkansas	45	D	F	↑
Alabama	42	F	D	↓
Oregon	40	F	B	↓
Hawaii	39	F	D	↓
Montana	39	F	D	↓
Nebraska	38	F	B	↓
Wyoming	37	F	F	↔
New Hampshire	36	F	F	↔
Texas	34	F	C	↓
Idaho	34	F	NA	NA
Wisconsin	29	F	C	↓
Alaska	19	F	NA	NA

to mind), editing and proofreading must have been done hastily, as an afterthought, or not at all.

Of course, there are honorable exceptions. Certain documents, including some in the group graded "A," are indeed long (some are too long), but in those cases the organization is transparent and the exposition is clear. Most of the very long documents, however, are far from clear. Their length, and often their poor organization, works against one of the fundamental requirements of a state standards presentation: that it be accessible to all interested readers.

The standards' excessive length is a result of accretion, prolixity, a tendency to dress up rather than clarify.

A few of the state documents are short. Some but not all of those are of acceptable quality. Thoughtful brevity is therefore not, *ipso facto*, a defect in standards documents. (Maine's standards certainly go too far. Its treatment of "The Universe" fits on half a page.) The excessive length of most current standards documentation is simply a result of accretion, prolixity, a regrettable tendency to dress up[8] rather than to clarify the documents, and—especially troublesome here—repetition. Repetition of words, sentences, or paragraphs in standards, whether in tabular or systematic format, can have genuine purposes— to convey meaning or to make the documents easy for certain readers, such as teachers, to use. But tedious repetition has the opposite effect. Navigation becomes burdensome; the chance that readers who ought to be acquainted with everything in the standards will really absorb the whole becomes negligible.

The easy solution to this problem is probably cheaper by an order of magnitude than the cost in time and money of putting these huge productions together. Hire a good, independent, professional editor, one who knows science and loves the English language. Grant him or her the right to get answers to queries from any and all contributors to the original—and to edit!

2. Thin Disciplinary Content

By "disciplinary" science content we mean the facts, the concepts, and the special methods of the scientific subjects that these standards *should* represent. Adequate disciplinary content must be there, even if the facts and ideas come from non-disciplinary, abstract, or thematic presentations that cross the traditional boundaries of the standard disciplines. By "discipline" we mean physics, astronomy, cosmology, chemistry, geology, biology (including ecology, genetics, and evolution), and what has now grown up as the derivative but nevertheless quite independent discipline, environmental science.

The problem of absent or meager disciplinary content is due in part to the success of the Inquiry movement, to its banners rather than to its good core substance. In science, as wherever else honest inquiry is done, acquisition of the investigative discipline's content requires skills in the acquisition process itself. And some aspects of investigative process are especially characteristic of natural science: development and use of technology to extend the reach of the senses, for example, or stringent peer review (which is *not* the same thing as cooperating nicely with fellow students). But process is useless if there is nothing to process, and substance never materializes if the processes of seeking it are missing or flawed.

So students need both: they need process and real content. Therefore we are distressed when we read a sprawling standards document in which all is more or less well except that there is not nearly enough *systematically developed* physics or chemistry or biology to make sense of the lofty thematic generalizations that are supposed to contain them. We are concerned when the K-8 science content is unable to support the content of grade 9-12 science courses, which are in turn inadequate to prepare those students who want to get ready for college science. And this happens even in some cases where the high school science courses are well planned.

More commonly, what we find is that the science know-how of the writers is adequate for K-8, perhaps, but falters thereafter. Thence the content proposed for the secondary grades becomes thin and superficial, or emerges error-ridden, or disorganized, or all of these. For such ills, too, the cure is straightforward: ensure that scientists competent in the subject at least check the proposed science content, or, even better, help to strengthen it.

3. Do-It-Yourself Learning

Many standards documents justify their learning expectations for science by reference to one or another educational or pedagogical theory. Nowadays the vogue is to mention constructivism, or discovery learning, or some combination of the two. They are indeed related ideas in

Educational Constructivism

Constructivism is not new. It was evident in the first draft (1992) of the National Science Education Standards, where it took the form of a claimed *postmodern* philosophy of science. That, in turn, incorporates one kind of constructivism ("social" constructivism) about knowledge, including scientific knowledge. The adopted philosophy was an application to learning standards of the increasingly popular *educational* constructivism, whose main tenet is that learning happens only by an individual's action, his or her making and doing things in the world, not as a result of any conveyance of knowledge (as in teaching).[10] A revision of that early draft eliminated the praise of postmodernism but left in place the notion that a learner can do no more than to construct knowledge, which is therefore personal, from things and events in his or her sensed environment. It is *supposed* to follow from this that scientific knowledge cannot be transferred from one person—a teacher (or from a book)—to another. The learning expectations of standards should therefore focus much more on *process,* the "doing" of science by the student, and much less on its reputed facts.[11]

By the late 1990s, emphasis on process as opposed to content was synergistic with various social pressures for such pedagogy, eventually under the explicit banner of constructivism. The slogans "depth instead of breadth" and "less is more" became catchwords. Typical of that stirring time, and not very different from materials now appearing every day, were such exhortations as the following, quoted from a series of papers entitled "Research Matters—to the Science Teacher," at the web site of the National Association for Research on Science Teaching:

> … The constructivist epistemology asserts that the only tools available to the knower are the senses. It is only through seeing, hearing, touching, smelling, and tasting that an individual interacts with the environment. With these messages from the senses the individual builds a picture of the world…. Therefore constructivism asserts that knowledge resides in individuals; that knowledge cannot be transferred intact from the head of a teacher to the heads of students. The student tries to make sense of what is taught by trying to fit it with his/her experience…. 'Others' are so important for constructivists that cooperative learning is a primary teaching strategy.... Thus, from a constructivist perspective, science is not a search for truth....[12]

But as the physicist and science educator Alan Cromer argued,

> … Constructivism is a postmodern antiscience philosophy that is based upon Piaget's work on how children construct concepts and conceptual relations and on the philosophy of two early nineteenth-century opponents of the Scientific Revolution, Giambattista Vico and George Berkeley.... It's a form of subjective empiricism that puts its emphasis on the thoughts of the knower and views the search for truth as an illusion…. Such an ideology would be of no interest to scientists and science educators were it not, in effect, the official ideology of the reform movements in the United States and elsewhere…. *But when push comes to shove, no one knows how students are to construct their own theories of atoms and electrons, of stars and galaxies, of DNA and genetics…"* [13]

The constructivist turn in K-12 science education is another case of good ideas gone bad. The good ideas are certainly there in the national models and are sometimes reflected in the standards documents we studied for this report. Inquiry now shares pride of place in science curriculum with disciplinary science content. Recently and in some places, the former has even begun to dominate the latter.

In 2000, the National Academy Press and the National Research Council issued *Inquiry and the National Science Education Standards*, a follow-up to the earlier standards models. This volume was intended to illuminate and justify the shift of emphasis. Central to its argument is a brief survey of current research on "How Students Learn Science." [15] Explicit constructivist argument is (again) absent. The stress, instead, is on research data bearing on the attributes of scientific expertise and on the stages through which children go in learning science.

As far as it goes, the account is even-handed. But it doesn't go far enough and is clearly a promotion of Inquiry (or, to use an older and more limited catchphrase, "discovery learning") as the preferred pedagogy for K-12 science. About the empirical support for Inquiry in science learning, this account is not entirely satisfactory. First, from research on the nature of expertise, which is indeed relevant to learning as inquiry, the evidence reported is that people who have it—the experts— "… *have a deep foundation of factual knowledge* [emphasis added]."[16] That is nothing like a finding in favor of "less is more"!

Second, an up-or-down verdict on Inquiry-based science learning is not yet available: meta-analyses of the large and uneven literature yield no compelling conclusion.[17] What the meta-analyses do indicate is that Inquiry—here, the processes of practical science—ought not to be ignored in the design of standards and curricula (with which principle every competent science teacher must surely agree). To us the meta-analyses indicate that more, and much better, research still needs to be done. They do *not* confirm "less is more."

the sense in which most educators understand their meanings, although in fact both terms have multiple meanings that are sometimes contradictory. Held up as the newest educational philosophy, as they have been for the last decade, these words imply that the standards writers (or writers of the national standards models) really know—at last! —how children learn science, and have systematically applied the new knowledge.

That knowledge, it is claimed, has a strong role in determining the new design of standards. Improvement in student learning would therefore appear to be inevitable. For all this, however, there is no conclusive evidence.[9] If, on the other hand, the terms "discovery" or "constructivism" are paraded in a standards document simply to indicate solidarity, or depth of empirical evidence, or robust theoretical support for the design decisions taken, then they are JUST catchwords—in this case, a form of self-congratulation.

The science know-how of the standards' writers is adequate for K-8, perhaps, but falters thereafter.

There is insufficient justification for epistemological radicalism in curriculum design. Constructivism has been, and remains, a largely ideological battleground. There is no agreement on its merits among philosophers who define and argue about different constructivisms (idealist, rationalist, Piagetian, social, and educational—as in the much-cited work of E. von Glasersfeld[18]). Much less is there informed consensus on the superior effectiveness of constructivist pedagogy.[19] There is no preponderance of evidence, from good research on a population scale, for the claim that science education based upon constructivism—or discovery learning—really does better, *ceteris paribus*, than "traditional" methods, so-called. The rare, recent investigation that incorporates controls (that is, isolates the variable of interest) tends rather toward the opposite conclusion. [20]

To recapitulate, underlying the stylish words is a perfectly sound idea: *Whenever practicable, science learners should find things out for themselves.* They should have ample opportunity to observe, to perform experiments. These should be self-planned when possible, and prearranged when appropriate. Students should be encouraged to devise their own methods of answering questions. And our criteria reflect all this. But it is ridiculous to expect schoolchildren to "construct" any substantial part of the core knowledge of modern science. That core is a vast, multidimensional matrix whose cells are facts, experiments, and theories, interconnected, mutually reinforcing, in continuous change and expansion, and inaccessible to purely inductive activity. Yet, to give but one example, Wyoming's standards declare, "Scientific inquiry is the foundation for the development of content and processes of science that enable students to construct their own knowledge." Are Wyoming's teachers, parents, and students to take that statement seriously?

4. Good Ideas Gone Bad

> Catchword, n: *A word or phrase whose original, explicit meaning dissolves in excessive repetition, becoming a mere label, usually for a school of thought or a theory.*

Readers of the current science standards encounter a few prevalent catchwords, of which we have now had a glimpse. By itself, that is neither surprising nor troubling. Every profession has catchwords; and science standards documentation—despite its ostensibly public character—is written by and for the education profession. But the state science standards certainly *should* be written for a wider audience. Documents written by and for educationists often include jargon that can be annoying, but is mostly innocuous. They also include catchwords, however, and those may not be innocuous. Our concern is with catchwords that arise from initially good ideas about how science can be taught and learned, but that have gone through a process of degradation. Certain of these good ideas have become so familiar that the natural process of simplification and abbreviation has followed. When and if the resulting words or phrases are used to suggest *more* truth, *better* evidence, more confidence than is justified by the reality, then they are troublesome. They spell trouble when, by taking precedence over genuine knowledge, they are allowed to drive the design of the standards. They are good ideas driven bad by overemphasis and repetition. Here are two examples.

a. Hands-On (Minds-On) Learning

A splendid idea: *Don't limit the study of natural science to memorization.* Arrange curriculum so that students acquire and employ some of the processes of knowledge acquisition known to work in real science. Two examples are (1) physical engagement with the subject in the field, laboratory, and library and (2) cooperation among inquirers with the same interest. Such approaches surely allow students to learn more and better science (and anything else!) than mere mechanical memorizing. To this idea, every working scientist and science teacher gives unqualified assent. But observe how it becomes corrupted and counterproductive by being run into the ground.

No science course among the hundreds the writer has ever taken, taught, or observed during 40 years as a faculty member, K-12 or college, has offered its subject matter *solely* as lists of things to be memorized, with no work or manipulation in the field, laboratory, or library. Yes, science courses require students to memorize some things: facts, words and definitions, and problem-solving techniques. But no survey is needed to establish this minimal but critical point: the widespread polarity between "rote" learning and hands-on, minds-on learning is a caricature. Yet many state standards include statements like this one, found in Washington's documents: "Learning in science depends on actively doing science. Active engagement in hands-on, minds-on science learning experiences enables students to make personal sense of the physical world…."

The real problem is, rather, in determining reasonable demands on student memory. It is not at all a matter of "just memorizing" versus "doing" science. You can't just "do" science, or any other intellectual work, without a minimum acquaintance with the facts. Caricatures are essential to politics, but they are inimical to making serious distinctions that play a role in deciding how to teach. The charge against "traditional" science education (so mocked), that it is just memorization of facts ("factoids"), is false. The implication that science can be learned "hands-on" *without* memorization is also false.

Science is learned, as the experience of at least two centuries shows, by a combination of memorizing facts, words, and methods of thought, and reinforcement of what does get into memory by repetition and by investigation in the field, laboratory, or library. So there is nothing new about "hands-on" science learning. "Hands-on" is a catchword, used to suggest that something new and different is going on when, often, it is not. Physical, investigative activity, if that's what "hands-on" is meant to suggest, should not be an excuse for eliminating content. Of "minds-on" nothing more need be said than that it is not even a catchword. *By definition*, the minds for whose education the standards document is a guide are on while learning, including learning in the field or laboratory.

False Dichotomy

For decades, it has been understood that facts and process, theory and practice, are needed together for the learning of science. As the editor of the *Journal of Geoscience Education* put it,

> It often seems as if the *au courant* proponents of post-modern educational theory and practice believe that it is possible to understand a subject, to think critically about it, and to solve problems in it without bothering to learn and know the details of the subject. This is nonsense and should be emphatically branded as such. .... [T]here are no shortcuts to comprehension that avoid the difficult task of learning, knowing, and appreciating the "facts" of the subject at issue.[21]

Finally, there is plenty of good science in which the hands are *not* on. The heart of theory making is thinking, not doing, and theory is central to all science. To be sure, good theory in science is eventually a matter of testing: of observation and experiment, verification or refutation. But in the first instance, thought alone, based upon what is already in memory or in books, is indispensable. There are theorists who do nothing but think (and read, and talk, and write about their thoughts).

It is ridiculous to expect schoolchildren to "construct" any substantial part of the core knowledge of modern science.

They are among the most honored scientists. Consider, for example, the stature accorded to "theoretical physics." The chant, therefore, of "hands-on," as the core principle of science learning and as new pedagogy, is another form of self-congratulation.

b. Everybody does it

A genuinely great idea and also a fact: *Ethnicity, national origin, age, sex, race, and religion have nothing to do with a person's native ability to learn or do science.* Therefore opportunities to learn and to practice it, should a student's interests grow in that direction, must never be limited by his or her background. It is a productive thing in science, as history has demonstrated, to emphasize the universals of human cognition. The inescapable result of modern experience is that such universals exist. It is proper to emphasize the worldwide production of important basic science and engineering.

Catchwords arise from initially good ideas about teaching science, but they have gone through a process of degradation.

Examples of real and important scientific achievement in cultures different from our own, past and present—real science from the ancient Chinese and Arab cultures, for example—are welcome in science teaching. But: none of this means that every individual is, or can be, a scientist.

Much less does it mean, as is sometimes suggested in standards documents, that each and every *culture* has done or now does good science. Even less justified is the implication that, because everybody can do and does his own kind of "science," scientists of one culture have no right to judge the scientific claims of another culture. It would be absurd for an aeronautical engineer in America or Europe or Asia to believe—or teach—that the twigs-and-foliage mock-ups made by cargo cultists of the Pacific islands during World War II were airplanes—just because in that culture they were believed to be airplanes, or an adequate substitute.

Thus, to assert repeatedly, explicitly or by implication, that all cultures everywhere contribute equally to science, that everybody has done it, or does it, or *can* do it, is silly. (Yet states such as Alaska, Arizona, New Jersey, and South Dakota cannot resist doing so.) It implies, also, that as compared with other kinds of performance, there are no differences in science ability or inclination among children (or cultures). That contradicts another catchword found in these documents: multiple intelligences, which argues exactly to the contrary.

"Everybody does it and can do it," repeated as a mantra, takes a good and important idea and drives it into the ground. The search for happy examples by writers not deeply knowledgeable about science leads to such absurdities as the citation of Ayurvedic medicine, instead of any of half a dozen brilliant mathematicians and physicists, as representative of Indian scientific intellect, or—even in Western science—the naming of Rachel Carson or Sally Ride rather than, say, Lise Meitner, or Irène Joliot-Curie, or Barbara McClintock as representing great women in science. Even the children, in support of whose self-confidence such things are usually said, don't necessarily believe them.

5. Avoiding Evolution

Appendix A displays a table of average scores earned by each state for each of our criteria. One criterion—new since the last Fordham review of state standards in 2005—calls specifically for serious treatment, especially but not exclusively within the life sciences, of the facts and theories of evolution. That is, this criterion is used to judge the expectation for students' understanding of the history of life on Earth. Our scoring system is less elaborate than that employed by Lerner in his September 2000 review of the state treatments of evolution.[23] The schemes are, however, similar enough to allow comparison and comment.

Lerner employed a six-level grade scale: A, B, C, D, F, and F-minus, best to worst. Our scale was (as indicated earlier) 3, 2, 1, 0, best to worst. It does no real violence to the earlier system if we translate its results to the terms of this, our current evaluation. We can combine the 2000 "A" and "B" categories (scores 80 – 100 in that review) to correspond with our category "3." We may then rename the categories of the two reviews, 2000 and 2005, as follows: "Sound," "Passing," "Marginal," "Failed," and "Not even failed" (Lerner's F-minus), best to worst—provided that we make room for that last grade of Lerner's (below 0) in our 2005 set. As it happens, it is still needed. Here, in Table 6, is the comparison of the results. (Note that these 2005 results include a last-minute change of the grade for Kansas.)

Table 6: *Earned grades for evolution, 2000 and 2005*

Grade Earned	Number of States 2000	Number of States 2005
Sound (A+B; 3)	24	20
Passing (C; 2)	7	7
Marginal (D; 1)	6	10
Failed (F; 0)	12	12
Not Even Failed (F-)	1	1
Total States	50	50

The outcome of this comparison is that, for the population of states, nothing much has changed in the intervening five years except a shift of four states from the category "sound" to "marginal." This distribution difference isn't significant. Of interest is the need for us to add a grade, for one state's effort in 2005, *below* "failed," just as did Lerner in 2000. As it happens, it is for the same state, Kansas, although this is for a new and different attack by the state's creationists.

First, as to the general lack of progress in dealing with evolution: It seems to us, examining our state documents in the grade categories "1" and "0," (see Appendix A) that the undistinguished performance of the whole group of states is not due to any notable success of current adventures in anti-science or plain bad science, such as intelligent design "theory" or the older, more literalist forms of creationism. *Rather, it looks as though things haven't changed much because the weak handling of evolution science content is just sister to the general weakness of disciplinary content for all science—despite the active revision of standards in most states since 2000.*

In a painful sense then, that is good news. It means that ongoing, strenuous, and well-supported efforts, political and in public relations, to change the purposes and tenor of K-12 science—by catering to the anti-evolutionism of fundamentalist religious groups—has yielded little or nothing over the last half decade. The bad news is that those efforts have not ceased, but are instead growing in funding, intensity, public relations skill, and reach, particularly political reach, even to the highest levels of government.

The decent (if not excellent) standards written for Kansas by a competent standards-writing committee have now (and for the time being, until the next election) been disabled by an incumbent and irremediably divided board of education. Its creationist majority is determined to resist evolution in any way it can. The just-adopted Kansas standards explain, inter alia, that there is no evidence for "macroevolution." In other words, that evolution as defined and described in biology didn't and can't occur. They also redefine the term *"science."* According to the Kansas board, "science" does and must recognize not only natural phenomena but also supernatural phenomena. Never mind that this is a contradiction in terms. "Supernatural" phenomena are those that by definition cannot be studied or explained by the methods of natural science. For these reasons we have had to revert to Lerner's F-minus, assigned to Kansas in 2000 for its treatment of evolution.

For us to have made no progress in establishing sound standards for K-12 education in evolution is discouraging.

We have yet to learn the decision of the judge in the federal court case of Kitzmiller et al. (parents, plaintiffs) v. Dover (PA) School District, defendant, now just ended. Most of the board members who forced anti-evolution and intelligent design on the biology curriculum of Dover were, however, defeated in the elections of November 9, 2005. The science standards of the state—Pennsylvania —have to date no hint of creationist influence.

Evolution is the organizing principle of modern biology, and its simple but powerful principles and algorithms have colonized scholarly disciplines formerly as remote from biology as economics, engineering, and literature. For us to have made no progress in establishing sound standards for K-12 education in evolution is very discouraging; but then, things could clearly have been worse. We aren't doing brilliantly—in general—in other, less controversial but equally important areas of natural science.

ALABAMA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.3	12
B. Organization	5.5	9
C. Science Content and Approach	8.5	27
D. Quality	4.5	9
E. Seriousness	3.0	6
Inquiry	1	3
Evolution	0	3
Raw Score	28.8	69
Final Percentage Score	42	100
GRADE	**F**	

Reviewed: Alabama Course of Study: Science (Bulletin 2005, No. 20)

The Preface to these standards asserts that the "Content Standards in this document are minimum and required" and that they are based on published guidance available from the National Research Council, the AAAS, and the National Science Teachers Association. The result is on the whole well organized, but thin. There are overviews for grade spans K-2, 3-5, 6-8, and 9-12 and half-page introductions for grades K-8. Earth and space science is addressed in grade 6; grade 7 covers life science and grade 8 covers physical science. For the high school grades there are standards for the basic science courses.

Treatments of earth and space sciences and of chemistry are on the whole adequate. The earth/space science material is fairly detailed and has some positive features. Third graders, for example, learn to classify rocks and minerals by properties, read weather maps, and identify the major layers of Earth, including the inner and outer cores. In middle school, the Earth/space science curriculum is placed in grade 6. In grades 7 and 8, life and physical sciences dominate.

Things go badly wrong in too many places, however, due to carelessness or outright error, in physics. In grade 2, for example, "4. Describe observable effects of forces, including buoyancy, gravity, and magnetism. Examples: buoyancy—boat floating on water,…magnetism—magnets adhering to metal."

The first example is misleading, since it will cause confusion later, in grade 5, when the student learns about the density of a homogeneous body. The second, presented as a generalization, is wrong; magnets do not—in general—adhere to metals. Or this: "transparent—most light passes through, translucent—some light passes through…."

No. The difference between transparent and translucent materials depends upon whether or not the light is scattered, not upon the amount of light that passes through. A translucent body may transmit nearly all the light incident on it.

Similar and more serious faults are to be found in the life science standards. Most distressing, however, is the long statement provided in the preface to this entire document:

> *The theory of evolution by natural selection, a theory included in this document, states that natural selection provides the basis for the modern scientific explanation for the diversity of living things. Since natural selection has been observed to play a role in influencing small changes in a population, it is assumed, based on the study of artifacts, that it produces large changes, even though this has not been directly observed. Because of its importance and implications, students should understand the nature of evolutionary theories. They should learn to make distinctions among the multiple meanings of evolution, to distinguish between observations and assumptions used to draw conclusions, and to wrestle with the unanswered questions and unresolved problems still faced by evolutionary theory.*

Although this is focused on evolution, and it paraphrases the "critiques" of evolutionary biology currently advanced by "intelligent design" creationism, it quite effectively derogates every branch of science. (There are, for example, many basic, "unanswered questions" about the fundamental forces of nature. Do we, for this reason, warn students to be suspicious of, or to "wrestle with," the "unresolved problems" of physics?) The Alabama preface sows confusion and offers a distorted view of what science is and how it is pursued. The quoted paragraph is preceded by mention of Copernicus, Newton, and Einstein, all physicists or astronomers; it then launches into an attack by misdirection on (evolutionary) biology. The statement is obviously of political, rather than scientific inspiration, and it reinforces the grade of "F."

ALASKA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	1.0	12
B. Organization	4.8	9
C. Science Content and Approach	4.3	27
D. Quality	0.3	9
E. Seriousness	3.0	6
Inquiry	0	3
Evolution	0	3
Raw Score	13.4	69
Final Percentage Score	19	100
Grade	**F**	

Reviewed: Science Content Standard (A-D) and Alaska Department of Education & Development Framework Project (2000)

NB: Alaska's Content Standards and Grade Level Expectations were revised and accepted in June 2005

Alaska's very spare documents fall repeatedly into unintelligible jargon. In places, political correctness dominates content or manner of instruction. The impression is given of more seriousness about native Alaskan cultures than about the whole of natural science.

As to process and inquiry, there is much stress on "real-life problems," but no specificity about which problems or their solution through science. "Big Ideas in Problem Solving" are said to include "diverse perspectives" and "effectiveness of cooperation." "Statistics and Probability for All" introduces manifold confusions: Statistics is described as "collecting, displaying, interpreting, and critiquing data." The concept of probability is said "to determine whether or not the results of a survey or experiment are the results of chance or are the result of a cause-effect relationship." Discussion of "Reasoning" garbles badly the relationship between deductive and inductive logic.

The Structure of Matter and Changes and Interactions of Matter sections are almost entirely about geology, which emphasis would be justifiable were the geology content strong; but it is not. In such circumstances, neglect of the relevant physics and chemistry is inexcusable.

The section on the universe is badly worded ("Observe and draw that there are more stars in the sky than anyone can easily count ...") and covers very little astronomy. The Forces of Nature section has nothing to do with the forces of nature (e.g., gravitational, electromagnetic). A section on "relativity" is meaningless and has nothing to do with the relativity of modern physics (the word appears in the title and once in the text). Earth science, space science, environmental science, and chemistry are represented mainly by generalities. There is no comprehensive guidance toward sound curriculum building or assessment.

The life sciences get no fuller or more thoughtful treatment. Attention to evolution, for example, is limited to (Level 2): "Analyze and critique supportive data for the theory of natural selection," and (Level 3): "Trace evidence through the geological record that a taxonomic line of animals has changed over time." There are, in general, unacceptably large gaps in all these content standards. The grade for Alaska's standards is "F." We hope that the state's revised standards (adopted after our cut-off date) are better. They can hardly be worse.

ARIZONA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	7.8	12
B. Organization	8.0	9
C. Science Content and Approach	17.8	27
D. Quality	6.0	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	2	3
Raw Score	49.6	69
Final Percentage Score	72	100
GRADE	**B**	

Reviewed: Arizona Science Standard Articulated by Grade Level (Updated 3-10-2005)

These standards are organized as six strands, following the National Science Education Standards. The first three strands are concerned with science process and are to be taught explicitly; but their materials are also embedded in the life, physical, and earth/space science content. Two specific strands—Inquiry Processes and History and Nature of Science—are given full play. Relatively competent grade 8 materials on experimental design are accompanied by platitudes on the contributions to science by diverse peoples and cultures. Overall, the standards are well articulated by grade level. In high school, they cover the expected content for complete courses. Organization is in general clear. For the Inquiry areas, however, there are very high expectations; and these are repeated in several grades. The effort to realize them must inevitably consume more than a fair share of class time.

Arizona expects a moderately rigorous physical science program, with appropriate content. Vocabulary is reasonable for grade level and subject matter. The chemistry content for K-8 is, however, sparse and is concentrated in grades 5 and 8. A few standards ask students to solve problems and quantify relationships. But some standards lump too much content together. Two standards contain a quantity of material that might be found in two or three full chapters of a high school chemistry textbook.

Some puzzles appear in the handling of physics, especially with respect to the order in which topics are taken up. To give two examples: In high school Concept 2, the subject is forces and motion. But this skimpy section discusses only momentum. Concept 3, Energy and Magnetism, seems to cover many things—but not energy explicitly. "Transfer of Energy" deals with a few such transformations (not "transfer"!); but at this point "energy" has yet to be defined.

As to the life sciences, there is no direct treatment of evolution until high school, where the subject is, however, competently presented. Throughout, process subject matter is interspersed to such an extent that some content detail is diminished—notably in biology. We are not convinced that the gain makes up for the losses. Overall, nevertheless, the Arizona standards, with their very conscientious coverage, are worthy of the grade "B."

ARKANSAS

	Points	Out of a Possible
A. Expectations, Purpose, Audience	4.5	12
B. Organization	5.0	9
C. Science Content and Approach	11.0	27
D. Quality	3.3	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	0	3
Raw Score	30.8	69
Final Percentage Score	45	100
GRADE	**D**	

Reviewed: Science Curriculum Framework (Revised 1999)
NB: Arkansas' revised standards are due out in January 2006, but the current standards are in use for this academic year.

The Arkansas standards are presented in two main parts: the 1999 Science Curriculum Framework, which addresses three grade spans (K-4, 5-8, and 9-12) and Benchmarks for K-4 and 5-8. The Framework has three strands: physical, life, and earth/space sciences. Each strand has three standards, and each standard has a number of Learning Expectations. All these are stated in very general language. The Learning Expectations are mostly unspecific. Standards and expectations, with a few exceptions, lack clarity. In part, this follows from an unhealthy prevalence of equivocal verbs such as "recognize" and "explore." PS 2.5, for example, asks students to "Explore energy changes." It is difficult to determine what specific knowledge is expected or what skill is to be acquired.

Physical science content is thin and what is offered is unclear. Some examples: PS 2.9 asks students to "Introduce the electromagnetic spectrum." PS 2.12 asks them to "Investigate sound waves and gamma rays." There is no way to know what students are expected to learn from such "introducing" and "investigating." And it is impossible to divine what kinship the writers discovered between sound waves and gamma rays! PS 3.6 ambitiously expects students to "Acknowledge the impact of scientific discoveries upon society." There is no hint as to what, specifically, is to be done. PS 2.7 reads: "Explain the relationship among mole, chemical bonding, and molecular geometry within chemical compounds." There, the writer may have had something definite in mind: but there is no obvious way to convert it to lesson plans.

There is a long section headed "The Nature of Science," raising the hope that here at last may be found a cogent assemblage of the *process* or *inquiry* standards. The hope is forlorn: "Scientific knowledge" is distinguished from "societal knowledge, religious knowledge, and cultural knowledge"; but there is no indication of what those other knowledges *are*, or how they *differ* from scientific knowledge or from one another. The document tells us that "fact" means "an observation that has been repeatedly performed." But not all facts are observations or repeatable. There is recurring reference to "scientific method" but never an adequate definition of such a method. As one reviewer observed, the practical illustrations of teaching these elevated concepts "bring the reader down to earth with a bump." Earth's layered structure, for example, is to be understood when students cut hard-boiled eggs vertically. (One wonders, Why not horizontally?)

For the life sciences, treatments of fundamentals—mitosis, meiosis, and cell division; basic embryology; the genetics of evolutionary change—are rather weak, and grade-wise progression is often in the form of mere repetition. Grade: "D."

CALIFORNIA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	11.7	12
B. Organization	9.0	9
C. Science Content and Approach	25.0	27
D. Quality	9.0	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	3	3
Raw Score	66.7	69
Final Percentage Score	97	100
GRADE	**A**	

Reviewed: Science Content Standards for California Public Schools and Science (1998)
Framework for California Public Schools (2004)

On science processes, and on history and philosophy of science, California's standards vary delightfully from the norm: they are *brief*, there is no bombast, and they are realistic about the capacities of children for making sense of abstract ideas. Process is stressed where it should be, and in plain and appropriate language. For example: Grade 3: "Repeat observations to improve accuracy, and know that the results of similar scientific observations seldom turn out exactly the same … differentiate evidence from opinion and know that scientists do not rely on conclusions unless they are backed by observations that can be confirmed."

A reviewer of the physics materials finds that "The standards are remarkably free of error and ambiguity." A very few errors are found nevertheless; but they are minor. From grade 5, for example,

> "*Students know* metals have properties in common, such as high electrical and thermal conductivity. Some metals, such as aluminum (Al), iron (Fe), nickel (Ni), copper (Cu), silver (Ag), and gold (Au), are pure elements; others, such as steel and brass, are composed of a combination of elemental metals."

Steel is indeed composed of two or more elements, but the basic component other than iron is carbon—which is not a metal.

Quoting and paraphrasing a reviewer of the life science treatment: "This is a honey of a document. You get the standards in one pdf, nicely organized, and flowing. Then you get a series of framework documents where these are set out a second time, only now there are also lots of concise descriptions of the phenomena, with terms carefully defined, information about what will actually go on in the classroom." It is encouraging to see more specific attention than usual to digestion, circulation, and other physiological processes even in the lower grades. In the 7th grade standards, earth sciences content is sensibly integrated with evolution. Physical principles are discussed, when the opportunity arises, in the context of living systems. For example these principles explore properties of light and of the eye, leverage in connection with musculoskeletal action, and pressure with the cardiac cycle and its function.

California has produced an exemplary set of standards for school science; there was no question among readers about the "A" grade. Now one must hope that teaching and learning follow apace.

COLORADO

	Points	Out of a Possible
A. Expectations, Purpose, Audience	8.8	12
B. Organization	7.3	9
C. Science Content and Approach	20.0	27
D. Quality	6.0	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	1	3
Raw Score	52.1	69
Final Percentage Score	76	100
GRADE	**B**	

Reviewed: Colorado Model Content Standards for Science (1995)
NB: Colorado is currently revising its standards, which are due out in September 2006.

Evidently influenced by the National Science Education Standards, Colorado introduces six "standards." Three of these present science content, and three deal with science as process. The latter material is in part intertwined with science content, which is very much to the good. Each of the six categories is expanded with content points identified as "rationale." These are the real standards. They are organized in grade spans K-4, 5-8, and 9-12. The document is for the most part well and modestly written, and to the point. In a few places there are fitting references to extra material beyond the standard.

Standard 1 covers the process topics. Here there are some significant refinements often absent in the standards of other states. Thus, "In everyday life we find ourselves gathering and evaluating information, wondering about patterns, devising and testing possible explanations.... These characteristic human activities mirror how scientists think and work." This refinement is a truism, but is nevertheless welcome in a document on pedagogy. Unfortunately, the last—and very important—statement is inverted. It should read, "… the way scientists think and work mirrors characteristic human activities."

About 20 standards touch on environmental science. These are found in grades 9-10 in biology (ecology) and in earth and space science. Addressed are the following: natural resources, hazards, carbon dioxide in the atmosphere/climate, water quality, and the impacts of technology on man and the environment. They are all worthy of inclusion but the treatment is qualitative. The opportunity is lost to display the importance of quantitative analysis, even for environmentalism.

In general, physical science is treated in a reasonable way, with no glaring errors. But the standards themselves are rather thin and fail to mention important areas. The Assessment Frameworks document fills some gaps. In contrast, life sciences are dealt with competently, albeit less completely than in the best standards documents we encountered. The treatment of biological diversity and evolution is just adequate: it starts early, in K-4. The treatment does include such forthright statements as that evolution is "…the major unifying concept in the biological sciences," and it supplies pointers to content indicating why that is indeed so. Important facts of embryology are introduced soon enough so that they can support (as they should) more advanced subject matter. But some essential content is deferred to study beyond the standards. Some of that, however, ought to be in the standards, for example the connection between nucleic acid sequences and biological classification.

These standards have been graded "B."

CONNECTICUT

	Points	Out of a Possible
A. Expectations, Purpose, Audience	7.0	12
B. Organization	7.0	9
C. Science Content and Approach	15.3	27
D. Quality	3.3	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	0	3
Raw Score	40.6	69
Final Percentage Score	59	100
GRADE	**C**	

Reviewed: Core Science Curriculum Framework (Updated January 2005) NB: Connecticut's Standards were updated in September 2005 with advanced high school standards (too late for this review).

The Core Science Curriculum Framework addresses instruction in grade categories PreK-2, 3-5, 6-8, and 9-10. It is heavily indebted to the National Science Education Standards and the AAAS Project 2061 Benchmarks. The organization centers on 11 themes and 11 guiding questions. Each grade has four general content standards and one or two more specific "support concepts." Listed alongside are Expected Performances. Those are the actual minimum knowledge and skills indicators for state tests at grades 5, 8, and 10. The content standards (with related questions, supportive concepts, and expected performances) are not grouped in categories reflecting fundamental theoretical structures of the sciences. Rather, the 11 themes are artificial and ad hoc.

In the physical sciences, where Connecticut's showing is stronger than in other areas, the standards are well thought out, well structured, and free of errors and misconceptions. But some important topics in physics are missing or underplayed. Among them are conservation of momentum, waves, modern physics, and fluid mechanics. There are also small irritants. As is too often the case, for example, the term energy is introduced (in Grade 4) and used without any attempt to define it. In Std. 6.1: "compounds … cannot be broken down by physical means" is not quite true, since many compounds can be broken down by heating. In Std. 9.1: The term "heat" is used in such a way as to imply that it is not a form of energy but something distinct.

Too often there is little or no relationship between the Theme (and Guiding Questions), the Content Standard, and the related Expected Performances. For example, on page 12, the theme is the Changing Earth. The question is: How do materials cycle through the Earth's systems? The Expected Performances ask students to sort different soils by properties and to relate properties of soils to their capacity to retain water and support growth of certain plants. Handling of the life sciences is respectable, but hardly optimal. There is nothing related to the meaning of biodiversity or to evolution until high school. There the actual classroom consequences of entries in the Framework are left unstated.

Connecticut is especially emphatic about its dedication to "real-world issues and technologies." (We always thought that natural science was about the real world.) A consequence of this emphasis (as emerges from the Position Statement, dated June 2004) is a tendency toward preoccupation with social and environmental questions. These are by no means unimportant, but it is reckless to proceed as though students will learn necessary science content as a result of heightened focus on social issues and drastically reduced specificity in the basics. Grade: "C."

DELAWARE

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.0	12
B. Organization	6.5	9
C. Science Content and Approach	17.8	27
D. Quality	4.5	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	3	3
Raw Score	46.8	69
Final Percentage Score	68	100
GRADE	**C**	

Reviewed: State of Delaware Science Curriculum Framework (Vol.1, June 1995)
NB: Delaware's Standards are under revision for release in 2007.

Delaware offers eight "Standards," each broadly stated, better described as "themes" than "standards." Each major section of the document comprises a theme followed by numbered subsidiaries: the latter are the actual learning standards. Related paragraphs accompany each standard to provide teaching suggestions and practical activities that address the relevant content. Many of these suggestions are helpful; but some address only a subset of the content and a few don't really match the standard.

A complete document for Standard One, "Nature and Application of Science and Technology," covers science processes. The substance is generally strong, including a thoughtful treatment of relations between science and technology. Unfortunately, insistent insertion of approved sentiments ("Explore the historical underrepresentation of women and minorities in many fields of science and engineering, and the strategies that education, business, and government are employing…"), however worthy, will weaken the effect. Even middle and high school students recognize this as political or social, rather than scientific content. Those students for whom these sentiments are supposed to be an encouragement are just as likely to be cynical about them.

The only really strong showing is in the life sciences, where the treatment ranges widely and touches the essentials, including cellular anatomy and organization, prokaryotes and eukaryotes, structure and function of proteins, chemistry and the functions of ATP, embryonic development, genetics, and systematics. Biodiversity and evolution are introduced early—in the K-3 segment—and the main, relevant content enters in subsequent grade spans. In high school, the standards call for real investigation—in the library and laboratory—of basic elements in the modern synthesis of evolution and in molecular biology.

Quality is lower in the physical sciences. The standards, bearing non-standard names, are nevertheless easily identified identifiable as chemistry (Materials and Their Properties) and physics (Energy and Its Effects). There are anomalies, however. For example, chemical energy is discussed in the latter "standard" rather than the former.

The material on physics, despite interesting organization, has errors and impracticalities. For example, in Grades 6-8, Force and Motion: "Give examples which show how the relationships among force, mass, and acceleration are important in common situations (e.g., hammering a nail, comparing rates at which a car and a heavily loaded truck can pull away from a stop sign)." These examples, critical for the lesson, are poorly chosen. The first is friction-dominated and the second depends on power-to-weight ratios. That will not be at all obvious to the 6th grader; the examples will confuse, rather than illustrate. "Energy can travel as waves" is a distortion of the correct "Energy can be transported by traveling waves." And it is not true that "… only electromagnetic waves can travel through a vacuum," since gravitational waves can also do so. Relegating wave motion to a single mention in a section entitled "Interaction of Energy With Materials" gives pause, since it is specifically noted that electromagnetic waves travel in vacuo.

Earth science starts off well but lacunae appear. There is some coverage of sediments and sedimentary rocks, but igneous and metamorphic rocks are not named and the processes that form them are limited to the nebulous "Rocks are changed by erosion and deposition and by exposure to heat and pressure." Environmental science is scattered and usually too generally treated for use in developing lessons and assessments. There is nothing quantitative in the chemistry standards, so that these documents will hardly help prepare Delaware students for a regular college chemistry course. Grade: "C."

DISTRICT OF COLUMBIA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	7.3	12
B. Organization	6.4	9
C. Science Content and Approach	14.8	27
D. Quality	5.4	9
E. Seriousness	5.4	6
Inquiry	2	3
Evolution	2	3
Raw Score	43.3	69
Final Percentage Score	63	100
GRADE	**C**	

Reviewed: DC: Draft Standards, Science dated Fall (1999)

At the time of review, these standards were in draft form and were said to be in the process of revision. What follows may not, therefore, apply to finished documents issued after this report is published.

There are five very broad standards: Scientific Inquiry, Life Science, Physical Science, Earth and Space Science, and "Systems," a thematic treatment of physical interaction within structures of increasing complexity. The treatment of physical science has merit; the life sciences get a presentation of average quality; earth and space sciences, and especially chemistry, are rather short-changed. The document is very long and repetitive: its Benchmark component, among others, simply recurs at every grade level. Eventually, this annoys even a patient reader.

For the physical sciences, this comment from a reviewer is characteristic: "There are some good things in the Benchmarks. For instance, at Grade 5 (earlier than usual and praiseworthy in that respect) we see 'The student will … produce evidence to infer when warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are at the same temperature.' And at the same grade level, 'compare results of scientific investigations with others to know results are seldom exactly the same, but if the differences are large, it is important to try to figure out why.'" On the other hand, atoms are not introduced until grade 8.

There are incorrect statements and careless uses of words. In Standard 3, grade 8, we see heat, light, and a list of other forms of energy called "transformations." At grade 11 we have the incomprehensible "Experiment and use quantitative analysis to explain relative motion of objects, the action/reaction principle, wave behavior, and the Doppler effect." "Compare forces to know the nature of electric and magnetic forces" is slapdash; and "understand the importance of the earth's location in regards to the sun" cannot have been proofread.

Earth and Space Science content is introduced early, with a good sampling of what is necessary, but in unnecessarily simplified language. There seems to be nothing more after grade 6, unless students choose an elective in high school. There is no adequate introduction to cosmology. Chemistry, extensive enough, suffers nevertheless from a minimalist vocabulary, shallow content, and absence of quantitative problem solving. On the other hand, the life sciences get adequate coverage with no more than the normal frequency of small mistakes. Moreover—*mirabile dictu*—students are expected to "assess the fossil evidence for human evolution from earlier species." To what extent this can actually happen "by the end of grade 8" is a question. It does speak, however, for the awareness and good intentions of this Standards effort as a whole.

For Scientific Inquiry, the national models are closely followed. But the frequency of vacuous assertions here, as in the offerings of many states, is too high. Thus it is mandated, in all seriousness, that by the end of grade 11 the student will "use multimedia resources to know that scientists research and investigate scientific phenomena." Grade: "C."

FLORIDA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.0	12
B. Organization	6.0	9
C. Science Content and Approach	11.3	27
D. Quality	1.8	9
E. Seriousness	5.8	6
Inquiry	2	3
Evolution	0	3
Raw Score	32.9	69
Final Percentage Score	48	100
GRADE	**F**	

Reviewed: Sunshine State Standards, Grade Level Expectations: Science (1999)

It's a good thing that Florida is reworking its science standards. The current documents are reasonably well organized but sorely lacking in content. Their handling of physics, stronger than for the other subjects, is disappointing, due to a prevalence of errors in fact and presentation. A second-grader, for example, "… knows that a thermometer measures the amount of heat absorbed by an object." This is careless and false: a thermometer measures temperature, or better, changes in temperature, not the amount of heat absorbed. We hope that any second-grade teacher who cannot distinguish between heat and temperature will not pass this disability on to the students.

The classification of simple machines is naive. Energetics of phase change is presented misleadingly; treatment of electricity and magnetism, a central subject of school physics, is minimal. In the physical sciences, as elsewhere, most Benchmark statements are at a low level and tend toward safe ambiguity. Quantitative relationships and even the most obvious applications of mathematics are passed over. The treatment of chemistry content in K-8 is scanty; but—as one reviewer observed—"Even less is required in 9-12."

What is provided for earth and space science is adequate but thin, and again, nebulous. For grades 9-12, the standards require that the student "understands the relationship between events on Earth and the movements of the Earth, its moon, the other planets, and the sun." A reviewer comments: "This is so vague it could be construed by some to mean astrology." There is nothing on minerals and rocks until quite late.

The "Nature of Science" materials serve in Florida's standards to cover Inquiry. Conventional sentiments are expressed, so that in grade 4 the student "uses criteria to understand and analyze the impact of scientific discoveries…." The criteria to be used, however—presumably an important issue for the fourth grade—are unnamed.

Life sciences and evolution are given shorter shrift than any of the others. The E-word is sedulously avoided. Here, there are some loose, if not incorrect, generalities offered as standards: "… knows that the fossil record provides evidence that changes in the kinds of plants and animals in the environment have been occurring over time." There is little in the way of useful guidance for teachers or others toward appropriate content in the biological sciences and especially in the history of life and the basic mechanisms of change.

The superficiality of the treatment of evolutionary biology alone justifies the grade "F," but there is in any case scant mitigation elsewhere in these documents. Florida standards are in revision. We hope that the work will be fruitful.

GEORGIA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	8.5	12
B. Organization	8.5	9
C. Science Content and Approach	18.0	27
D. Quality	5.8	9
E. Seriousness	5.8	6
Inquiry	2	3
Evolution	3	3
Raw Score	51.6	69
Final Percentage Score	75	100
Grade	**B**	

Reviewed: Georgia Science Performance Standards (2004)
NB: Georgia is adding new high school standards for 2006.

Georgia presents its science standards by grade level through K-8 and then as courses for high school. Middle school is organized around the disciplines: Grade 6 presents earth science, 7 is for life science, and grade 8, physical science. An "Executive Summary" announces hopefully that, "… with fewer topics, teachers will be able to go deeper"; and "… our goal is for students to 'Do science, not View science.'" Georgia has moved physics to grade 8 "… because the brain-based research [sic] gives us a look at what cognitive level students tend to be [sic] at certain grade levels." These lofty commonplaces are not encouraging, and the choice of words is often puzzling. For example, grade 4: "… identify when comparisons might not be fair because some conditions are different." Comparisons of what with what? "Fair" in what sense?

Nevertheless there are good, simple statements on process. They stand out through the entire standards set. Thus, 5th grade: "Similar scientific investigations seldom produce exactly the same results, which may differ due to unexpected differences in what is being investigated, unrecognized differences in the methods or circumstances of the investigation, or observational uncertainties." Indeed.

Despite the absence in high school of earth sciences material, Georgia endeavors to touch the main topics elsewhere. But there are gaps, resulting in part from reliance for source material on the AAAS 2061 Benchmarks. Changes on the earth are introduced without sufficient treatment of the fundamentals: what the solid earth is made of—minerals. Part of the needed material is introduced (an excellent teacher could expand it), but it is incomplete and too much focused on Georgia. The rock cycle is never taken up on a global scale or in terms of material recycling.

As to chemistry, too little is asked of elementary students to prepare them for the high school course. The important topic of chemical equilibrium is not mentioned and reaction kinetics is limited to one standard, where changing temperature, concentration, pressure, and catalysis are given as means of changing reaction rates. Electrochemistry, organic chemistry, and the gas laws are absent; and bonding is reduced to "Compare and contrast types of chemical bonds." These standards need to be fleshed out, and vague or confused statements corrected. One positive feature of the organization, however, is the presence of a mathematics strand along with the science content.

In physics, these standards offer a few uniquely sensible, and correct, words about the distinction between chemical and physical change: "When students first begin to understand atoms, they cannot confidently make the distinction between atoms and molecules or make distinctions that depend upon it—among elements, mixtures, and compounds, or between 'chemical' and 'physical' changes." On the other hand, the high-school physics course ignores a number of fundamentals, including thermodynamics, optics, and a real treatment of waves. It also ignores the basic concepts of modern physics: quantum mechanics and relativity. The organization of the physics course is useless for preparing a student for college-level work.

By far the best feature of these standards is their handling of life sciences. Introduction of the important ideas of modern biology begins early, and their development is steady and carefully sequenced. High school work is a real advance over what has preceded it in the primary grades, yet it is solidly based on the acquired background. The treatment of biological diversity and evolution is straightforward and comprehensive; but for unnecessary parsimony on molecular biology, it would be outstanding. (We understand that the intelligent design creationists are very active in Georgia, too, but so far it appears that they haven't succeeded in mutilating the state standards.) Grade: "B."

HAWAII

	Points	Out of a Possible
A. Expectations, Purpose, Audience	3.5	12
B. Organization	5.8	9
C. Science Content and Approach	9.3	27
D. Quality	1.5	9
E. Seriousness	5.8	6
Inquiry	0	3
Evolution	1	3
Raw Score	26.9	69
Final Percentage Score	39	100
GRADE	**F**	

Reviewed: Hawaii Science Content Standards (1999)

For printing, this document requires a ream of paper. One reviewer described it as "bloated." The presentation is poorly organized, too: actual content is presented at a low level, with errors; redundancies abound. The quality of writing is, in general, so weak that one wonders if there has been even a single proofreading. "Science as Inquiry" material displays the fault in its most obvious form. Thus, "… students use inquiry about and investigate their wonderings about things occurring in and outside the classroom," and "… for example, Galileo dropped two balls at the same time and proved that all objects fall at the same rate." As one reviewer noted, "Someone dropped the ball there."

A review focused on physics closed as follows: "As far as the physical sciences are concerned, this document is useless. It is disorganized with respect to content, full of misconceptions, undemanding, and not well organized by grade level." Lacking as well, in all grades, is serious chemistry content. A mere listing of topics for grades 9-12 does not constitute a coherent presentation of chemistry. The treatment of earth science and environmental sciences is no better.

The life sciences effort is better, with fewer errors and broader coverage; but again, the writing is careless and some assertions indicate misunderstanding of important content. In the Glossary (p. 48), for example, we find: "Evolution vs. creation: two approaches to help explain the origin of life; the former based on Darwin's Theory of Evolution and the latter on divine intervention." But: Darwin's theory made no mention of the origin of life, other than a passing reference, in an early edition, to "the Creator." In modern biology, origin of life is a quite independent discipline, and its success, or lack of it, has no effect on the theory of evolution. For grade 7, we find, "Have students review the evidence that support and refute the theory of natural selection. The review can be done through textbooks, the internet, and journals." Despite the implication of this statement, there has been, to date, no "evidence" that "refutes" the theory of natural selection. Natural selection occurs; it has, demonstrably, occurred throughout the history of life on Earth. There is far too much of this sort of thing in the life science standards, either the result of ignorance or an attempt to avoid political trouble. Grade: "F."

IDAHO

	Points	Out of a Possible
A. Expectations, Purpose, Audience	2.7	12
B. Organization	4.0	9
C. Science Content and Approach	8.7	27
D. Quality	1.3	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	0	3
Raw Score	23.7	69
Final Percentage Score	34	100
GRADE	**F**	

Reviewed: Idaho Power Standards and Idaho Administrative Code (2005)

The amorphous organization of these standards ensures that they will not be read—not to mention studied—by anybody who doesn't absolutely need to do it. Two large documents contain the effective science standards: pages 100-130 of the Idaho Administrative Code (IDAPA 08.02.03), in a section entitled "Rules Governing Thoroughness"; and "Idaho Power Standards." Both offer portentous but content-shallow statements about science that are repeated grade to grade, year to year.

In strong contrast to the luxuriance of the prose is its scant clarity. About two such typical statements, a reviewer had questions: "The student will understand the structure and function of matter and molecules and their interactions." This is repeated from grade 4 through grade 6. But just what is the "function" of matter? Are the students to study molecules and matter, but not atoms? And, "The student will understand the relationship between matter, energy, and organization to trace matter as it cycles and energy as it flows through living systems." What is meant here by "organization"? It is possible that the writer(s) of statements like these had something specific in mind; but how is the reader to know what it was?

For physics, through Grade 6, the only soundly presented material involves measurement, which is well organized, with gradually rising expectations beginning in kindergarten. But there is little else except vague statements. For Physical Sciences (Grades 9-12): "650. Concepts of Physical Science. 01. The student will understand the structure of atoms. … b. Understand the processes of fission and fusion." There is no way that a high-school student could satisfy this requirement without prior exposure to the detail of other physical and chemical principles. There is no such exposure.

For earth and space sciences, the 3rd grade has material on the solar system, length of day, seasons, phases of the moon, and eclipses; 4th grade repeats it. Fifth grade calls for what amounts to the whole of earth systems science! "Investigate the interactions between the solid earth, oceans, atmosphere, and organisms." Under this there is some mention of water cycle, cloud types, and fossils for evidence of past life. There is also an introduction to the rock cycle and the composition and layering of the earth. This content is repeated at 6th grade. In subsequent grades there is a little expansion of content and more generalities about interactions, but insufficient detail in any of it to guide lesson planning or assessment.

Treatment of the life sciences is similarly scant. In kindergarten, remarkable intellectual feats are required: "The student will understand the theory that evolution is a process that relates to the gradual changes in the universe and of equilibrium as a physical state." And, "The student will understand the theory of biological evolution. Observe and explore the characteristics of plants and animals." That is for five-year olds.

The problem of this entire undertaking, not least its deference to Inquiry, is a pervasive vagueness combined with hortative turns of phrase. In grade 2, for example, students will "brainstorm questions that can be investigated." In grade 5, they will be expected to "know that science and technology are human endeavors related to each other, to society, and to the workplace." Grade: "F."

ILLINOIS

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.8	12
B. Organization	6.75	9
C. Science Content and Approach	18.5	27
D. Quality	5.5	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	3	3
Raw Score	48.6	69
Final Percentage Score	70	100
Grade	**B**	

Reviewed: Illinois Learning Standards for Science (1997, modified 2004)

These documents are a labyrinth. A lay reader—that is, a person other than someone involved in their creation—would be unlikely to take the trouble to discover what they really signal about what students are to learn in science, and when. A separate document containing "Descriptors" provides most welcome expansion and specificities for the broad standards of the main document.

In the physical sciences, despite that burden of poor organization, the standards themselves are notable. Science content is not only correct, precise, and clearly described, but exemplified with well-chosen practical experiments, and graded with care. A student moves gradually upward, learning and building on prior work. Unfortunately, steady progress is interrupted at the higher levels. In grades 9-10, for example, students are expected to "Use kinetic theory, wave theory, quantum theory and the laws of thermodynamics to explain energy transformations"—a most unlikely burden of learning if meant literally. But then, in grades 11-12, "Analyze reactions (e.g., nuclear reactions, burning of fuel, decomposition of waste) in natural and man-made energy systems." As a reviewer remarked, "Quite a comedown." Still, if the physics materials were reorganized for logical access and convenient cross-referencing, this would be an excellent set of standards.

In the material on Inquiry, the 1970s trendy word "brainstorm" is far too much in evidence. That the word is argot (along with some others like it) is not the issue. Authors have the right to choose a style. The problem is that such words are used to avoid specification of the cognitive process actually required. Still, aside from poor taste, the content offered under Inquiry is solid; it invokes insights not normally found elsewhere, and does so in a few passages of *good* writing. For example, students are expected to become familiar with the roles, in science, of "insight, creativity, skill, intellectual honesty, tolerance of ambiguity, persistence, openness to new ideas, and sheer luck." An articulate scientist who had just missed winning a coveted honor might have written that.

Earth and space sciences are covered in subgoals E and F. The standards are ambitious. If they are interpreted liberally and the examples are all followed in classroom work designed to follow the expectations given, a strong program will result. Except for ecology, which is built up in an orderly way throughout, serious treatment of life sciences content starts slowly and doesn't achieve desirable density until the high school years. But there it does happen, and a quite good biology program emerges. Even human evolution is taken up, and at a not impractical level of detail. Students are expected to involve themselves in such questions as the identification, via molecular biology, of genetic similarities between species, genera, and higher taxa. The grade for Illinois is "B."

INDIANA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	11.0	12
B. Organization	8.5	9
C. Science Content and Approach	23.8	27
D. Quality	7.5	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	3	3
Raw Score	62.8	69
Final Percentage Score	91	100
GRADE	**A**	

Reviewed: Indiana's Academic Standards for Science (2000)

One reviewer opened discussion of these standards by saying they were "expressed in admirably straightforward language. They seemed far more realistic than many about what could be expected of children at any given age. Unlike many, these standards struck me as a genuinely useful resource to teachers, not just a public relations or political exercise." Of course, complaints and suggested corrections were not entirely absent. Although most of the reviews by content area yielded honor scores, reservations were expressed, for example, about the treatment of chemistry and thermodynamics.

Nevertheless, the Indiana standards, organized and written with evident care, have positive features for which we looked in vain in many of the others. One such element is an early, explicit, and sequentially orderly application of mathematical thought and practice to data and problems in natural science. Thus even in grade 2, "Recognize and explain that, in measuring, there is a need to use numbers between whole numbers, such as $2^1/_2$ centimeters," while in Grade 6, "Explain why shapes on a sphere like Earth cannot be depicted on a flat surface without some distortion."

The content of earth and space science is presented in adequate depth, again in a way that will be helpful to teachers. A good deal of environmental science is worked in early, albeit at some expense to the introduction of chemistry, serious mention of which is delayed until grade 8. This is a common problem with thematic, as opposed to discipline-based, presentation of the sciences. Terms from one discipline must be used first in a different discipline before they have been properly defined. Moreover, and for this reason, there are lacunae even in some of the standards for high school courses. Students are asked to understand covalent bonding, for example, although there has been no adequate prior treatment of atomic structure or chemical bonds in general.

The usual residue of small mistakes appears in the physical sciences, but, happily, we encounter none of the careless ones that crop up in too many other states. Most of what is said about the nature and history of science and its processes—there is somewhat more of this than we thought necessary and proportionate—is sound and well said. In the life sciences, the early introduction of fossils is noteworthy. Although evolution content does not appear explicitly until grade 8 (the word itself is used throughout, however), the subject is handled solidly. Indeed, Indiana stands out in discussing appropriately the issues of human evolution. High school life science content is in general explicit, mostly to the point, and at a high level. We had no difficulty in assigning the grade "A." Sad to say, we hear of political moves in this state to derogate or downgrade the teaching of evolution. Should this happen, Indiana will go the tragic way of Kansas.

KANSAS

	Points	Out of a Possible
A. Expectations, Purpose, Audience	5.5	12
B. Organization	6.8	9
C. Science Content and Approach	17.3	27
D. Quality	4.3	9
E. Seriousness	5.8	6
Inquiry	2	3
Evolution	3	3
Raw Score	44.7	69
Final Percentage Score	65	100
GRADE	**F**	

Reviewed: Kansas Science Education Standards (2005)
NB: This is a draft version.

In the prior report on state science standards, issued in 2000, Kansas received the grade of "F." Creationists on the State Board of Education had disfigured an otherwise acceptable standards draft in order to expunge all reference to evolution and to all other historical science in support of evolutionary ideas. Eventually, however, following an election, the composition of that Board changed. Consequently, what we have now is a respectable document. (There are reports, however, that on the state Board creationist initiatives have again gained prominence, and that a soon-to-be-issued revision of these standards will once again play havoc at least with biology.)

Its greatest strength is in the handling of life sciences, especially evolution. There the work starts early, makes practical additions in successive grades, and culminates in high school with a solid treatment of evolutionary thought in modern biology. We would have liked, however, to see more of the molecular biology relevant to evolution and development, since it lies at the heart of so much else in biology today.

Where physical science is concerned, the standards are not especially strong or demanding. Physics standards for grades 9-12 are deficient: errors and misunderstandings abound, and at one point a potentially dangerous experiment is recommended. A Benchmark of Standard 2, high school, asserts "The Second Law of Thermodynamics states the universe tends to become less organized and more disordered with every chemical and physical change." This is simply wrong. The statement of the First Law is just as bad and the definition of energy even worse. High school chemistry is uninspired and presented on a rather low intellectual level. To be sure, the benchmarks touch on a suitably wide variety of topics, but do so without making clear what it is that the student is supposed to learn. Important content on chemical bonding and reaction rates is addressed with only one or two statements—not a good showing in relation to the two or more chapters devoted to it in a typical high school chemistry text. Mathematical problem solving is missing.

As to Earth and Space Sciences, a reviewer observes: "The overall coverage is not too bad, and there could be a meaningful program provided the full implications of all those Instructional Examples were interpreted liberally and carefully taught. There's something about the solid earth, atmosphere and hydrosphere systems, stars and the solar system, motions of the earth and planets. It could use some more careful treatment of solid earth structure and materials…but the focus on activities and themes has gone to such extremes that nothing seems to hang together."

The treatment of science process includes, as is now typical, three subheads: Science as Inquiry; Science and Technology; and History and Nature of Science. There are useful insights, but there are also banalities: "…science teachers should not ridicule, belittle, or embarrass a student for expressing an alternative view or belief." As a reviewer reported, "This substantive content is earnest and well-intentioned, but quite muddle-headed." The consequence thereof is illustrated by the definition of "scientific investigation:" "…using scientific inquiry to ask an [sic] answer a question."

The whole effort, compared to the earlier, defaced standards, is a great step forward. For the current standards, we confer a "C," but with profound concern. Should there be a repeat of the earlier creationist interference with all science having anything to do with evolution, the Kansas standards would once again fall to "F."

Note added In Proof: The early warnings have been justified. Kansas has adopted standards whose treatment of evolutionary material has been radically compromised. The effect transcends evolution, however. It now makes a mockery of the very definition of science. The grade for Kansas is accordingly reduced to "F."

KENTUCKY

	Points	Out of a Possible
A. Expectations, Purpose, Audience	5.5	12
B. Organization	6.0	9
C. Science Content and Approach	11.5	27
D. Quality	3.3	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	1	3
Raw Score	35.3	69
Final Percentage Score	51	100
Grade	**D**	

Reviewed: Program of Studies and Core Content for Science Assessment (2001)

Kentucky presents two documents: a "Program of Studies," which contains the standards, and what appears to be a later document, "Core Content for Science Assessment." The latter is based upon the former but improves on it by enlarged scope and greater clarity. The "Program" document organizes content by primary grades K-3, 4, 5, 6, 7, 8 and high school. The "Assessment" document collects subject matter for assessment at grades 4, 7, and 11. Kentucky tries, but often fails, to provide enough content, sufficient specificity, and clear and precise wording. Content develops slowly, with much repetition, in the early grades.

The Inquiry materials are, as is common, abundant and well intentioned, but also indifferent to the relation between doing science and studying or learning scientific facts. The doing is grossly overstressed since students are learning from teachers and not actually making discoveries of their own. In grades 9-12, for example, the students "will *examine* nuclear structure, nuclear forces, and nuclear reactions (e.g., fission, fusion, radioactivity)." They will "*investigate* how the structure of matter (e.g., outer electrons, type of bond) relates to chemical properties of matter …" and the like. But of course, the students are not going to do, or "examine," or even "investigate" these questions. They are going to encounter them and will perhaps learn something about them, up to a point. There will be no personal discovery, or construction, in the ordinary meaning of the words, of those fundamentals by students.

For physics, the four "Program of Study" documents are too sketchy to be directly useful. The Core Content document, on the other hand, is relatively short, well organized, and almost free of errors—at least in physics and cosmology. Demands made on the student are generally appropriate to grade level, and become more sophisticated with rising level. There are no separate physics (or Chemistry) documents.

Disciplinary content, counting primary through high school, is not quite adequate. Vague expression jeopardizes the design of meaningful assessments. The coverage of earth and space science is conscientious but, again, flawed by occasional lack of content specificity where that is obviously needed, and by inflation.

In the standards for life science, as a reviewer remarked, "One comes away with the distinct impression that the writers of this document do not understand evolutionary theory, nor, for that matter, much biology in general. The topics listed are not shown to integrate in any way—it's one thing after the next—as if the writers are downloading boilerplate." "One thing after the next" does, however, amount to a great many topics offered. Were they better organized, and supplemented with a few necessary words and explanations, the life science showing would be respectable.

The gravest lack is the absence of the word "evolution." Yet this remarkable document does manage to include, if not necessarily to make perfect sense of, many of the key ideas and categories of evidence in evolutionary biology. We must conclude that the writers tried to get the needed content into the standards and, by omitting that politically fulminating E-word, to suggest to suspicious persons (who might use, perhaps, a search engine on the documents) that it isn't there. For this reason the grade could have been reduced to "F," but the effort elsewhere, including the actual content of evolutionary biology provided, is strong enough so that we allowed the score-determined grade "D" to stand.

LOUISIANA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	8.0	12
B. Organization	8.0	9
C. Science Content and Approach	20.3	27
D. Quality	5.0	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	2	3
Raw Score	51.3	69
Final Percentage Score	74	100
GRADE	**B**	

Reviewed: Louisiana Science Framework (1997) and Science Grade Level Expectations
NB: Some editorial changes have been made to the Grade Level Expectations since we reviewed them.

This enormous but very conscientious document from 1997 relies heavily on material (some of it attributed and some not) from the AAAS "Science for All Americans" volume. In some grades, Inquiry and process dominate all other science activity. As will by now be evident, we are not convinced that this is an invariably good thing, even though it remains fashionable. Thus, "Science teachers are asked not to teach more, but to teach less so that it can be taught better." Or, "Science education reform emphasize[s] … particular attention to those groups, such as ethnic and language minorities and women, previously bypassed." There is also the expected deference to constructivist pedagogy.

The physical science section and the astronomy part of the earth and space science section are quite well constructed. Grade ranges are fairly coarse, and the standards themselves are not highly specific, But the content, order, and logic of the presentation, and the increasing sophistication by grade level, are all satisfactory.

A Grade Level Expectations document expands these standards into detail in a grade-by-grade format. As in the standards document, the material is presented correctly, in logical sequence, and with careful attention to increasing levels of sophistication. There are problems in the early handling of chemistry, but in high school the expectations are well articulated. The writing actually reflects the content of a good chemistry text. It deals with metric unit conversion, significant figures, scientific notation, Lewis dot structures, calculations based on balanced equations, the gas laws, calorimetry, and the like. Good intentions drove this writing of high school chemistry standards. Similar application would benefit related science in the earlier grades.

For earth and space sciences, the grade level expectations expand the Benchmarks to sentences, and, as the title implies, spreads them out by grade—in this case from pre-K to high school (with separate high school courses suggested). Overall content coverage is good, although extrasolar astronomy (and cosmology) is delayed, unnecessarily in our view, until high school. Addition of detail does introduce some confusing language here and there, but on the whole detail is a virtue. In environmental science, the stated expectations are strictly non-mathematical; but at least they are clear. Number 28 is an error but with charm: it discusses decreasing atmospheric carbon dioxide by a reduction of "combustible" engines.

Treatment of the life sciences is adequate or better, with a good range of knowledge touched in those years in which biology figures. The study of evolution begins, in effect, in grade 3, with consideration of fossils. "Change over time" first becomes explicit, however, in grade 8; and evolutionary biology proper is delayed until the 10th grade. However, evolution is done well enough in that year, especially because it is integrated with ideas and methods from contributing subdisciplines, such as genetics, population genetics, and embryology. There are gaps, but then the life sciences cover an enormous range. Grade: "B."

MAINE

	Points	Out of a Possible
A. Expectations, Purpose, Audience	5.8	12
B. Organization	6.6	9
C. Science Content and Approach	11.8	27
D. Quality	2.8	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	0	3
Raw Score	35	69
Final Percentage Score	51	100
GRADE	**D**	

Reviewed: Maine Learning Results (1997)
NB: Maine's standards revisions are due for release at the start of 2007.

The Maine document is remarkably concise. Its brevity is such that standard "G"—the Universe—fits on half a page. Were that concision coupled with precision and specification, the result would be both unique and worthy of highest honors. Precision and specification of content are not, however, its characteristics. The organization of standards by grade levels is PreK-2, 3-4, 5-8, plus the secondary grades. Standards are identified by letters of the alphabet and expanded in performance indicators, which constitute the specific material offered and which are closest to real learning standards.

A preface states that this is not a curriculum (it isn't) and that pedagogy will not be prescribed (it isn't). It offers some vague outcomes-based-education goals and asserts "no assumption is made about when a standard is achieved." Science process material is routine, and generally adequate. A representative concern, however, arises under Inquiry. In Standard J, grades 3-4, we see, "Explain how differences in time, place, or experimenter can lead to different data," and "Explain how different conclusions can be derived from the same data." There is no qualification of these facts with the connected facts of science process: for example, that repetition of experiments is important and commonplace, and that there are standard techniques for identifying and eliminating error, both random and systematic.

There are four life science themes: The first is Classification. A taxonomy of organisms is attempted at increasing grade-block levels, culminating, in high school, with "Explain the role of DNA in resolving questions of relationship and evolutionary change." Next is Ecology, with food webs and food chains. Here, for high school, we are given a rare example of what will actually happen in the classroom, and it is not promising: "Create a poster illustrating the cycles of water, oxygen, and carbon dioxide as they relate to photosynthesis and respiration." For Cells, there is a suitable but hardly innovative or even practical high-school exercise: "Create a model contrasting the processes of meiosis and mitosis."

The last theme is Continuity and Change, and here evolution is taken up. It begins in the lowest grades with reference to fossils and in grades 3-4 deals obscurely with adaptation ("Explain how adaptations, in response to change over time may increase a species' chances of survival"). In grades 5-8, students are asked to "Describe how fossils can be used by scientists to trace the history of a species." "Lineage" would be infinitely more practical than "species"! In high school, many proper words are used about biological diversity and evolution; but they do not add up to a coherent treatment of biodiversity and its mechanisms.

Earth Science (Standard F) fits on two-thirds of a page and contains 20 statements over all grade spans. A number of these are so sweeping as to be useless: "Describe factors that can cause short-term and long-term changes to the earth." Others are clearer, albeit broad: "Classify and identify rocks and minerals based on their physical and chemical properties, their composition, and the processes which formed them." Nevertheless a good deal is missing, notably the mechanics and effects of solid earth processes such as earthquakes and volcanoes or explicit attention to weathering, erosion, and the rock cycle.

For the physical sciences, the comments of the reviewer in prior studies continue to apply : these documents do give evidence of good intention and of some competence among the writers. But they are too scanty, too many of the features of fully competent standards (such as proper attention to mathematics in scientific inquiry) are missing, and in general the preparation in primary grades seems inadequate to support quality courses in high school. There may be, indeed there probably are, quality science courses in Maine schools; but the standards documentation does not really encourage them. "D."

MARYLAND

	Points	Out of a Possible
A. Expectations, Purpose, Audience	7.4	12
B. Organization	7.5	9
C. Science Content and Approach	18.4	27
D. Quality	5.3	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	3	3
Raw Score	49.6	69
Final Percentage Score	72	100
GRADE	**B**	

Reviewed: Voluntary State Curriculum—Science (2005)

Much in the reviewed documents appears to be in draft form, which probably accounts for the discontinuity between the K-8 standards, most of which are workmanlike or better, and the advanced material treated as "Core Learning Goals," which is in places slapdash.

The matrix organization shows how each concept is enriched with advancing grade level. Physical science materials are systematic and thoughtful. Of course there are some small errors. For example: in grade 5, "Identify ways of storing energy in an object. … Putting it on the end of a compressed spring." The energy is in the compressed spring, not in the object. For grade 7: "Recognize that input work is always greater than output work." Not quite right; "or equal to" must be added. And what is perhaps a typo: "Recognize that vocal chords vibrate to produce sound." No. The vocal *cords* produce sound. The high-school standards for physics, perhaps unfinished, are inadequate.

In earth/space science: there is no significant treatment of astronomy or cosmology. In contrast to the elegant organization and exposition of the preK-8 materials, the advanced earth/space science in "Core Learning Goals" is merely a list of generalities that would provide little guidance for course development or assessment. Some statements are so broad as to be empty: "The student will apply the law of conservation to the processes that affect rocks and minerals," or, elsewhere, "The student will identify that data are biased."

Only for the life sciences is the advanced (high school) material appropriate; and it is very good indeed. This high school program not only provides basic content for cellular, molecular, and organismal biology, but also a sophisticated treatment of ecology. The first mention of evolution is in grade 8, but it is a good start. High school biology includes a major section, well done, on evolutionary biology. The only lack is some introduction of human evolution.

Chemistry standards are rather thin, but what exists is clear and reasonable. In grade 4 students learn that weight can be measured on a spring scale and mass on a balance. In grade 6 they really do learn that volume of solids can be determined by water displacement, that chromatography can be used to separate mixtures, and what density is. Grade 7 students classify acid, base, and neutral solutions using the pH scale. Overall, though, too much chemistry content is missing, and there is no serious attention to the role of mathematics in science.

The process standards suffer from the usual illiteracies ("Identify that inventions … have made work easier …" in first grade) and some curiosities, such as "beehive" provided as an example of design in nature. Perhaps the writers meant "honeycomb." These are little things, but words matter. "Issue" and "problem" are used as synonyms, in the currently stylish fashion. But they are not synonyms, and interchanging them causes confusion in non-casual writing. Then there are the repetitious comforters to the effect that everyone can and does contribute to the advance of science and invention. Good intentions, and no great harm done here; but the work that standards are meant to do is not done by belaboring these sentiments. Maryland's documents are a good start, not yet the potential accomplishment. Grade, with recognition of serious effort and future hope: "B."

MASSACHUSETTS

	Points	Out of a Possible
A. Expectations, Purpose, Audience	10.8	12
B. Organization	9.0	9
C. Science Content and Approach	24.3	27
D. Quality	8.6	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	3	3
Raw Score	64.7	69
Final Percentage Score	94	100
GRADE	**A**	

Reviewed: Massachusetts Science and Technology/Engineering Curriculum Framework (May 2001)
NB: Massachusetts is currently updating its high school assessment framework.

The standards are contained in a Science and Technology/Engineering Curriculum Framework. After a full but relatively platitude-free introduction, it organizes the expectations for science learning under categories Earth and Space Sciences; Life Sciences; Physical Sciences; and Technology/Engineering. Content is presented in grade clusters of PreK-2, 3-5, 6-8, and 9-10. Standards are also provided for course development beyond Grade 10. The scope is ambitious: this Framework calls for science to be taught every year, with full courses in high school and a separate technology offering in middle and high school.

The standards are well and clearly organized; writing and editing have been done with care. Hence the entire presentation—from generalized statements of standards to generous detail on what is actually to be done in the classroom or laboratory—is comprehensible. The audience for standards documents ranges from academic content experts to high school students and their parents. From the Massachusetts document, all members of this variegated audience can understand, with reasonable effort, exactly what is required and expected at each level.

The document is also comprehensive. Material on Science as Inquiry is integrated, throughout, with the disciplinary content, which is adequately specific; and so makes it an organic element of instruction and learning rather than an add-on. Mathematical problem solving is stressed in concert with investigation and experimentation. Finally, the need for students to communicate effectively about their work in science, orally and in writing, is made clear.

Like the few other state offerings that receive high praise from all our reviewers, this one is not entirely free of oblique or trivial "activities" and of small but annoying errors—errors that would be detected and corrected if a final editing were done by properly qualified scientists. Examples: "4.1 Differentiate between wave motion (simple harmonic nonlinear motion) and the motion of objects (nonharmonic)." This doesn't make sense. Wave motion is often produced by sources in simple harmonic motion; but it is not the same thing at all. And the last part of the sentence is mere words. "4.6 Recognize the effects of polarization, wave interaction, and the Doppler effect." These cannot be lumped together in any straightforward way. And, "4.8 Explain the relationship between the speed of a wave (e.g., sound) and the medium it travels through." There is no way a high-school student can do this properly, since it requires differential equations. For sound, there is a relation between speed and air temperature. But if only that is the issue, the statement should say so.

There are six Environmental Science standards. These relate to energy sources and are found, logically, under Earth Science in grades 9-10. The life science material, including evolutionary biology, starts early (K-2) and is sound. Especially impressive for instruction in biological diversity and evolution is the recently posted high school material, free as it is of common errors and glosses. For the Massachusetts standards, "A."

MICHIGAN

	Points	Out of a Possible
A. Expectations, Purpose, Audience	4.0	12
B. Organization	4.0	9
C. Science Content and Approach	12.4	27
D. Quality	4.0	9
E. Seriousness	4.5	6
Inquiry	1	3
Evolution	3	3
Raw Score	32.9	69
Final Percentage Score	48	100
GRADE	**D**	

Reviewed: Michigan Curriculum Framework Science Benchmarks (Summer 2000)
NB: Michigan is starting to revise its standards.

The Michigan science standards are organized under three strands: "Using scientific knowledge," "Constructing new scientific knowledge," and "Reflecting on scientific knowledge." "Using" here includes what, in principle, these standards documents are supposed to present: substantive content that science students are expected to learn in the course of schooling. The subdivision of knowledge by level is coarse: elementary, middle, and high school. Science content tables are presented as "using scientific knowledge in life science," "using scientific knowledge in physical science," and "using scientific knowledge in earth science."

In earth science, the standards themselves (statements of expectations) are general and thin, as in "Describe features of the earth's surface." There are sections called Geosphere, Hydrosphere, Atmosphere and Weather, and Solar System, Galaxy and Universe. But lists of "key concepts," which are primarily lists of single words, follow these. Were it the case that the constituent science implied by those words, e.g. "rivers," were taught thoroughly and at the appropriate levels, there would be more than adequate earth science content in the Michigan standards. But one can't tell from the documents.

The breadth of the thematic standards is supposed to be enriched by detail in the Key Concepts (KC) and Real-world Contexts (RWC) that follow each Standard. But the KC are long lists of words, synecdoches, presumably, for what students are supposed to learn. For example, an identical Standard (C) I.1 in both middle and high school asks the students to "Design and conduct scientific investigations." What follows is a laundry list: test, fair test, hypothesis, theory, evidence, observations, measurements, data, conclusion, forms for recording and reporting data, tables, graphs, journals. The KC do not really specify what the student is actually to know or do and the RWC add little.

In elementary chemistry, there is no stated opportunity to learn about atoms and molecules. IV 2.2 for middle school says, "Describe common chemical changes in terms of properties of reactants and products." The RWC lists "alkaline drain cleaners." So far in this document there has been no mention of acids, bases, neutralization, alkaline—let alone the reaction that turns fat into soap. IV 2.1 for high school says, "Explain chemical changes in terms of the breaking of bonds…." This is doubly careless. Chemical bonding has not been covered in any previous standard; and chemical reactions involve the making, as well as the breaking, of bonds.

Physics is given shortest shrift. The implication that there is no need for specific discussion of forms of energy is unacceptable. There is essentially nothing under "Motion of Objects" at the high-school level—the very level at which kinematics and Newtonian dynamics should be the central subject matter. Provided are mere lists of things or phenomena, with little or no discussion of their significance. On p. 33, the high-school student is encouraged to join the writers in confusion about the distinction between kinetic and potential energy and the distinction among different forms of energy such as electrical and heat energy.

Biology does better. The treatment of evolution, *inter alia*, is reasonably comprehensive. There is enough attention to the life sciences as a whole, including cells, genetics, organismal biology, and ecology. Gaps remain, however, that must cause difficulties; for example, there is no real treatment of embryology. Without that, only the most superficial grasp of evolutionary biology is possible. Also, there is nothing to suggest that grade-appropriate laboratory or fieldwork will be included.

For science process, there is, by comparison, a certain amount of specificity. And some of it makes sense, especially the statements about what teachers are supposed to be trying to achieve (that, e.g., their charges will eventually be "… able … to make informed judgments on statements and debates claiming to have a scientific basis"). On descending into detail, however, things deteriorate. Trivially topical or cute section titles do not substitute for thought: "Making the Force Be With You," or "Now Hear This." Grade: "D."

MINNESOTA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	7.3	12
B. Organization	8.0	9
C. Science Content and Approach	18.0	27
D. Quality	5.5	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	2	3
Raw Score	48.8	69
Final Percentage Score	71	100
GRADE	**B**	

Reviewed: Minnesota Academic Standards K-12 (2003)

For science standards, Minnesota presents a 23-page tabulated matrix without introductory statements or explanations. Such a tabulation could nevertheless be a positive feature, at least to this extent: In contrast to many other such documents, this one makes its organization immediately obvious, and the contents are easy for the reader to locate. The table columns are labeled Grade level, Strand, Substrand, Standard, and Benchmark. Benchmarks are, in effect, the working standards. Learning expectations are by grade level for K-8; high school is a single span. Presumably, high school courses are to be designed locally with reference to the strands, which are: History and Nature of Science; Earth and Space Science; Life Science; and Physical Science. All are at least touched upon in grades K-5. History and Nature of Science is mandated for all grades, but the middle grades limit science content to a single focus each.

The physical sciences get good representation in the lower grades, becoming thin and undemanding in the upper grades. As is too often the case, small errors detract from quality. G6:II.A.5: "The student will distinguish between [sic] volume, mass and density." It is trivial so to "distinguish." The real point is to define one of them (density) in terms of the other two. G6:II.A.6: "The student will use the characteristic properties of density, melting point, boiling point and solubility to identify and distinguish mixtures and pure substances." What are the density, melting point, and boiling point of a mixture? G9-12:II.A.2: "The student will be able to explain the relationship of an element's position on the periodic table to its atomic number and atomic mass." Here "mass number" is more appropriate than "atomic mass." The concept of potential and kinetic energy is introduced for the first time at G9-12 (II.C.1, 2)—rather late. On the whole, however, the organization for physics is good.

Life sciences are handled reasonably well, with a fair distribution of content over the subdisciplines of biology. Material on the existence and properties of fossils starts in grade 5. The term evolution appears explicitly in grade 7, albeit without, yet, the evidentiary underpinnings most important in the contemporary discipline. This continues in high school, but there it thins even further. The molecular, development, and population-genetic components of modern theory are little in evidence. It is not as though they are too obscure to figure in a good high school biology program. In any event, there is no evidence so far in Minnesota's standards of effort to weaken evolutionary biology.

Process material, under the heading Nature of Science, gets—relatively—full treatment and is on the whole reasonable, although there is redundancy and none of the usual vacuities is avoided. What is achieved, in a science standards document, by asserting that "the student will recognize that everyone can do science and invent things"? And one must wonder, when third-graders are supposed to "understand the nature of scientific investigations," whether the writers ever had any easing of their addiction to boilerplate. In the end, most such boilerplate is innocuous. But some varieties may not be. "The student will recognize that science and technology are influenced by cultural backgrounds and beliefs and by social needs, attitudes, values and limitations." Yes, certainly! But the whole point of a K-12 science education is to establish beyond misgivings that there are sound practices, elaborated over more than 300 years, taken very seriously in the natural sciences, whose purpose is—precisely—to detect and eliminate biases due to "social needs, attitudes, values and limitations." Grade: "B."

MISSISSIPPI

	Points	Out of a Possible
A. Expectations, Purpose, Audience	5.3	12
B. Organization	6.8	9
C. Science Content and Approach	9.8	27
D. Quality	3.5	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	0	3
Raw Score	32.4	69
Final Percentage Score	47	100
GRADE	**F**	

Reviewed: Mississippi Science Framework (2001)

The Mississippi Science Framework, 2001, a relatively recent and already massive document, offers an integrated curriculum for grades K-8 and more than 20 science courses for high school. Based in large measure on the National Science Education Standards, the three strands used are Life (L), Physical (P), and Earth/Space Science (E). There are Grade Level Cluster Benchmarks at grades 4, 8, and 12. These are non-specific general statements. "Competencies" appear to be the real standards, but these too lack sufficient detail. Each cluster of Competencies is marked with a "P," "L," or an "E". Then come pages of optional Suggested Teaching Strategies, which seem to be a collection of favorite teacher activities, only some of which are potentially useful. Some repeat year after year (watching ice cubes melt). Most offer little or no science content. One asks students to "create useful objects from trash." Another is: "Using oil and feathers, experiment to discover what happens to a bird's feathers in an oil spill."

> Process: A fascinating table on p. vi, inspired by the National Standards, explains the putative shifts of emphasis introduced with this new framework, including:
>
> From: covering many science topics, to: studying a few fundamental science concepts;
> From: implementing inquiry as a set of processes, to: implementing inquiry as instructional strategies;
> From: science as exploration and experiment, to: science as argument and explanation.

The document headed "Science Skills and Reasoning" has little helpful content. "Utilize critical thinking and scientific problem solving in designing and performing scientific research and experimentation" does not seem to implement in any substantive way "inquiry as an instructional strategy." "Literature connections" turns out to be a reading list, much of it juvenile books about butterflies, small children walking on the bottom of the sea, the "Twilight man," and such. "Technology connections" is a list of possibly useful CDs.

The physical sciences (P) fare best. Coverage is broad and many standard topics are mentioned. But for K-8, there is not enough real chemistry content, the vocabulary is weak, and there is no serious use of mathematics. The prevalent philosophy is stated: "Competencies are intentionally broad in order to allow school districts and teachers the flexibility to create a curriculum that meets the needs of their students." In "real-world" education, that leaves too much to chance. There is undue emphasis on "activities," too many of which squander time. The frequency of errors, garbled statements, and gross misunderstandings is high. This example must stand for a long list: G6: "Using a battery, two pieces of wire, and a bulb, have students investigate electrical currents." Using the equipment specified, some of the students may get the bulb to light. But they will certainly not be able to "investigate electrical [sic] currents."

Earth and space science background is built up in K-8, in places well enough, but high school courses do not take full advantage of this. They are shallow and repeat material from earlier grades. Language is imprecise. Students are asked to "research the six common minerals," but we have no way of knowing which six. The basic rock cycle is taken up, as is the elemental composition of Earth layers. Comets are mentioned, and "red and blue shifts," but there is no cosmology. There is an introduction of plate tectonics, but no discussion of the critical evidence upon which that upheaval in geology was based. Were Inquiry really foremost as an "instructional strategy," that evidentiary trail would be the entire point.

In the life sciences, there is plenty of coverage, but it is rather sporadic. A few lines of evidence for evolution are touched upon, but Mississippi takes remarkable pains to avoid using the word "evolution," which might alone justify the grade "F." There is evidence in these standards of ongoing effort to produce workable and high-quality documentation: unfortunately, the goal has not yet been met.

MISSOURI

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.0	12
B. Organization	8.0	9
C. Science Content and Approach	17.5	27
D. Quality	3.5	9
E. Seriousness	5.8	6
Inquiry	2	3
Evolution	3	3
Raw Score	45.8	69
Final Percentage Score	66	100
GRADE	**C**	

Reviewed: Missouri's Framework for Curriculum Development in Science, K-12 (1996)
NB: Missouri released new science standards in November 2005.

The first and shorter of the two Missouri documents is the state's "Show-Me" Standards. It consists of generalities. The second, "Missouri's Framework for Curriculum Development in Science K-12" carries the substance: Scientific Inquiry, Scientific Relevance, Matter and Energy, Characteristics of the Universe, Physical Systems, Living Systems, and Ecology. Each of these starts with a content overview, followed by expectations, arranged as "What all students should know," "What all students should be able to do," and "Sample learning activities." Within each section, the material is presented for K-4, 5-8, and 9-12. However, the K-4 material is broken down so as to present goals for the ends of grade 2 and 4. This is a complex but reasonably transparent organization.

Life sciences get good treatment with few errors or troubling turns of phrase. Ecology is an independent category, given full emphasis throughout. Ideas of evolution are developed competently. K-4 introduces fossils. In grades 5-8, the concept of adaptation is built up from evidence, and natural selection is examined in context. In high school, the basis of some contemporary systematics emerges in the treatment of nucleic acid and protein composition. Students are expected to read and interpret published primary articles.

Earth science content is creditable but suffers from the "themes" approach, as in "The surface of Earth changes slowly (e.g. erosion, weathering) or quickly (e.g. earthquakes, floods, rock/mud slides, volcanic activity)." This is a second grade item, yet the time scales of these processes are almost impossible for young children to comprehend. There is also the "destructive and constructive forces" theme, for which the "physical evidence" is faulting, volcanoes, folding of rock, and the like. These are interesting phenomena for children to know about; relegating them to generalized "destructive or constructive forces" renders them meaningless.

The standards are ambitious and occasionally offer a pearl: "Variations in the physical conditions and chemical composition of soil are a result of the type of rock from which it came, climate, the process by which it was deposited, and biological activity." On the same page, however, is the vacuous "identify and describe the scope of the impact of human activity on the atmosphere."

The standards do far less for physical science. As one reviewer put it, "… the writers reached the limits of their competence at the end of Grade 4. While the standards appear adequate up to that grade level, they are … unsuitable for any educational purpose beyond it." There is too much science process and not enough physics and chemistry content. The statements are not specific enough to indicate what is required. Topics in environmental science are scattered and non-specific. The K-12 Content Overview places great emphasis on using mathematics in science, yet there was almost nothing quantitative in the document.

Abundant process materials follow the national models, and there are a few bright spots, such as acknowledgement that there is no fixed, stepwise process that can be called "the scientific method." A few of the sample learning activities are interesting: "… read a collection of articles, including peer-reviewed articles from science journals, newspaper articles, and 'supermarket tabloid' articles about a science-related issue … analyze the credibility and documentation of each…" Trimmed, and sharpened, this material could be made a model for keeping the treatment of science process in standards useful and under control. Grade: "C."

MONTANA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	3.8	12
B. Organization	4.5	9
C. Science Content and Approach	8.5	27
D. Quality	2.0	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	0	3
Raw Score	26.8	69
Final Percentage Score	39	100
GRADE	**F**	

Reviewed: Montana Standards for Science (1999)
NB: Montana's new standards are due out in February 2006.

The remarkably compact Montana standards are all right as far as they go, but they go only very little of the necessary way. They are far too coarse-grained for the purposes they are supposed to serve. By themselves, they cannot be used to construct curriculum or examinations, to guide textbook publishers, or—and this is by no means a lesser concern—to explain to the interested public just what Montana students are supposed to learn about science. An accompanying tabulation is even more laconic. One reviewer, examining the life sciences offering, concluded that were this document to be the sole official source on Montana science education, this would be an inevitable conclusion: "… You could go to school in Montana and never learn anything about the parts of the body or their function, about embryos, about the process of disease … zero hits for gene, chromosome, mutation, blood, muscle, physiology…." Evolutionary biology content is addressed, but the presentation is strictly minimal.

The Content Standards, Benchmarks, and Performance Standards all produce the same letdown: they are too general, and they begin with verbs like analyze, infer, investigate, and evaluate, which are used as if they had no specific meaning. Statements to the effect that students will "know" something are remarkable by their absence. Chemistry content is mostly missing. Under Physical Science, Standard 2, there are 18 Benchmarks, six per grade span. This means all the topics of chemistry and physics are supposed to be contained in 18 sentences. A sample: In grade 4, students will "identify and predict what changes and what remains unchanged when matter experiences an external influence." The content of a high school chemistry course is nowhere to be seen. Grade: "F."

NEBRASKA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	2.8	12
B. Organization	6.3	9
C. Science Content and Approach	8.5	27
D. Quality	1.5	9
E. Seriousness	6.0	6
Inquiry	0	3
Evolution	1	3
Raw Score	26.1	69
Final Percentage Score	38	100
GRADE	**F**	

Reviewed: Science Standards Grades K-12 (1998)

The Nebraska Science Standards Grades K-12 is a minimal document heavily in debt to the available national standards, but not nearly as comprehensive. Its sections include Unifying Concepts and Processes; Science as Inquiry; Physical, Life, Earth and Space Science; Science and Technology; Science in Personal and Social Perspectives; and the History and Nature of Science. Grade spans are K-1, 2-4, 5-8, and 9-12. There is a separate section called STAR (Standards That Are Reported)—standards for which assessment will be done, and for which reporting to the Department of Education is required. Major weaknesses in the documents make them problematic: substantive science content is sparse at all grade levels, and such content as is offered is often marred by vague terminology. Mathematical problem solving is virtually non-existent.

Less than full honors are due to the treatment of life science; but evolution is considered and some of the essential content is touched. Meaningful detail, however, is not indicated until high school. There, although some details are mentioned, we find troubling statements, inexcusably vague for grade 12 or just carelessly written. For example, students are asked to "investigate and use" the theory of biological evolution to explain the diversity of life. But any serious reader already knows that this is what is supposed to happen. *How*, exactly, is that investigation to proceed? To that question, mostly silence. Students are to *investigate* whether natural selection provides a scientific explanation of the fossil record and the molecular similarities among the diverse species of living organisms. Well, yes. But that is, again, what the entire unit of curriculum is supposed to be. Again, "investigate" is a mere honorific; "whether" is insincere. One reviewer describes the treatment of earth science as "empty and bleak." One of many examples of carelessness in the treatment of physics is this: P.12B.1 "Students know that magnetic forces and electric forces can be thought of as different aspects of a single electromagnetic force." This unreasonably assumes significant prior knowledge. If the student is expected merely to parrot the statement, it is pedagogically useless. A real understanding presupposes understanding of Ampère's law and Faraday's law, neither of which has even been hinted at.

Science process gets fuller treatment, but it is not much more enlightening as to specific knowledge and skills expected. More troubling is the frequent mixing of central and marginal issues, as though boilerplate were being condensed and repeated but not really understood. Thus there is a history of science section that refers to the need for "ethical codes followed by scientists (e.g., humane treatment of animals and truth in reporting)." No indication is given of the relative importance of these two codes for the whole project of natural science or for its epistemic ground rules. Grade: "F."

NEVADA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	4.5	12
B. Organization	7.3	9
C. Science Content and Approach	12.5	27
D. Quality	2.8	9
E. Seriousness	6.0	6
Inquiry	0	3
Evolution	2	3
Raw Score	35.1	69
Final Percentage Score	51	100
GRADE	**D**	

Reviewed: Nevada Science Standards, approved (2005)

Nevada, like a few other states, opts for minimalism in presentation of its standards. Treatment of science processes and the nature of science is fair enough but scanty, and in a few places it borders on the inane: "… science involves asking questions and comparing the answers with what scientists know about the world." That isn't wrong: and if "what scientists know about the world" were identified as the vast matrix of existing observation, experiment, and theory, the statement would be a great beginning. It would suggest and lead to usable benchmarks and lessons. As given, it does neither. The document as a whole is well structured but quite poorly executed, especially at the higher grade levels.

If the earth and space science material is read and interpreted very liberally by capable teachers, much of the usual content will be taught. Statements are sometimes too sweeping; "Students know the properties that make water an essential component of the earth system" could lead in far too many directions. How will lessons on this subject be built? There are a few significant omissions. Minerals are examined but never named. Sedimentary processes are well developed but the rest of the rock cycle is missing. The astronomy section mentions that the universe is expanding but contains no further cosmology. For high school, there is the statement "Students know how successive layers of sedimentary rock and the fossils within them can be used to confirm the age, history and changing life forms of the Earth." But relative dating of sedimentary layers cannot yield the age of Earth, and the Nevada standards don't mention absolute dating.

In physics, there is evidence of real effort to cover major content areas. But careless writing or misunderstandings spoil the effect. Examples: P.12A.9: "Students know that the number of electrons in an atom determines whether the atom is electrically neutral or an ion." Not really. The determining factor is the difference between the number of electrons and the proton number. P.5B.1: "Students know that electric currents can produce magnetic forces and magnets can cause electric currents." The writing promotes confusion. Magnets don't "cause" electric currents. A magnet moving in the vicinity of a closed conducting path gives rise to an electric current.

There is not enough chemistry, and what is offered is repetitious. Mathematical problem solving is ignored; everything is qualitative.

Life sciences are handled the same way, mainly with generalizations—a few of which need correction. Thus, "Students know that multicellular organisms can consist of thousands to millions of cells working together."

Billions or trillions would be a much better generalization. Evolution is taken up starting in grades 6-8 with discussion of fossils. In high school, most of the essential points of high school evolutionary biology are touched, albeit lightly and again with generalities. It is hard to guess what is really expected to happen in class. These standards get by, but just. Grade: "D."

NEW HAMPSHIRE

	Points	Out of a Possible
A. Expectations, Purpose, Audience	4.3	12
B. Organization	1.8	9
C. Science Content and Approach	9.8	27
D. Quality	2.0	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	0	3
Raw Score	24.9	69
Final Percentage Score	36	100
GRADE	**F**	

Reviewed: New Hampshire K-12 Science Curriculum Frameworks (1996)

The standards are in six strands: Science as Inquiry; Science, Technology and Society; Life Science; Earth and Space Science; Physical Science; and Unifying Themes and Concepts. The New Hampshire documents get off to an unfortunate start by asserting that they were developed "to positively impact" science education in the state, which goes without saying. They are "pointed at specific concepts and skills that students should know and be able to do." This is so, but is hardly an example, for the state's presumably interested readers, of good English usage. Nor are the common banalities lacking: "learning science by doing science," and "… cognitive research suggests that students learn best by constructing their own knowledge." Many of us seek the plain-language meaning of, and clean examples confirming, that research; but they are no more provided here than elsewhere in standards documents. "Broad Goals" include "… students will recognize and understand the wide variety of similarities and differences that exist among objects and events." The "Science as Inquiry" section is better than the disciplinary content equivalents, and so is "Science, Technology, and Society." But all seem to have been written in haste.

Strand 5, Physical Science, is organized like the others. The chemistry-related standards are mostly low-level and vague. Under 5a, tenth graders are asked to "Describe, compare, and classify elements, compounds, and mixtures." Under 5b, they are also asked to "Demonstrate that it takes time for a substance to change or interact and that these rates are affected by such factors as temperature, pressure, and change of state, e.g. fermentation, decomposition, combustion." This confusing statement, with its irrelevant examples, is the only standard that attempts the important topic of reaction kinetics. There is nothing quantitative. The grades 6 and 10 Proficiency Standards for physics seem to pluck up subjects from the standards almost at random. The only quantitative demand is in the Unifying Concepts section: "Quantify certain changes and use a mathematical expression to determine past or future states of the system, e.g. gas laws, Newton's laws of motion." This suggests that a single try at a quantitative calculation might satisfy the requirements of 10 years of science study.

For Life Sciences, genetics begins in grade 6 and continues in grade 10. Evolution gets correct but cursory attention. High school biology is supposed to emphasize biological knowledge in a social/ecological context—biological concepts as they relate to human well-being and to the common good. Fair enough; curricula can be built on such themes. But neither the concepts nor the connections are sufficiently spelled out to guide a curriculum or lesson planner. Without the connections, good intentions are more self-congratulation than guidance. In grade 10, students are asked to "Design and perform an experiment to show that the number of living things any environment can support is limited by the available energy, water, oxygen, minerals, and ability of an ecosystem to recycle organic material." Would that this, exactly, could be done by a tenth grader, even a superbly educated one—let alone by a student learning science according to sketchy standards such as these. Grade: "F."

NEW JERSEY

	Points	Out of a Possible
A. Expectations, Purpose, Audience	8.6	12
B. Organization	7.1	9
C. Science Content and Approach	19.8	27
D. Quality	6.6	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	3	3
Raw Score	53.1	69
Final Percentage Score	77	100
GRADE	**B**	

Reviewed: New Jersey Core Curriculum Content Standards for Science and New Jersey Framework (2004)

This is a mammoth document. It is unlikely that anyone not required to read through it will undertake the labor. New Jersey's standards are a multi-author, worked-over, professional operations manual. That need not be in all respects a bad thing. But the virtue of transparency for other parties interested in science education—thoughtful parents, for example, officials other than educators, and even non-science schoolteachers—is violated by the sheer size and complexity of the text.

A semi-narrative style is used to set forth good science content, and it succeeds, in general, in clear form. There is thoughtful alternation, especially in physics, between experimental and theoretical content. Among the student laboratory experiments suggested, some are well suited to their specified learning goals—not at all a common virtue in state science standards. Two documents comprise the current New Jersey set: New Jersey Core Curriculum Content Standards for Science and New Jersey Science Curriculum Framework. Taken together, they provide a good basis for the intended functions, at least in curriculum and assessment guidance.

The Framework clearly followed the Standards. The latter divides content by grade clusters K-2, 3-4, 5-6, 7-8, and 9-12. "Standards" are meant to be general statements; they give rise to Cumulative Progress Indicators (PIs), which are the effective standards for science content. A strength of the organization is that technologies are introduced in their basic science context (for example, telescopes with astronomy).

The Framework document may well have been written to clear up ambiguities of the standards and to supply detail by way of teaching examples. In some cases this succeeds; the collection of "activities" will be a resource for teachers. But there are problems. The Framework introduction asserts that it is "steadfastly focused on the standards" but in fact it incorporates its own standards, and some of these are more sweeping, rather than more specific, than their predecessors. Example: "Identify the major features of the Earth's crust, the processes and events that change them, and the impact of these changes on people." Finally, some activities do not fit the supposed standard. And, despite their generally good quality, a few are trifling. A high school activity has students tracking hurricanes, but fails to address the important mechanisms by which these storms arise and amplify. Students in grades 3-4 make "constellation projectors"; these amount to throwing spots of light on the wall. Fun, perhaps, but not likely to be instructive.

Considering the physical bulk of this documentation, chemistry content is surprisingly sketchy. Standard 8 wants students to "Gain an understanding of the structure and behavior of matter." For K-4, the PIs are similar to those in the original (now supplemented) document, but grade 2 requirements have been eliminated and other PIs have been eliminated or moved to higher grades. In grades 5-8, properties are used to separate mixtures; the formation of new materials is said to imply new properties, atoms form molecules in different states of matter, the number of atoms and mass do not change during a reaction, similar properties allow for grouping of the 100 known elements, and so on. Yes; good. But these few PIs are all the chemistry for nine years of school (K-8). For grades 9-12 there is a surprising paucity of chemistry content.

The handling of evolution is excellent as is the handling of the life sciences as a whole. A characteristic statement of principle to be learned: "Evolution is the central theme of biological science. The mechanism of evolution is natural selection. The raw materials for this mechanism are mutations, and these mutations can be passed from one generation to another by reproduction. Students should be able to explain the genetic basis for evolution." Toward this proper goal, at one stage or another, students are introduced to fossils, the history of horses, industrial melanism and its rapid changes under natural selection, oxygen transport proteins, and other details of the argument. Laboratory activities and exercises are included; many of them are well thought out.

As might be expected in a production of this size, the science process material is abundant and touches all the fashionable bases, including some sound material on how successful investigations proceed. Ritual incantations are, however, too frequent: learning-by-doing, the equivalence of all peoples and cultures as contributors to science, "critical thinking," decision making, problem solving—and the importance of "getting along with others." The treatment of technology includes a sound statement on its symbiosis with science. On the other hand, much of the material on "workplace readiness" could have been left out without noticeable loss. These standards are a laudable effort that, with a tough editor and a few content experts, could easily be made exemplary. Grade: "B."

NEW MEXICO

	Points	Out of a Possible
A. Expectations, Purpose, Audience	10.3	12
B. Organization	8.5	9
C. Science Content and Approach	22.3	27
D. Quality	7.3	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	3	3
Raw Score	59.4	69
Final Percentage Score	86	100
GRADE	**A**	

Reviewed: New Mexico Science Content Standards, Benchmarks, and Performance Standards (2003)

New Mexico's version of science standards includes Science Content Standards, Benchmarks, and Performance Standards (PSs). The latter are the most detailed and are the real content resource for curriculum. Standards are presented by grade from kindergarten through grade 8, and then in a single span for 9-12. The detailed K-8 treatment will help schools and districts to design optimal content for high school courses. Central to the quality of New Mexico's effort is science content that is—as a reviewer reports—"rich, varied, ambitious, and builds from grade to grade."

The main complaints were about occasional over-reaching on concepts or careless writing. Thus, in physics (as an example of over-reaching), "Describe how some waves move through materials (e.g., water, sound) and how others can move through a vacuum (e.g., x-ray, television, radio)." "On what basis," the reviewer asked, "Can fourth-graders understand that light is a wave phenomenon? Does one do diffraction or interference experiments at this level?" On careless writing: "Recognize that acceleration is the change in velocity with time." Reviewer: "… [As physics,] … this statement would be correct if [and only if] the words 'rate of' were inserted in the proper place."

In the primary grades, a commendable effort is made to touch on essential content in, for example, chemistry. But quite a lot of it is, necessarily, *just* touched. High school chemistry, which ought to go much further than mere touching, does not quite do so. The PSs presented in grades 9-12 do not constitute a really comprehensive chemistry course. Missing are serious treatments of such topics as the gas laws, stoichiometry, and the mole concept.

Environmental science content appears occasionally in the document, especially in the sections on Science and Society. It is mostly at a low level—recycling, pollution, and the like. The life sciences, by contrast, are treated quite fully and exceptionally well. The build-up to teaching and effective learning of evolutionary science reveals original thought on content and presentation, not just copying from national models.

On process—inquiry and the nature of science—New Mexico provides an unusual amount of well-articulated good sense ("… persistence, respect for evidence, open-mindedness balanced with skepticism") mixed with some typical vacuous assertions collected from the available national models ("Understand that scientific conclusions are subject to peer and public review"). All told, though, New Mexico's standards do their job much better than adequately, and the general quality of science content is just high enough to substantiate the grade of "A."

NEW YORK

	Points	Out of a Possible
A. Expectations, Purpose, Audience	10.5	12
B. Organization	7.0	9
C. Science Content and Approach	23.5	27
D. Quality	8.5	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	3	3
Raw Score	60.5	69
Final Percentage Score	88	100
GRADE	**A**	

Reviewed: New York State Learning Standards for Science (1996)

New York's science standards appear as several documents comprising a colossal whole, but the material we expect to find in a proper account of what students are expected to learn is in the document named Core Curriculum. Targets for learning are set forth in grade spans of K-4, 5-8, and, for high school, as courses. "Key ideas"—"broad, unifying statements"—are followed by "Performance Indicators," which are in turn broken down into "major understandings." These are the statements we see as real content standards. The Core Curriculum states that it "represents only a portion of the content.... It is expected that additional content will be supplied locally." Fair enough if that "portion" is itself cogent and sufficiently wide-ranging over "key ideas." New York's standards are cogent and wide-ranging.

Earth and space science get well-written and adequate coverage, although some of the vignettes of classroom activity and student work are less than inspiring. A bit thin in the early grades, this sequence does end having included all the essential topics, carefully presented. The important skills, such as map reading, are given attention in the appropriate place. In the high school material, some of the Inquiry skills are made content-specific, as in the analysis of stream parameters.

Physical sciences show only a few lapses, none of which is disabling. In physics, there is a fine treatment of required laboratory time and space, of units, experimental error, and significant figures. The historical overview is good, though one might question the appropriateness of some of the names in the list of outstanding physicists and astronomers. The main chemistry content is in Key Ideas 3-5 under Standard 4. Presented are about 10 pages of mostly competent chemistry content. The "Major Understandings," however, are often at a low level or incomplete.

Life sciences, on the other hand, get treatment more rigorous and detailed than is the norm in current state science standards. There is good coverage of physiology—organ systems and their functioning. Reproductive and developmental biology are there, and so, surprisingly, is immunology. Ecology and human impacts on environment (including, especially, technological impacts) are well treated. And eventually evolution is presented correctly, as the central, unifying theoretical structure of modern biology.

Process subject matter is abundant—too abundant, in our opinion—but intertwined with science disciplinary content as opportunities arise. But as in even the best standards sets such as this, the quality is mixed. Epistemologically obscure or meaningless encouragements mix with sound advice and good practice. Grade: "A."

NORTH CAROLINA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	9.0	12
B. Organization	7.8	9
C. Science Content and Approach	21.8	27
D. Quality	6.0	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	1	3
Raw Score	54.6	69
Final Percentage Score	79	100
GRADE	**B**	

Reviewed: Science Standard Course of Study and Grade Level Expectations, K-12 (2004)

Science Standard Course of Study (SCS) and Grade Level Expectations, K-12, reflect a 2004 revision of North Carolina's earlier standards documentation. The revision was undertaken in order to "reflect the National Science Education Standards better," but reflections there are in plenty also of TIMSS, NAEP, Benchmarks for Scientific Literacy, NSTA Pathways, and other national guidebooks.

The new Scope section explains that this revision has less coverage of some topics but more emphasis on "teaching for understanding and the ability to apply that understanding to real life." We are not convinced that teaching for understanding has been accomplished in new ways, and chemistry is one of those topics whose content has been neglected in favor of "real life." Nevertheless, these were highly commendable standards in the prior version and they remain competent in the new one.

The most positive feature is the evidence that, for most of the science content, the writers really know the subjects they write about. They are able, moreover, to imagine the best ways to introduce those subjects, so that learning effects are cumulative grade by grade. The treatment of physics is excellent; errors and misconceptions are rare and in no case are they disabling. Laurels are due the writers who introduced the second law of thermodynamics in this traditional, unpretentious, but perfectly sound way: "It is impossible to build a machine that does nothing but convert thermal energy into useful work." How preferable it is to the groping in other teaching guides for ways to make sense of "entropy"! We readily forgive the substitution of the word "machine" for the technically correct "heat engine."

The document organizes its emphases according to the National Science Education Standards: unifying concepts of systems, order, and organization; evidence, models, and explanation; change, constancy, and measurement; evolution and equilibrium; and form and function. There are four strands: Nature of Science, Science as Inquiry, Science and Technology, and Science in Personal and Social Perspectives. It is obvious that, if the meta-science and process material does not literally outweigh specific disciplinary content, it accounts at least for a remarkable fraction of the emphasis, and perhaps eventually of classroom time. We cannot regard this with equanimity.

Earth science-space science material is ambitious, and includes some splendid moments, such as introducing the ancient geometer's measurement of Earth's circumference! One does worry, however, that the Standards seem never to require that students identify minerals by name, based on observable properties. In grade 1 they "Describe rocks and other materials in more than one way, using student-made rules." This is fine as an introductory activity, but it should culminate in some grade with the real thing—naming actual minerals using a chart of their properties. North Carolina *does* the real thing for points of content far more demanding, such as methods of relative dating and the Coriolis effect. Classifying phenomena such as volcanic activity and deposition as "forces" is a mistake. On the other hand, the 8th-grade section on the special properties of water is thoughtful. There is some minor overreaching. A reviewer comments: "I wonder how [mere] students will 'Analyze seismic waves including velocity and refraction' to 'Evaluate the level of seismic activity in North Carolina.'"

Life science content starts slowly but picks up. There is good treatment of human physiology. The units on microbes and disease are well done. Heredity ought to be preceded by some introduction to meiosis, because the discussion must remain primitive unless a mechanism for the segregation of "traits"—in gametogenesis and fertilization—is understood. Cell biology in general is rather vague. There is no proper mention of evolution until 9th grade. In due course, the main points of (now) classical, modern synthesis evolution are touched. But there is not much originality or insight in this treatment.

On the whole, North Carolina has mounted a good science standards effort that would be better were the process materials less intrusive and more of the indispensable chemistry content included. Grade: "B."

NORTH DAKOTA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	3.8	12
B. Organization	6.0	9
C. Science Content and Approach	12.3	27
D. Quality	3.3	9
E. Seriousness	5.8	6
Inquiry	1	3
Evolution	1	3
Raw Score	33.2	69
Final Percentage Score	48	100
GRADE	D	

Reviewed: Science Content Standards for Grades K-12 (2005)

North Dakota Science Content Standards for Grades K-12 are a March, 2005, draft of 95 pages. There are eight very broad standards with related benchmarks covering each grade, K through 8, and the spans 9-10 and 11-12 in high school. Benchmarks are listed along the side of each page; the remainder displays four column-level "Achievement

Standards." Presumably, these will support assessment schemes. From "Advanced" to "Novice," each column differs from its neighbor by just one success (or failure) word. For example, "insightful," "reasonable," "obvious," and "unreasonable" in that order; or "always," "consistently," "sometimes," and "rarely" in otherwise identical sentences. Whether or not this system can work as a test-scoring tool, it makes a mind-numbing read.

Many of the Benchmarks are poorly written; much work remains to be done. Some examples follow. 6.2.4: "Use appropriate tools and techniques to gather and analyze data." No examples of tools and techniques are mentioned. 9-10.2.2: "Identify questions and concepts that guide scientific investigations." No examples given. 9-10.2.5: "Design and conduct a guided investigation." There is no indication of how a "guided" investigation differs from (presumably) an unguided one. Under History and Nature of Science: 9-10.8.2: "Understand how views and attitudes have influenced the development of science (e.g., religion, previous knowledge, cultural, superstition, folklore, legends)." Depending on the teacher, lesson plan, and the wakefulness of the students, this can produce anything from an extreme, social-constructivist denial of objectivity to a kindly Kuhnian reminder that attitude counts. The most likely effect upon students who really pay attention will be to plant seeds of 1980s-style relativism.

In chemistry, blocks of necessary qualitative content are missing, and the Benchmarks make no provision for quantitative work of any kind. Typical high school chemistry is not really covered here. Physics follows well-known national models closely and thus starts out well enough, but with advancing grades it, too, becomes less and less demanding. Beyond Grade 6, physics falls far behind reasonable content expectations.

Earth/space science starts slowly but does, eventually, touch many of the usual bases. The word "mineral" doesn't appear until grade 6, but fourth graders "Classify rocks … using their physical properties." Following that, weathering is said to be caused by "wind, rain, and people"—but not necessarily by chemical change (one mineral to another) or any process of physical weathering, such as abrasion and exfoliation. Fifth graders measure weather conditions, but air pressure is conspicuously absent. Grade 6 has the vague "Know how rocks are formed (e.g. melting, cooling, metamorphism, combinations of minerals)" but the rock cycle is delayed until grade 8. The whole document badly needs rewriting. The most astonishing expectation: In grades 9-10 the advanced-proficient student will "analyze the past evidence of natural hazards and geologic events to predict future hazards with few, if any, errors." We hope so.

Treatment of evolution, like the rest of life science, is fairly superficial. It doesn't become serious until grade 9, when the expectation is "Relate the concept of natural selection to its evolutionary consequences. Recognize evidence for evolution (e.g., fossil records, vestigial structures, similarities between organisms, and DNA)." For grade 11, there is this interesting expectation: "Explain how change through time has ensured adaptation to changing environments. Relate the changes in the Earth's atmosphere to the evolution of photosynthetic life forms." The first half has obvious answers for a student who has worked in grade 9; but a good answer to the second half would require careful citation of geochemical evidence, for which the preparation here would appear deficient.

The themes and science process materials, whose presence, taken together, is supposed to justify some reduction of science-discipline content, are bewildering under continuously repeated student-performance rubrics. Thus, on p.16, under "explanation," the group of least proficient students "formulate an *un*reasonable explanation supported by data" [emphasis added]. Page 17, on methods, suggests that library and internet searches are methods of scientific investigation. Perhaps, but then the adjective "scientific" isn't needed. On "bias" the kinds mentioned are gender, race, religion, economic, generational; but not the most important for science: unshakeable commitment, come what may, to an existing theory. Grade: "D."

OHIO

	Points	Out of a Possible
A. Expectations, Purpose, Audience	7.8	12
B. Organization	7.5	9
C. Science Content and Approach	20.3	27
D. Quality	5.5	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	3	3
Raw Score	51.1	69
Final Percentage Score	74	100
GRADE	**B**	

Reviewed: Academic Content Standards, Science (2003)
NB: Ohio's content standards are separated into individual grade levels, and the requirements are detailed by science subtopics. Sample questions/exercises and teaching resources are also provided.

Like a good many of its counterparts, this document is huge, and thus strongly discourages reading by others than those who must read it. There is a general quality of overkill, introduced by "The science standards focus on what all Ohio students need to know and be able to do for scientific literate citizenship, regardless of age, gender, cultural or ethnic background, disabilities or aspirations in science." Oh, for an editor! Most reviewers of these standards would agree with the statement from one of them: "The Ohio standards, though much better than those of many other states, still suffer to some degree from sloppy language and occasionally inadequate understanding of the subject matter. It would not take a great deal of work to make them excellent."

The document's expectations are separated into "Standards" (overarching goals or themes), "Benchmarks" (expectations for grade spans K-2, 3-5, 6-8, 9-10, and 11-12), and "Grade Level Indicators" (the real learning expectations). Earth and Space Science, Life Science, Physical Science, Science and Technology, Scientific Inquiry, and Scientific Ways of Knowing are covered. The document's bulk is due in part to repetition. A reviewer described the whole as "an exhaustive and exhausting document: everything is repeated twice in different format." Still, with effort, a willing reader can comprehend the Standards as a whole.

What there is to comprehend is mostly quite sound. Via one theme or another, life science gets knowledgeable treatment and has few mistakes. Fossils are taken up in grades 3-4 and the study of evolution proceeds from there, building in reach and complexity to a set of strong and fully-expressed Benchmarks in grades 10 and 11. At that point dating by radioactive decay makes a good, hard connection with the earth sciences.

The handling of physics is generous and orderly, spoiled only by infelicities and the triumph of zeal over precision. An Example: Grade 6: "3. Describe that in a physical change (e.g., state, shape, size) the chemical properties of a substance remain unchanged." Aside from the eargrating "Describe that …," this is logically empty. A physical change is by definition not a chemical change; but also, a counterexample: radioactive decay of the nucleus (a physical change) does alter an atom's chemical properties. Most standards dwell unnecessarily on this old and arbitrary distinction.

In chemistry, content is inadequate over the grades. What little is there is at a low level; quantitative work, despite introductory nods to "problem-solving," is hardly touched. The Benchmarks and grade-level indicators are too broad and non-specific to be really useful in making curriculum or assessments. In the lengthy Glossary at the end of the document, words are defined at an elementary level and significant chemical terms are absent. Environmental science is scattered mainly through the earth and space science sections. All is qualitative. The earth sciences material is replete with sweeping generalities.

These Standards, impressive in size and in the evident labor invested in them, simply devote too many words, too much space, and too much emphasis to scientific inquiry, science process, and technology. Editing of those materials toward a modest firmness, and expert corrections of small misunderstandings in content, would elevate the already honorable grade of "B."

OKLAHOMA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.0	12
B. Organization	7.5	9
C. Science Content and Approach	12.0	27
D. Quality	1.3	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	0	3
Raw Score	34.8	69
Final Percentage Score	50	100
GRADE	**F**	

Reviewed: Priority Academic Student Skills Standards Framework, Science (March 2005)

Oklahoma's standards, "Priority Academic Student Skills" (PASS), are presented in a document of moderate size (48 pages), distinguished by straightforward organization and accessibility of components. Grounded in the National Science Education Standards and other national programs, it calls for an integrated approach with "science experiences at each grade level from all areas of the content standards."

Exposition is by grade through the eighth and by course in high school: Physical Science, Biology, Chemistry, Physics. Every grade or course has science process material and some disciplinary content. Grades 1–8 have content standards in life, physical, and earth/space science. "Standards" are broad statements followed by two or more "Objectives"—which are the effective standards. High school physical science includes a little earth/space science. There is almost no mention of environmental science, and scant attention is paid to technology.

These Standards have incorporated and sequenced the science process topics quite thoroughly, and on the whole, well enough. This is at the expense of science disciplinary content, which is nowhere fully adequate. The introduction states that fewer topics will be explored while "more emphasis is placed on in-depth understanding."

In physics, the Oklahoma standards are relatively undemanding at every level and especially in high school. Terse as they are, the statements of knowledge to be acquired still display misunderstandings here and there. Thus, in high school, 3.1: "All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves." This is not quite right. EM waves are not fields, though they are composed of electric and magnetic fields. And, "Energy can be transferred but never destroyed. As these transfers occur, the matter involved becomes steadily less ordered." This is an oversimplification and misstatement of the second law of thermodynamics.

Chemistry content standards are everywhere elementary (the high school level included): atoms, elementary particles, elements, solids, liquids, and gases. The objectives appear inclusive enough, but they use terms like oxidation/reduction, reaction rates, ions, molar weight, and balancing equations without explanation or prior introduction. Those words are, in short, pointers or placeholders rather than standards or objectives in some useful form.

Treatment of the life sciences is superficial. No really substantial content is indicated up to grade 5; by the 8th grade, elementary concepts of ecology have appeared, along with mention of other biological realities such as cells. There is in every grade a heavy admixture of science process. Fossils are introduced in grade 4, biological reproduction, lightly, in grade 7. In high school, there is discussion of change under environmental pressures, and a certain amount of the necessary content is indicated (but not developed). *The word "evolution" is never used.* The Oklahoma Standards may represent the result of taking too literally the idea that in science education, "less is more." "In-depth understanding" is not evident in this document. Grade: Dropped from "D" to "F" due to avoidance of the word "evolution," with no mitigating treatment of the scientific evidence for descent with modification.

OREGON

	Points	Out of a Possible
A. Expectations, Purpose, Audience	3.0	12
B. Organization	5.5	9
C. Science Content and Approach	8.3	27
D. Quality	1.8	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	2	3
Raw Score	27.6	69
Final Percentage Score	40	100
GRADE	**F**	

Reviewed: Standards for Science (2005)

Science, in Oregon's Academic Content Standards, is encompassed within a short, and in some respects obscure, grid format. It has the virtue of brevity tainted by the vice of inscrutability. It was adopted in April 2001 for the 2004-2005 school year. Included are Physical Science (chemistry and physics), Life Science, Earth and Space Science, and Scientific Inquiry. Column headings are "Common Curricular Goals (CCG), Content Standards, Benchmarks for Grades 3, 5, and 8, CIM/CAM, and Pass Criteria." (CIM and CAM are certificates, respectively, of "initial mastery" and "advanced mastery" under the statewide knowledge and skills testing program.) The document does not really address high school science.

There are very few standards overall; they are broadly general and tend to be repeated at higher grade levels with little or no change. The science process standards are perfunctory and their development in higher grades suggests little expectation of student growth. Thus for 3rd grade: "Make observations. Based on these observations, ask questions or form hypotheses, which can be explored through simple investigations." For high school, "Based on observations and scientific concepts, ask questions or form hypotheses that can be answered or tested through scientific investigations."

The CCG "The Earth is Space" has some solar system materials, without much observation. "The Universe" comprises "Describe natural objects, events, and processes outside the earth, both past and present," which must serve for the rest of astronomy—and there is no elaboration. Nothing appears about stars, galaxies, or the evolution of the universe. So far as it goes, which is not far, the physical science material is appropriate and well stated but there is little by way of meaningful organization. Some significant topics are developed, but others (electromagnetism, electrical circuits, extra-solar-system astronomy, and cosmology) are scanted or simply omitted.

Chemistry Benchmarks are few and shallow. A few Benchmarks relate to environmental science, found under Earth and Space Science. In very general terms, they deal with resources, recycling, and reusing. Life science treatment is light and routine. Such standard topics as do appear are adequately but minimally stated. The process materials neglect such important fundamentals as isolation of variables and the real distinctions among observation, experiment, hypothesis, and theory. Evolution gets a more detailed treatment than other life science. It begins, in effect, only in grade 8, where students are expected to explain how random variations in species can be preserved through natural selection. But the main points are then touched upon in grade 10. This is thin but rather better handling on the whole than that afforded the other Common Curricular Goals. Grade: "F."

PENNSYLVANIA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	7.0	12
B. Organization	5.3	9
C. Science Content and Approach	16.8	27
D. Quality	4.5	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	3	3
Raw Score	44.6	69
Final Percentage Score	65	100
GRADE	**C**	

Reviewed: Academic Standards for Science and Technology and Environment and Ecology (January 2002)

Pennsylvania's science standards are divided into eight areas: Unifying Themes, Inquiry and Design; Biological Sciences; Physical Science; Chemistry and Physics; Earth Sciences; Technology Education; Technological Devices; and finally Science, Technology, and Human Endeavors. Only three of the eight sections deal with science discipline content. The standards are uneven. Treatment of earth and space sciences is rather good, that of the life science very good. The physical sciences suffer by comparison. There are fuzzy statements, disorganization in some parts, and a few actual errors.

Coverage of the physical sciences is fragmented, and the disorganization of this material makes it hard to follow. We find, as 3.4.12.D: "Correlate the use of the special theory of relativity and the life of a star." This is meaningless; but it appears verbatim in the Mississippi standards as well. What was the common source? Or, 3.4.10.A: "Predict the behavior of gases through the use of Boyle's, Charles' or the ideal gas law, in everyday situations." The ideal gas law incorporates the other two as special cases. And, 3.4.12.A: "Explain how radioactive isotopes that are subject to decay can be used to estimate the age of materials." As contrasted to "radioactive isotopes" not subject to decay?

The sections named "Inquiry and Design" and "Science, Technology, and Human Endeavors," together with the attendant glossary, exemplify the science process problems. Good intentions are marred in places by ambiguity or unrealistic expectations. Thus, for grade 12, "Critically evaluate the status of existing theories (e.g., germ theory of disease, wave theory of light, classification of subatomic particles, theory of evolution, epidemiology of aids [sic]." Some discussion of each of these in 12th grade would be just and useful; "critical evaluation," if that means what it ordinarily means, is unlikely.

In chemistry, too little content is required for grades K-7. And for all the grade spans listed, the Standards and Descriptors are too generally worded to guide meaningful assessment. The Standards and Descriptors also leave too many gaps in content to prepare high school seniors for a (non-remedial) college chemistry course.

Life sciences, including the main subdisciplines of biology, are handled well and in a thoughtful grade sequence. As to evolution: In grade 4 extinct forms are to be compared with living organisms. Fossils are examined in more detail in grade 7, where the ideas of natural selection, adaptation, and environmental pressures are taken up. The main elements of evolutionary theory appear in grade 10, and human evolution (at least via the progression of form among early hominids) is taken up in grade

12, all without troubling error. These standards are a good start but they need a lot of work. Grade: "C."

We await with deep concern the outcome of the trial just concluded in Harrisburg, PA, where the plaintiffs are a group of parents and the defendant is the Dover, PA school district, which has issued statements belittling evolutionary biology and recommended readings on intelligent design creationism.

RHODE ISLAND

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.3	12
B. Organization	6.3	9
C. Science Content and Approach	14.3	27
D. Quality	3.0	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	3	3
Raw Score	39.9	69
Final Percentage Score	58	100
GRADE	**C**	

Reviewed: Rhode Island Science Framework (1995, Drafts 2005)

Rhode Island's Standards are uneven. They run the gamut, so far as the main science disciplines are concerned, from "excellent" to "poor." The document is sprawling; navigation is chancy. The Framework is described as the "product of the work of hundreds of individuals over a three-year period." Unfortunately, it shows. "Developing a Common Core of Learning" offers sensible guidance but it is also replete with uplift language more appropriate to business school: "… develop strategies to manage stress," "knowing how and when to negotiate or compromise," "… quality work which satisfies the needs of clients and customers…."

There is more than the usual applause for constructivism, although evidence of understanding of any of its actual imperatives or philosophical positions is lacking. Thus we find that "the central purpose of learning is to make a personal meaning of the reality that surrounds you." Well, yes and no. What all the constructivism here amounts to, in context, is a truism: memorization and rote learning, taken alone, are not the best way to acquire knowledge. Well, yes.

In the life sciences at least, Rhode Island standards make an unusually thoughtful effort toward actualizing "hands-on" learning. But one reviewer found "comic relief in the form of a project allegedly integrating science with language arts and mathematics: 'collecting and organizing the litter thrown away at lunchtime is an exciting mathematics activity for the students.'"

The physical sciences, which start well enough in the primary grades, deteriorate as the grades ascend. A reviewer complains that "At the higher levels they are grossly undemanding, disorganized, and almost unbelievably spotty. For instance, entropy is mentioned and a stab made at defining it but there is not a single mention of the second law of thermodynamics. Electromagnetism is sandwiched into mechanics, which is itself incompletely treated." The chemistry content of K-8 is inadequate to support a decent high school program. No chemical topic is developed "in depth." High school content, collected in only nine Benchmarks, is inadequate to prepare students for a college course.

The earth/space science topics addressed are sometimes presented in the form of activities, the messages of which are shallow. There is not much buildup of sophistication, or anything quantitative, in the higher grades. Some core material of these disciplines is omitted.

By comparison, however, the life sciences shine. There are, to be sure, the common mistakes. Metazoans are given merely millions of cells. And students are supposed to be able to recognize changes between an original and a mutated DNA sequence and to transcribe and translate the DNA to an amino acid. It is all too vague to allow judging whether that is highly sophisticated and perhaps correct (for a single triplet, say?) or just—talk. But there is unusually good treatment of developmental biology, and in high school the general approach to molecular biology is rather sophisticated.

Rhode Island's standards are evidently the result of serious planning and effort. The result could, and should, have been better. There is too much that just isn't science. There is too much technology. Benchmarks in the physical sciences are often too vague to enable meaningful assessments. This outcome is testament to the dangers of taking "less is more" and "depth rather than breadth" as the main, rather than contributing, principles of good science education. Grade: "C."

SOUTH CAROLINA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	11.5	12
B. Organization	8.3	9
C. Science Content and Approach	23.3	27
D. Quality	9.0	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	3	3
Raw Score	64.1	69
Final Percentage Score	93	100
GRADE	**A**	

Reviewed: South Carolina Science Curriculum Standards (2000)

These science standards are based on the National Science Education Standards and a number of other national guides to standards and curricula. Unlike many other states, however South Carolina used the national standards as a starting point, not for slavish replication. As a result, these standards are content rich; they constitute a genuine effort to define science literacy from K through 12. Each grade K-8 offers Inquiry, Life Science, Earth Science, and Physical Sciences. The Inquiry material tends in places toward redundancy, but nevertheless builds with grade. High school standards (grades 9-12) are dealt with in a single span and include the four usual areas of emphasis.

The physical science standards are well organized and remarkably free of errors. Reports a reviewer, "In one or two instances the choice of historical figures is a bit odd (e.g., Marie Curie is included in a list of contributors to nuclear theory but Maria Goeppert Mayer is not.)." Another reviewer reports, "It was refreshing to see most of the content I expect in a high school chemistry course. These were listed under the heading of Performance Objectives or Competencies. There were also suggested activities. Many of these were reasonable, although some were silly. A sampling of the important topics included here: electron configuration, emission spectra, trends in ionization energy, electronegativity, atomic and ionic sizes."

In life sciences, there is rather more replication of boilerplate from the national guides than these competent writers needed; nevertheless the treatment overall is good. It goes beyond those national sources. A reader has the sense that there was qualified thought at work. Grade 8 has some sophisticated content, including discussion of human diseases in the context of organ system function. In high school biology this is done again—study of Tay-Sachs disease and hemophilia supporting the study of genetics in an original and lucid manner. The handling of evolution, which begins quietly with the introduction of fossils in grade 3 and continues thereafter, is exemplary.

There is welcome prose here propounding the principle that standards of good science education are intended for *all* students. But that is followed by a bit of honest realism: "… different students will achieve understanding in different ways, and different students will achieve different degrees of depth and breadth of understanding, depending on their interest and ability." The Inquiry standards form a sequence nicely adjusted to the sophistication of students in each grade. Of course, there are silly statements, too: high school students are asked to "formulate a tentative hypothesis based on literary [sic] research and previous knowledge." There are some mistakes in the glossary accompanying the grades 9-12 document. In general, however, the science process material is presented in such a way that it makes sense at every level of content for the science disciplines. Grade: "A."

SOUTH DAKOTA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	5.4	12
B. Organization	6.0	9
C. Science Content and Approach	11.0	27
D. Quality	3.3	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	1	3
Raw Score	35.7	69
Final Percentage Score	52	100
GRADE	**D**	

Reviewed: South Dakota Content Standards (2005)

In these documents, the most general category of learning expectations is dubbed "Goals." Successively more detailed categories are "Indicators," "Benchmarks," and "Standards."

Only the last allow the reader to identify knowledge and skills that students might be expected to acquire. The Goals are: Nature of Science, Physical Science, Life Science, Earth and Space Sciences, and (apparently a catch-all to satisfy sociological and environmentalist interests) Science, Technology, Environment, and Society. Grade clusters for the Benchmarks are K-2, 3-5, 6-8, and 9-12, but there is some exasperating repetition of content from grade to grade.

A feature of South Dakota's handling of science process material is a frank statement in the introduction. It defines the design imperative as "deemphasizing memorization of facts" and "emphasizing scientific inquiry." This makes clear what drives choices of emphasis and omission and in principle the drive is a good one. Learning science by rote memorization is certainly a losing proposition, as scientists and teachers of science have long known. The question is, what demonstrable contribution is made to scientific literacy—defined as modestly as possible—by substituting the Inquiry materials for "facts"? Thus far, enlightenment is elusive.

Physical science content is damaged by mistakes of fact and carelessness in writing, both faults arising from the evident lack of sufficient knowledge on the part of the writers. A few examples: p. 86: "5.P.3.1. Students are able to demonstrate and explain how to measure heat flow into an object. Example: Measure temperatures of various materials placed in sunlight. • Interpret a thermometer." This is a series of non-sequiturs. The example does not exemplify the standard, and the bulleted statement is meaningless. For grade 6: "Recognize scientific knowledge as [is?] not merely a set of static facts, but is dynamic and affords the best current explanations. Examples: flat Earth, spontaneous generation." There were no "scientific" thinkers, going back at least to Eratosthenes, who *explained* that the earth was flat, that is, whose scientific *knowledge* was to that effect! Or, "Describe significant characteristics of different forms of energy. Explain energy transfers and transformation of light." What is "transformation of light," and what does it have to do with "significant characteristics"?

For chemistry, there is an effort at proper sequencing, but too little content in K-8 and (as elsewhere) too much science process instead. It is very difficult to visualize what students will actually learn and do in the classroom. The high school chemistry curriculum implied by these standards will not prepare graduates for a regular college course. Quantitative reasoning in the sciences, including environmental science, is either inadequate or absent.

The earth and space sciences get much better, and on some topics good, treatment. Reviewers complain, however, of repetition of the same content in grade after grade, with insufficient modification or enhancement. The same may be said of life science. There is, for example, an adequate but fragmented sequencing of content essential to evolutionary biology. This is done while use of the word itself, "evolution," is absurdly sparing—as though the writers hoped it wouldn't be noticed. Other life science content is scanty. The prose is more careful than for physical science, but here too it is not easy to guess what will actually happen in class. Grade: "D."

TENNESSEE

	Points	Out of a Possible
A. Expectations, Purpose, Audience	9.8	12
B. Organization	8.5	9
C. Science Content and Approach	20.0	27
D. Quality	8.8	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	3	3
Raw Score	57.1	69
Final Percentage Score	83	100
GRADE	**B**	

Reviewed: Science Curriculum Standards (August 2001)
NB: Tennessee is revising its standards for 2006-2007.

Tennessee starts with a cheerful boosterism on the cover page: "Tennessee Sounds Good to Me," and science process gets its canonical due. Pointers to constructivist educational theory, explicit and implied, are present: "Although learners rarely discover knowledge that is new to humankind, current research indicates that when engaged in inquiry, learners build knowledge new to themselves." Reviewer's rhetorical question: "We didn't know this without that current research?"

In their presentation of science content, the Tennessee standards documents do well, and in some places very well indeed. However, despite an otherwise capable development of science disciplinary content, the achievement is compromised by excessive length, complex organization, and unnecessary small errors. There are the usual broadly stated Standards, which lead to Learning Expectations, then to Benchmarks, and finally to Performance Indicators variously subdivided, referring to state assessments as well as to teacher use. This plan is followed for the grade span K-3, then for single grades from 4 through 8, and finally for courses and programs in high school. Four themes, "major goals," organize the standards: Process of Science, Unifying Concepts of Science, Habits of Minds, and Science in Society. The organization is further complicated by subdivision of individual Benchmarks into "levels."

Tennessee covers the physical sciences very well, but small errors of fact or exposition are scattered throughout. A Performance Indicator: "6.14… construct open, closed, series, and parallel circuits." This doesn't make much sense. One doesn't construct an open circuit or a closed circuit; one just builds a circuit that is either "open" or "closed," depending on the position of the switch. Physics, Standard 2.0: "2.2 compare Celsius, Kelvin and the Absolute temperature scales." The Kelvin scale is an absolute temperature scale. Or, "Identify the characteristics of internal energy and temperature/heat (joules/calories)." This is confusing and misleading. Temperature and heat are two different things, and only heat energy is measured in joules or calories.

There is really no chemistry until grade 5, at which point some material germane to chemistry, rather than to generic "matter," appears. But chemistry content then enters at an increasing rate through grade 8, which provides adequate background for high school Chemistry 1. It, and Chemistry 2, would probably serve as preparation for college chemistry. Other high school physical science is also well done. Earth and space science are adequately represented and sensibly sequenced.

Life sciences get good handling, especially in high school, where there is a broad range of subject matter in genetics, physiology, and ecology—that is, covering the scales of organization from subcellular to population and community. Remarkable and encouraging, however, is the reversal of Tennessee's approach to evolutionary science (including the relevant geology and cosmology). In 1998, the approach was to ignore them. In that review, the grade for Tennessee's standards was "F." Now, in 2005, evolutionary science is covered and properly sequenced (fossils are introduced in grade 3). The presentation is clear and relatively generous in high school biology. Tennessee's 2005 standards are graded "B."

TEXAS

	Points	Out of a Possible
A. Expectations, Purpose, Audience	3.0	12
B. Organization	4.0	9
C. Science Content and Approach	8.0	27
D. Quality	0.8	9
E. Seriousness	5.8	6
Inquiry	1	3
Evolution	1	3
Raw Score	23.6	69
Final Percentage Score	34	100
GRADE	**F**	

Reviewed: Texas Essential Knowledge and Skills for Science (1998)
NB: Texas standards are scheduled for revision in 2007.
The review of Texas's state standards included material called "Snapshots." Though not officially part of the state's science standards, the Texas Education Agency links to the material from its science standards webpage. The material was provided by the Charles A. Dana Center at the University of Texas at Austin

The Texas Standards are a kind of legal document, which is to say the presentation simply assumes the rightness of its own organization—no introductions or explanations needed. Standards are by grade level, and for high school by course, which is a good thing. But many of the introductions are identical, or almost so, for every grade. This contributes nothing to a reader's understanding of what learning is expected. The organization is by themes so broad that almost any content from any field of science might fit anywhere.

Thematic unities, so persuasively urged in the national guides, have an effect here opposite to that advertised. They produce breadth of assertion instead of depth of understanding. The content of the upper primary and secondary grades suffers most. A reviewer surmises that the writers of the physical science sections know very little of the subject beyond the fourth-grade level: "As the level rises, the incidence of confusion, misunderstanding, and plain ignorance grows rapidly." A series of "Snapshots" adds to the more formal Standards illustrations of related classroom activity and, in principle, expands the expectations of the standards. Quite a few of these are helpful. Others are silly. The whole is dominated by science process and themes such as "Systems."

An example for grade 4: "A system is a collection of cycles, structures, and processes that interact. Students should understand a whole in terms of its components and how those components relate to each other and to the whole. All systems have basic properties that can be described in terms of space, time, energy, and matter. …" This is repeated through grade 7. It is a collection of abstract notions that may, in some cases, mean no more to the teacher than to students aged 6 to 13.

Some of the Snapshots do bring abstraction down to earth; but others make incorrect statements or waste time. Example: "Snapshot 8.8 (B). Select an atom to explore in depth. Use the periodic table to identify the characteristics of the atom, including atomic mass and electrical charge. Dress like your atom and deliver an oral presentation describing your special features." "8.9 (B). Interpret information on the periodic table to understand that physical properties are used to group elements…." Not really: the elements are grouped according to their chemical properties. Or, "Snapshot 8.9 (A). Perform an investigation to illustrate a chemical reaction such as mixing ammonium hydroxide (ammonia and vinegar) and iron acetate (vinegar and steel wool) to form ammonium acetate and iron hydroxide (a green blob)." Mixing ammonia and vinegar will not yield ammonium hydroxide. And iron (III) hydroxide is red, not green.

The nadir of the concretizing activities is reached, however, in the anthropomorphic turn meant to stimulate the student's imagination: "Write an autobiography from the perspective of a sedimentary rock." "Write a resume from the point of view of an ocean current." And still worse, "Complete a job application from the perspective of an isotope" (this last in high school). This reeks of condescension if not pedagogical madness. A reviewer responds: "… [this] is a sign of a deepseated feeling that students must be entertained or jollied and cajoled into science. How sad!"

In the science discipline content here reviewed, Texas provides, by way of scant substance or careless writing or plain errors, something not really adequate. There is a remarkable contrast between overambitious expectations (example: 3rd grade: "… evaluate the impact of research on scientific thought, society, and the environment") and the banal activities by which such capacity is represented ("Illustrate the phases of the moon using chocolate sandwich cookies.")

Texas, a state which, like others, has recently had trouble with creationist attempts to delegitimize evolution, has, at the time of this writing, resisted them most honorably. Evolution figures in the life science standards in due proportion. The broad statements of concept are adequate. But rather than fleshing out the content, the Snapshots (as in high school biology) dissolve into superficiality. "Plan and implement an investigative procedure, such as researching the two species of squirrels found on opposite sides of the Grand Canyon or organisms unique to the Galapagos Islands, to research the results of natural selection on species. Ask questions, formulate a testable hypothesis, determine what data should be collected, make inferences from the data, and draw conclusions." This "researching" is more science process than science; large expanses of necessary content are missing. Grade: "F."

UTAH

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.8	12
B. Organization	6.3	9
C. Science Content and Approach	15.5	27
D. Quality	4.0	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	2	3
Raw Score	42.6	69
Final Percentage Score	62	100
GRADE	**C**	

Reviewed: Integrated Science Standards (2005)

Utah wholeheartedly embraces the current version of depth-rather-than-breadth as well as a number of other currently favored ideas on pedagogy. The documents do encourage teachers to add different but relevant content to that treated in depth in the standards. We do not know how often this actually happens. In one place, the documentation applauds its own virtues ("coherent," "developmentally appropriate," "comprehensive, "feasible"…). The science process material, toward which much of that self-congratulation seems to be directed, has the virtue of real and thoughtful integration with disciplinary content. That is what is supposed to happen; it isn't that schoolchildren are supposed to study philosophy of science. Rather, they are to develop good scientific practices on the basis of their exposure to sound ideas on science practice—and alongside their practice of "hands-on" science.

To some extent, this can happen under the Utah Standards, even though the process material is widely scattered and astonishingly repetitive through the documents. There are good process in-sights that come as early as grade 3. For example, "… it is an oversimplification to assume that there is one scientific method that is common to all science," that "objectivity is a matter of degree," and most positively, that scientific claims "should always be considered incomplete, tentative, and subject to being modified or discarded." This comes a bit early for children of that age; but then, the notions reappear through the grades. On the other hand, one finds a good many portentous assertions such as that "science is a search for meaning," and many constructivist codewords, such as "brainstorming" and "hands-on investigation of scientific concepts." In short, Utah gets a pass on process.

So far as disciplinary content is concerned, Utah's best showing is in the life sciences.

The content is mostly sound, there are few substantive errors, and Inquiry is integrated with each grade's biology content. The idea of devoting grade 4 life science to the state's own natural history evoked enthusiasm: this is a broad, "thematic" approach that makes science content sense, too, and is open to enrichment by real (as opposed to assumed) local knowledge. In grade 5, there is a strong treatment of heredity. Grade 6 life science focuses on microbial life. More attention to developmental biology would have been appropriate; and the high school biology is not quite up to the standard of innovation set for the primary grades. The study of evolution starts, at an appropriate level, in grade 4 and builds well thereafter. A high school standard says, without equivocation, what the content to follow does present: "Students will understand that biological diversity is a result of evolutionary processes."

The physical sciences do not fare nearly so well. A reviewer reports, following lengthy citation of problems with content, "The Utah Standards provide another example in which the subject-matter competency of the writers peters out at the middle-school level." For example, there is nothing on modern physics. Electromagnetism is treated very lightly, with little or no attention given to Ampère's and Faraday's laws and their applications. As set forth, the Standards can provide the basis for about the first one-third to one-half of an ordinary high-school physics course. Even within the domain of mechanics, there is no mention of momentum or rotational mechanics.

Content for Earth and space is thin and pushed up to the higher grades. Some trivial exercises are mandated for the primary grades, but they are mostly of the "some things sink and some float" kind. A start is made in grade 4 with weather and finally, by grades 7-8, real attention begins to be paid to Earth composition, structure, dynamics, and the relevant geophysics. The high school course, as represented in the standards, touches many important topics, but too lightly and more often with generalities than with the relevant basic science.

K-8 chemistry content is weak, and is insufficient preparation. A reviewer reports, "Too many topics that deserve chapter length-status are dismissed with one or two Objectives…." The use of mathematical problem solving is minimal. A great deal of thought and labor has gone into Utah's standards; and they have some high points. But without further development they fall short of honorable mention. Grade: "C."

VERMONT

	Points	Out of a Possible
A. Expectations, Purpose, Audience	4.8	12
B. Organization	7.0	9
C. Science Content and Approach	14.8	27
D. Quality	4.0	9
E. Seriousness	6.0	6
Inquiry	2	3
Evolution	3	3
Raw Score	41.6	69
Final Percentage Score	60	100
GRADE	**C**	

Reviewed: Vermont's Framework of Standards and Learning Opportunities (2000)

Vermont's science standards come in two parts: a Framework of Standards and Learning Opportunities, and a set of Grade Expectations, in which the broad Standards are expanded to indicate what students will actually do, grade by grade, pre-kindergarten through the four-year high school span (9-12). The two-part whole is a massive production and obviously the product of some dedicated organizing. That does not forestall certain confusions that lie in wait for the reader.

"Vital Results" and "Fields of Knowledge" are the two main categories of Standards. Vital Results stands for communication, reasoning, problem solving, personal development, and social responsibility. Fields of Knowledge are the arts, language, literature, history, social science, and—finally—science, mathematics, and technology.

In the form of supplementary material, this document has much more. All Standards are for grade clusters PreK-4, 5-8, and 9-12. Science Standards proper start with Inquiry, Experimentation, and Theory. There is some extravagant language, such as the requirement that learners in PreK-4 "Complete a pure mathematics investigation, or complete research." For grades 5-8, there is the immodest "Examine important contributions made to the advancement of science, technology, and mathematics, and respond to their impact on past, present, and future understanding." Translated into substantive knowledge or activities, such imperatives would be well beyond the competence even of the best students. Here, as in many other state science standards, process seems to be the most important product.

Vermont's best documentation is in the life sciences. Despite an organization plan that sometimes defies navigation, much of the expected content turns up somewhere. There is a sincere effort, moreover, to sequence it decently, juxtaposed with suitable material from the other science disciplines. Structure and function of cells is developed from an early start; physiology and heredity are introduced thoughtfully; there is enough embryology, something far from typical of science standards. Ecology is introduced but not confused, as elsewhere, with political and other externalities.

There are some mistakes. Example: "Cell differentiation is regulated through the expression of different genes within the embryo cells. During embryonic development of complex multicellular organisms, chemicals within the cells deactivate portions of the genetic code as influenced by the cell's environment and past history." No. Vastly more important in embryogenesis is that "chemicals" (morphogens) within embryonic cells activate different suites of genes.

Evolution starts in the beginning grades with the introduction of extinct species (woolly mammoths). It becomes serious in middle school and is given proper exposition in high school.

Physics starts well enough, and its content is well organized. Details in the lower grades are good; but a disappointed reviewer reports, "… it gets worse and worse with increasing grade level, revealing the fatal limitations of the physical knowledge of the writers." There are also infelicities, errors, and misstatements. S7-8:21: "b. If there is a change in the speed or direction of an object, an outside force needs to be applied and the forces acting on the object are unbalanced (Newton's First Law)." Very confusing; this interchanges cause and effect. S7-8:23: "Creating a diagram, model, or analogy for a material in a warmer and cooler state showing or describing the motion of the molecules." Could it possibly be that the writers were unfamiliar with the concept of "higher or lower temperature"?

Such errors, but omissions as well, multiply for chemistry despite a conscientious beginning in the earliest grades. A reviewer: "Grade 5-6 students are … offered [no more than] the same tired examples of a chemical reaction: rusting and vinegar/baking soda. Page S32 gives 'electrophoresis' of water as an example of the formation of a new substance … the word meant is electrolysis; and that produces two products, not one…. [T] hat minor topic, Chemical Equilibrium … [has been] forgotten …. A discussion of bond energies is missing…."

In earth and space science, overarching, abstract themes often detract from interesting content and continuity. Earthquakes and volcanoes appear as fast and slow processes and as consequences of moving plates, but not as the fascinating phenomena they are in their own right. The word "mineral" shows up once in the section, but in a general way so that students learn nothing about individual minerals. Rocks are acknowledged to "change" but the processes involved are merely hinted at. "Change is something that happens to many things." There is no mention of metamorphism. The statement of the water cycle never quite says that evaporation and precipitation cause water (and heat energy) to move from one place to another.

The Vermont Standards are another sincere, large-scale effort with good features. But the effort is flawed by careless writing and editing, and, for some scientific disciplines, by inadequate knowledge of the science on the part of the writers. Grade: "C."

VIRGINIA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	11.5	12
B. Organization	9.0	9
C. Science Content and Approach	24.5	27
D. Quality	9.0	9
E. Seriousness	6.0	6
Inquiry	3	3
Evolution	3	3
Raw Score	66.0	69
Final Percentage Score	96	100
GRADE	**A**	

Reviewed: Revised Science Standards of Learning Curriculum Framework and Science Standards for Learning (2003)

Virginia's is another enormous package. Unlike most, however, this one can be read with profit—even, in places, with pleasure—by a literate layperson. It was written to be read, and not just by state or school employees who *must* read it. There are two documents: "Science Standards of Learning," and a significant expansion, the "Standards of Learning Curriculum Framework." Standards are arranged in grade levels for K-6, then as life science and physical science for middle school (7-8), and finally by courses in high school.

A reviewer reported as follows: "Despite the great number of pages, I didn't see much verbiage and no silliness…. Elementary content grows through the strands Scientific Investigation, Reasoning and Logic; Force, Motion and Energy; Matter; Living Systems; Interrelationships in Earth/Space Systems; Earth Patterns, Cycles, and Change; and Resources. The introduction states that the standards are 'not intended to encompass the entire science curriculum' nor 'prescribe how the content should be taught.' I found this refreshing; and if the standards are the whole curriculum (at least in Earth/Space Science) it is enough. …"

The "Framework" repeats the Standards and amplifies them under three heads: Understanding the Standard; Overview; and Essential Knowledge, Skills, and Processes. These explain each standard and provide examples of what is to be learned and done. Such an organization, executed conscientiously, does demand a great deal of paper. In this case, then, the bulk may be justified. The combination of broad standards and detailed explication in the Framework reveals a well-sequenced curriculum, starting before grade 1 and culminating with a certain sophistication in high school—even in chemistry, where so many states fall down.

In physics, errors and misstatements do turn up, albeit fewer than in other state standards whose writers have tried to offer something comprehensive on the subject. The errors are mostly minor. Thus, "… refraction of light through water and prisms.…" Refraction does not occur "through" uniform transparent media but at their interfaces. This seems a common misconception in state standards. Or, "*Work* is the product of the force exerted on an object and the distance the object moves in the direction of the force." Wrong. Work is the product of the distance an object moves and *the component of the force along the direction of motion*. The object may not move at all in the "direction of the force." Curiously, several important quantitative relations are expressed algebraically in the physical science section but not in the physics section.

The life science treatment is sophisticated. It begins in kindergarten, but grade 1 already introduces material that is both serious and interesting to children: "Conduct simple experiments/investigations related to plant needs by changing one variable (food, air, water, light or place to grow) at a time. Students do not need to know the term variable." Interweaving of science content with science process continues through grade 6. In middle school, cell biology is balanced by ecology. Genetics begins, and so does the real study of evolution. The high school program opens with the history of discovery in biology! This, to keep things balanced, is matched in the program by biotechnology. Evolution has its appropriate place and is presented without the usual glosses and misunderstandings. The standards draw evidence from a variety of sources, including the fossil record, radiometric dating, genetics, biogeography, comparative morphology, and embryology.

Virginia, finally, manages to get matters of Inquiry and process right that most other states muddle. Virginia defines "theory" with the right words: "A theory is an explanation of a large body of information, experimental and inferential, and serves as an overarching framework … subject to change as new evidence becomes available." Grade: "A."

WASHINGTON

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.8	12
B. Organization	7.0	9
C. Science Content and Approach	17.0	27
D. Quality	4.0	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	3	3
Raw Score	44.8	69
Final Percentage Score	65	100
GRADE	**C**	

Reviewed: Washington Science Grade Level Expectations (2005)

Washington's Grade Level Expectations are not really by grade level; each column in the tabulated collection is labeled with several grades. The document itself acknowledges the need for a standard articulated sequence to eliminate gaps and overlaps when students move from place to place in the state, but that need has not been met. The effective spans are K-2, 3-5, 6-8, and 9-10. There are no detailed suggestions for the last two years of high school.

The tone of Washington's science standards can be conveyed by its handling of science process. It is one of those states whose focus is on repetitive coaxing: "Learning in science depends on actively doing science. Active engagement in hands-on, minds-on science learning experiences enables students to make personal sense of the physical world.…" Of course educators who propagate such clichés (they are clichés now) do know—must know—that some important science (say, theoretical physics?) is not "hands-on" and that there is no such thing as "minds-off" science. But they feel, evidently, the need to fly the ensign.

Writing is frequently careless, as in the glossary. Here, for example, is the definition of "claim." "Claim: A valid conclusion of a scientific investigation." Are there then, no invalid claims? No historical claims? There is undeniably, however, wheat mixed with such chaff. Useful material appears in the "Overview of science instruction," which is relatively specific about grade-level activities and requirements.

The life sciences make a very good showing. Although they are less comprehensive for genetics than for physiology and "systems," the Standards offer a sound progression of ideas and skills, notably for ecology and evolution. But Washington does less well by the physical sciences. As one reviewer put it, "As is the case for so many state standards, good intentions have been hobbled by insufficient technical knowledge and sloppy writing. In the hands of a few experts, this document could be very much improved."

There are plenty of examples. From the standards: "Describe pressure as a force (e.g., pressure increases result in greater forces acting on objects going deeper in a body of water)." Pressure is not a force; it is a force per unit area, which isn't the same thing at all. Writing like this obstructs good science teaching. In earth science, students are asked in grades 3-5 to "describe and sort" rocks based on physical properties; but not to name or classify them. Sweeping statements sometimes tie disparate things together and miss important details: "Understand that Earth's system includes a mostly solid interior, landforms, bodies of water, and an atmosphere." While emphasizing that the mantle is mostly solid, this ignores the planet's liquid core.

For grades 9-10, students are asked to "identify an unknown substance using … physical and chemical properties." These students will not have the background knowledge to accomplish the task at other than the most basic level. And it is impossible to know what is expected when students are asked to "explain the similar properties of elements in a vertical column … of the periodic table." But the periodic table is not introduced until grade 10, where the student is wrongly told that the position of an element in the table is determined, *inter alia*, by its neutron number. There is not much serious chemistry content under the heading Properties of Substances. On the other hand, most of what one expects by way of science content is at least touched upon in the Washington Standards, and in some places there is evidence of original thought.

These middling documents lie in the middle of the distribution of quality and have been assigned the grade "C."

WEST VIRGINIA

	Points	Out of a Possible
A. Expectations, Purpose, Audience	6.8	12
B. Organization	8.3	9
C. Science Content and Approach	19.5	27
D. Quality	5.8	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	1	3
Raw Score	48.4	69
Final Percentage Score	70	100
GRADE	**B**	

Reviewed: Science Content and Standards for West Virginia Schools (2003)
NB: West Virginia's standards are set to be updated in 2008.

West Virginia presents "Science Content Standards and Objectives for West Virginia Schools." An "Executive Summary" for this overlong (for its actual content) document reports that 120 comments concerning its draft were received. These complained of overemphasis on evolution and denounced the replacement of education in the scientific disciplines by "coordinated and thematic science." There seems to have been nothing done about these complaints except to release some soothing words in response. On evolution, that was exactly the right response. On the second issue, we are not sure.

Six all-purpose Standards organize the document and are repeated for every grade. Standard 4 (only) is science content. The other Standards are Nature of Science, Inquiry, Themes, Design and Application, and Science in Personal and Social Perspectives. These are "drawn from the National Science Education Standards and the Project 2061 Benchmarks to promote a rigorous and challenging science curriculum."

The functional standards are called objectives, which are so stated as to complete a sentence beginning "Students will…." Objectives are succeeded by the Performance Descriptors (PDs): "Distinguished," "Above Mastery," "Mastery," "Partial Mastery," and "Novice"—evidence, as a reviewer points out, of the wide success of the self-esteem movement. As published, the PDs restate the Objectives and proceed to one or more paragraphs of exegesis. For any Objective, the several Performance Descriptors often differ by a just word or two.

The physical sciences get good coverage, quite a lot of which is boilerplate of respectable origins; but the written standards are blemished by errors of understanding or incompetent writing. "SC.4.4.24: investigate the change in the length, tension, or thickness of the vibrating object on the frequency of vibration (e.g., string, wire, rubber band)." A rubber band is a poor choice because it cannot be stretched without simultaneously changing all three independent variables. "SC.5.4.10: recognize that elements are composed of only one type of matter." As stated, the sentence says nothing because it only defines element in terms of an ill-defined "type of matter." One could just as well say that water is composed of only one type of matter—water. Or, "SC.8.4.18: identify types of energy and their sources (e.g., petroleum refinement, windmills, geothermal)." Petroleum "refinement" is neither a type nor a source of energy.

There is a good representation of most life science topics we expect in a K-12 curriculum, although the material is severely scattered under the design imperatives. Scientifically competent editing would be a boon. For example, p. 74: "Demonstrate how living cells obtain the essentials of life through chemical reactions of transpiration, respiration and photosynthesis." Transpiration is not a cellular activity. And on p. 90 (10th grade): "Relate the role of DNA analysis to genetic disorders, forensic science, molecular genetics, and biotechnology (e.g. protein synthesis, heredity, cell division, cellular functions)." First, what exactly are they getting at with such an omnibus as "relating"? Second, do they really mean "analysis," or something much more specific, such as "sequencing"? Despite such lapses, the life science presentation is generally competent and usable.

An integrated approach with 50 percent or more of instructional time devoted to activities leaves insufficient time for content, which, in a subject such as chemistry, is especially thin in K-8. It cannot support the advanced high school classes. Such chemistry as does appear is reasonable, particularly in high school, and especially in a fine AP chemistry course. But in general there is not enough of it and, again, there are a good many statements in need of editing or correction. The same can be said of earth and space sciences, where there are a few strong points, and of environmental science, which is scant and qualitative. Grade: "B."

WISCONSIN

	Points	**Out of a Possible**
A. Expectations, Purpose, Audience	2.3	12
B. Organization	3.8	9
C. Science Content and Approach	6.5	27
D. Quality	0.5	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	0	3
Raw Score	20.1	69
Final Percentage Score	29	100
GRADE	**F**	

Reviewed: Model Academic Standards (1998)

NB: Wisconsin is working on a framework for grades 3-8 for 2006.

The Wisconsin Model Academic Standards announce confidently that they "set clear and specific goals for teaching and learning." That was not the judgment of our review. They are, in fact, generally vague and nonspecific, very heavy in process, and so light in science discipline content as to render them nearly useless—at least as a response to problems for which state learning standards are supposed to be a remedy.

Wisconsin's school districts are required to devise a curriculum from these very general statements. Advanced science courses are entirely of local design. There are *in toto* eight standards, labeled A through H. Only three are concerned with science content (physical science, life and environmental science, and earth and space science). All the remaining five are about process. Required performance standards are given for grades 4, 8, and 12. There is a low level Glossary of Terms, followed by "Terms Unique to Science." All seem to be derived from the National Science Education Standards.

Samples of vague disciplinary *content* standards: From Standard D, physical science: D.12.12: "Using the science themes and knowledge of chemical, physical, atomic, and nuclear reactions, explain changes in materials, living things, earth's features, and stars." Standard E, Earth and space science: E.4.7: "Using the science themes, describe resources used in the home, community, and nation as a whole." And E.4.8: "Illustrate human resources used in mining, forestry, farming, and manufacturing in Wisconsin and elsewhere in the world."
Specificity in the science *process* standards is no higher. Standard A, "Science Connections." For grade 4: "When studying a science-related problem, decide what changes over time are occurring or have occurred." Or, Standard B: "Nature of Science." B.4.3: "Show how major developments of scientific knowledge in the earth and space, life and environmental, and physical sciences have changed over time." Interpretation of all such "standards" by teachers across an entire state must inevitably range from the sublime to the ridiculous.

There is no more depth in the Standards for biology, exemplified by these selections, for Grade 12: "State the relationships between functions of the cell and functions of the organism as related to genetics and heredity." Or, "Understand the impact of energy on organisms in living systems," and "Apply the underlying themes of science to develop defensible visions of the future." Local specialists and teachers needn't worry about biology content in planning to comply with such standards.

Responding to one instruction—E.8.7, "Describe the general structure of the solar system, galaxies, and the universe, explaining the nature of the evidence used to develop current models of the universe"—a reviewer asks, with asperity, "Why not just say 'Explain astronomy'?"

"Science," we are told in the Standards, "follows a generally accepted set of rules." Would that we were told what those rules were! More to the point, would that the teachers making lessons, curricula, and tests were given real guidance on those putative rules of science and the degree to which they differ, if they do, from "accepted sets of rules" in other human occupations. Grade: "F."

WYOMING

	Points	Out of a Possible
A. Expectations, Purpose, Audience	3.5	12
B. Organization	5.0	9
C. Science Content and Approach	8.0	27
D. Quality	0.8	9
E. Seriousness	6.0	6
Inquiry	1	3
Evolution	1	3
Raw Score	25.3	69
Final Percentage Score	37	100
GRADE	**F**	

Reviewed: Wyoming Content and Performance Standards (July 2003)

The Wyoming Science Content and Performance Standards give learning expectations for three grade spans: K-4; 5-8; and 9-12. This coarse subdivision is made worse by the extreme paucity of science disciplinary content. Cited as one among the otherwise standard inspirations for this document is the California Superintendent's Challenge Standards in Science, not the much better State Board-adopted Science Content Standards. There are a very few classroom vignettes entitled "action snapshots." Inquiry issues and performance levels account for most of this short and minimal document.

The stylistic features might be exemplified by the following front-page statement: "The purpose of science education is to help young people develop the ability to reason, think creatively, make responsible decisions, and solve problems." We wonder: are there any intellectual disciplines that do *not* make that claim? Or better: Is *that* all science is good for? And then, a rather typical constructivist paean: "Scientific inquiry is the foundation for the development of content and processes of science that enable students to construct their own knowledge." Such "knowledge," presumably, as the basic history of life on Earth, the constancy of the velocity of light, or the strangely systematic succession of elemental chemical properties in the context of atomic structure? Not very likely.

"Snapshots in action" are revealing. An example, for grade 4: "Ms. Drip helps students understand the changes in physical states of matter using water as an example. Students observe snow melting and becoming a liquid. Then by heating the liquid, it becomes liquid." A reviewer: "Does no one proofread anymore?"

The Glossary attests further to the minimal care and science expertise expended in the making of these Standards.

"**Equilibrium:** the state of balance that all things, living and nonliving, seek to attain." Reviewer: "Misleading and unscientific. I know of no nonliving things that 'seek to attain' anything, and the same applies to most living things as well. Moreover, not all equilibria are stable."

"**Form:** the structure of a substance or organism." Reviewer: "A definition without meaning."

"**Geochemical Cycle:** a cycle that earth materials move through such as the water cycle or the rock cycle." This is a circular definition, defining a cycle as a cycle.
"**Tetonic Plate Activity:** the movement of the rocky plates that compose the earth's crust." In recognition of the grand local mountains, it may be "tetonic" in Wyoming. Elsewhere it is "tectonic."

It is well to note that the Wyoming standards do refer to evolution, inter alia, in the life sciences, more or less correctly but insufficiently. Grade: "F."

APPENDIX A: STATE SCORES BY CRITERIA GROUP

State	A Total	B Total	C Total	D Total	E Total	Inquiry	Evol.	Sum	% Score	LTR
Alabama	6.3	5.5	8.5	4.5	3.0	1	0	28.8	42	F
Alaska	1.0	4.8	4.3	0.3	3.0	0	0	13.3	19	F
Arizona	7.8	8.0	17.8	6.0	6.0	2	2	49.6	72	B
Arkansas	4.5	5.0	11.0	3.3	6.0	1	0	30.8	45	D
California	11.7	9.0	25.0	9.0	6.0	3	3	66.7	97	A
Colorado	8.8	7.3	20.0	6.0	6.0	3	1	52.1	76	B
Connecticut	7.0	7.0	15.3	3.3	6.0	2	0	40.6	59	C
Delaware	6.0	6.5	17.8	4.5	6.0	3	3	46.8	68	C
District of Columbia	7.3	6.4	14.8	5.4	5.4	2	2	43.3	63	C
Florida	6.0	6.0	11.3	1.8	5.8	2	0	32.9	48	F
Georgia	8.5	8.5	18.0	5.8	5.8	2	3	51.6	75	B
Hawaii	3.5	5.8	9.3	1.5	5.8	0	1	26.9	39	F
Idaho	2.7	4.0	8.7	1.3	6.0	1	0	23.7	34	F
Illinois	6.8	6.75	18.5	5.5	6.0	2	3	48.6	70	B
Indiana	11.0	8.5	23.8	7.5	6.0	3	3	62.8	91	A
Kansas	5.5	6.8	17.3	4.3	5.8	2	3	44.7	65	F
Kentucky	5.5	6.0	11.5	3.3	6.0	2	1	35.3	51	D
Louisiana	8.0	8.0	20.3	5.0	6.0	2	2	51.3	74	B
Maine	5.8	6.6	11.8	2.8	6.0	2	0	35.0	51	D
Maryland	7.4	7.5	18.4	5.3	6.0	2	3	49.6	72	B
Massachusetts	10.8	9.0	24.3	8.6	6.0	3	3	64.7	94	A
Michigan	4.0	4.0	12.4	4.0	4.5	1	3	32.9	48	D
Minnesota	7.3	8.0	18.0	5.5	6.0	2	2	48.8	71	B
Mississippi	5.3	6.8	9.8	3.5	6.0	1	0	32.4	47	F
Missouri	6.0	8.0	17.5	3.5	5.8	2	3	45.8	66	C
Montana	3.8	4.5	8.5	2.0	6.0	2	0	26.8	39	F
Nebraska	2.8	6.3	8.5	1.5	6.0	0	1	26.1	38	F
Nevada	4.5	7.3	12.5	2.8	6.0	0	2	35.1	51	D
New Hampshire	4.3	1.8	9.8	2.0	6.0	1	0	24.9	36	F
New Jersey	8.6	7.1	19.8	6.6	6.0	2	3	53.1	77	B
New Mexico	10.3	8.5	22.3	7.3	6.0	2	3	59.4	86	A
New York	10.5	7.0	23.5	8.5	6.0	2	3	60.5	88	A
North Carolina	9.0	7.8	21.8	6.0	6.0	3	1	54.6	79	B
North Dakota	3.8	6.0	12.3	3.3	5.8	1	1	33.2	48	D
Ohio	7.8	7.5	20.3	5.5	6.0	1	3	51.1	74	B
Oklahoma	6.0	7.5	12.0	1.3	6.0	2	0	34.8	50	F
Oregon	3.0	5.5	8.3	1.8	6.0	1	2	27.6	40	F
Pennsylvania	7.0	5.3	16.8	4.5	6.0	2	3	44.6	65	C
Rhode Island	6.3	6.3	14.3	3.0	6.0	1	3	39.9	58	C
South Carolina	11.5	8.3	23.3	9.0	6.0	3	3	64.1	93	A
South Dakota	5.4	6.0	11.0	3.3	6.0	3	1	35.7	52	D
Tennessee	9.8	8.5	20.0	8.8	6.0	1	3	57.1	83	B
Texas	3.0	4.0	8.0	0.8	5.8	1	1	23.6	34	F
Utah	6.8	6.3	15.5	4.0	6.0	2	2	42.6	62	C
Vermont	4.8	7.0	14.8	4.0	6.0	2	3	41.6	60	C
Virginia	11.5	9.0	24.5	9.0	6.0	3	3	66.0	96	A
Washington	6.8	7.0	17.0	4.0	6.0	1	3	44.8	65	C
West Virginia	6.8	8.3	19.5	5.8	6.0	1	1	48.4	70	B
Wisconsin	2.3	3.8	6.5	0.5	6.0	1	0	20.1	29	F
Wyoming	3.5	5.0	8.0	0.8	6.0	1	1	25.3	37	F

NB: State scores by criteria are available online at www.edexcellence.net/institute.

APPENDIX B: BIOGRAPHICAL SKETCHES OF AUTHOR & REVIEWERS

Paul R. Gross is University Professor of Life Sciences emeritus of the University of Virginia and former vice president and provost of the university. He was elected a Fellow of the American Academy of Arts and Sciences in 1982. He was the director and president of the Marine Biological Laboratory, Woods Hole, Massachusetts, 1978 to 1988 and has been a Trustee of The University of Rochester, Associated Universities, Inc., and the American Academy of Liberal Arts. Earlier, he served as Professor of Biology and Dean of Graduate Studies at Rochester and Professor of Biology at MIT. In addition to papers and monographs in cell and molecular biology and animal development, he publishes widely on science and culture. His latest book is *Creationism's Trojan Horse* (Oxford University Press, 2004), written with Barbara C. Forrest.

Ursula Goodenough is Professor of Biology at Washington University. She received her Ph.D. at Harvard University and was a member of the Harvard Biology Department prior to moving to St. Louis. Her research has focused on cellular and molecular-genetic analysis of sexual differentiation in the unicellular green alga *Chlamydomonas*, and on the molecular basis of ciliary motility. She teaches cell biology and molecular evolution and has written three editions of a widely used college textbook of genetics. Her leadership positions in the American Society for Cell Biology have including its presidency, and she serves on national science committees, review panels, and editorial boards. She is the author of *The Sacred Depth of Nature* (Oxford University Press, 1998).

Susan Haack was educated at Oxford and Cambridge. Formerly a Fellow of New Hall, Cambridge, and then lecturer, reader, and professor of philosophy at the University of Warwick, U.K., she has taught since 1990 at the University of Miami, where she is Cooper Senior Scholar in Arts and Sciences, professor of philosophy, and professor of law. Her books include *Deviant Logic; Philosophy of Logics; Evidence and Inquiry: Towards Reconstruction in Epistemology; and Defending Science—Within Reason: Between Scientism and Cynicism.* She has published numerous articles in professional philosophy journals, scientific publications, and such general-interest magazines as *Skeptical Inquirer and Free Inquiry, as well as literary magazines, including The Times Literary Supplement.*

Lawrence S. Lerner is Professor Emeritus in the College of Natural Sciences and Mathematics at California State University, Long Beach, where he won a number of outstanding teacher awards. He is the author of two university-level physics textbooks, co-translator and editor of a seminal work by Giordano Bruno, and author of about 150 book chapters, review articles, journal articles, and patents on condensed-matter physics, the history of science, science and religion, science and society, and science education. He led Fordham's previous reviews of state science standards in 1998 and 2000.

Martha Schwartz has taught science and elementary mathematics from seventh grade through early graduate school. She is also experienced in teacher training and teacher professional development. She holds a B.S. in mathematics from Arizona State University, a teaching credential from UCLA, a Master's degree in geology from California State University Long Beach, and a Ph.D. in geophysics from the University of Southern California. She is a member of the Assessment Review Panel in science for California and has worked on school improvement, standards, and testing for a variety of organizations.

Richard Schwartz holds a B.S. degree in chemistry from Arizona State University, a teaching credential from UCLA, and a Master's degree in environmental science from California State University, Dominguez Hills. He taught secondary science for 34 years, the last 32 at Torrance High School in Torrance, California. He is a former member of the California Curriculum Commission and a 1995 recipient of the American Chemical Society's regional award in chemistry teaching. Presently retired from teaching, he helps manage the geochemistry laboratory at the University of Southern California.

ENDNOTES

[1] See http://www.edweek.org/ew/articles/2005/03/30/29science.h24.html?rale=14RcsgF70mPtCa...

[2] For surveying current activity and heuristics on Inquiry in K-12 education, one might start a search with the following web sites (among many other possibilities): http://www7.nationalacademies.org/dbasse/; http://www.project2061.org/; http://www.nsta.org; http://www.aibs.org/core/index.html.

[3] Hermann J Muller. "One Hundred Years without Darwin Are Enough." *School Science & Math.* April, 1959, 304-16, as quoted in John A. Moore. *Science as a Way of Knowing.* (Cambridge, MA: Harvard University Press, 1993), 133-34.

[4] Barbara Forrest and Paul R. Gross, *Creationism's Trojan Horse: The Wedge of Intelligent Design* (New York: Oxford University Press, 2004). It should be noted that labeling the vast domain of modern evolutionary theory and its applications as "Darwinism" is pure propaganda; it makes as much sense as labeling modern physics as "Newtonism."

[5] Examples: Forrest and Gross, op. cit., Robert T. Pennock, *Tower of Babel: The Evidence Against the New Creationism* (Cambridge: MIT Press, 1999); Mark Perakh, *Unintelligent Design* (Amherst, NY: Prometheus Books, 2004); Matt Young and Taner Edis (Eds.), *Why Intelligent Design Fails: A Scientific Critique of the New Creationism* (New Brunswick: Rutgers University Press, 2004); Jerry A. Coyne and H. Allen Orr, *Speciation* (Sunderland: Sinauer Associates, 2004); Sean B. Carroll, *Endless Forms Most Beautiful: The New Science of Evo Devo* (New York: W. W. Norton & Co., 2005). Pointing any internet search engine toward "Intelligent Design" will yield a cornucopia of material, pro and con, on "Intelligent Design Theory," including the outpouring of books, mainly but not solely from religious publishers, from *proponents* of Intelligent Design. Because of current legal battles, not even the indexing services can keep up with related newspaper accounts, published letters from scientific societies and ad hoc groups of scientists (such as Nobel Laureates), and opinion pieces.

[6] Lawrence S. Lerner, "State Science Standards: An Appraisal of Science Standards in 36 States" (Washington: Thomas B. Fordham Foundation, 1998); L. S. Lerner, "Good Science, Bad Science: Teaching Evolution in the States (Washington: Thomas B. Fordham Foundation, 2000).

[7] Chester E. Finn, Jr ., and Michael J. Petrilli, *The State of State Standards 2000* (Washington: Thomas B. Fordham Foundation, 2000).

[8] Connecticut, for example, dresses up its standards with pretty pictures of a child with a flower, a man in a space suit, and the like. Other standards incorporate business school-style diagrams of thought or organizational arrangements.

[9] For the situation five years ago, see Paul R. Gross and Sandra Stotsky. "*How Children Learn Science: Do We Know Now?*" In S. Stotsky (ed.), *What's at Stake in the K-12 Science Wars: A Primer for Educational Policy Makers.* (New York: Peter Lang Publishing, Inc., 2000, 115-148).

[10] The constructivist argument on the primacy of making is not new. It goes back, in fact, at least to Giambattista Vico (1668-1744), one of the founders of philosophy of history (and the adopted patron saint of *Finnegan's Wake*). One of Vico's catchphrases was *verum ipsum factum*, truth is what is made. The extractable meaning was that truth can exist only for entities constructed (made) by man—mathematics, for example. There cannot be a true science of nature because man does not make nature. Cf. Robert Audi (Editor), *The Cambridge Dictionary of Philosophy* (Cambridge University Press, 1995), 835-36.

[11] See Paul R. Gross, *Politicizing Science Education* (Washington: Thomas B. Fordham Foundation, 2000), 11-14.

[12] Anthony Lorsbach and Kenneth Tobin, "Constructivism as a Referent for Science Teaching," available for several years on the NARST web sites. Last accessed 11/17/99 at http://science.coe.uwf.edu/narst/research/constructivism.htm.

[13] Alan Cromer, *Connected Knowledge: Science, Philosophy, and Education* (New York: Oxford University Press, 1997), 10-11.

[14] American Association for the Advancement of Science, *Benchmarks for Science Literacy* (New York: Oxford University Press, 1993); *National Research Council, National Science Education Standards* (Washington: National Academy of Sciences Press, 1996); American Association for the Advancement of Science, *Blueprints for Science Literacy* (New York: Oxford University Press, 1998); National Science Foundation, Inquiry: *Thoughts, Views, and Strategies for the K-5 Classroom* (Arlington: National Science Foundation, Division of Elementary, Secondary, and Informal Education, 1999).

[15] National Research Council, *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (Washington: National Academy Press, 2000), 116ff.

[16] *Idem*, 116.

[17] *Idem*, 124-126.

[18] Ernst von Glasersfeld, "Cognition, Construction of Knowledge, and Teaching," *Synthèse* 80: 121-140 (1989).

[19] Michael R. Matthews, ed., *Constructivism in Science Education: A Philosophical Examination* (Dordrecht: Kluwer Academic Publishers, 1998). But see also the newest professional journal devoted to constructivist epistemology. Volume 1, No. 1, consulted online October 28, 2005: http://www.univie.ac.at/constructivism/journal/1.1/. See the editorial by E. A. Riegler, "The Constructivist Challenge." The reader who wishes a broad view of the current publication activity—and controversy—in philosophy of education, including science education, needs only to go to the internet and point a search engine to "education and constructivism." The web sites of the national science teachers' organizations are particularly rich sources, and their postings change rapidly.

[20] See, for example, David Klahr and Milena Nigam, "The Equivalence of Learning Paths in Early Science Instruction: Effects of Direct Instruction and Discovery Learning," *Psychological Science* 15 (10): 661-67 (2004).

[22] James H. Shea. "The Trivialization of Factual Knowledge." *Journal of Geoscience Education* 45 (1): 1 (1997).

[23] Regardless of the details of the time and place of its beginning, in some 300 years the Scientific Revolution has spread across the world. Citizens of all nations that have been able to educate children in science have become honored contributors to its inexorable progress.

[24] L. S. Lerner, "Good Science, Bad Science." *Op. cit.*

[25] L. S. Lerner, "State Science Standards: An Appraisal of Science Standards in 36 States," p. 25; in: Chester E. Finn, Jr 2000., and Michael J. Petrilli, *The State of State Standards 2000* (Washington: Thomas B. Fordham Foundation, 2000), pp. 64-65.