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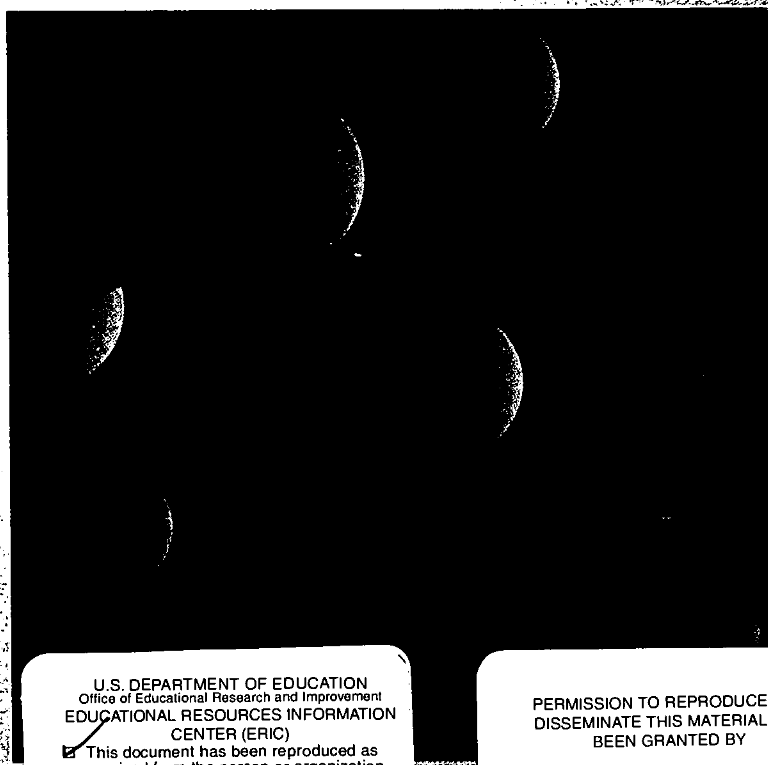
ABSTRACT

The Thomas B. Fordham Foundation has commissioned studies of state academic standards in five core subjects. This is the fifth of these studies, focusing on state standards for science. Thirty-six states presented standards for evaluation. Some states were in the process of revising standards, while others simply had no standards to present. Evaluation was based on 25 criteria grouped into 5 major categories: (1) purpose, expectations and audience; (2) organization; (3) coverage and content; (4) quality; and (5) negative criteria. Six states earned an "A" (Arizona, California, Hawaii, Indiana, New Jersey, and Rhode Island). Seven others earned a "B." While more than a third of the states earned good grades, seven states earned "C"s, seven earned "D"s, and nine failed. The very universality of science should make the development of standards easier, since there are sound models in the United States and abroad to guide their development. The standards, or lack of standards, are analyzed individually for each state. (Contains six tables and three figures.) (SLD)

State Science Standards

An Appraisal of Science Standards in 36 States



March 1998

By Lawrence S. L

THOMAS B. FORDHAM FOUNDATION

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State Science Standards

An Appraisal of Science Standards in 36 States

by
Lawrence S. Lerner
California State University, Long Beach

THOMAS B. FORDHAM FOUNDATION
OUTSIDE THE BOX

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FOREWORD

The Thomas B. Fordham Foundation is pleased to present this appraisal of state science standards, prepared by Dr. Lawrence S. Lerner, Professor of Physics and Astronomy at California State University, Long Beach, in consultation with a distinguished panel of fellow scientists and science educators.

This is our fifth such publication. In July 1997, we issued Sandra Stotsky's evaluation of state English standards. Last month, we published examinations of state standards in history and geography. Our report on math standards is being issued concurrently with this one.

Thus we have now provided expert appraisals of the states' success in setting standards for the five core subjects designated by the governors and President Bush at their 1989 education "summit" in Charlottesville. The national education goals adopted there included the statement that, "By the year 2000, American students will leave grades four, eight, and twelve having demonstrated competency in challenging subject matter including English, mathematics, science, history, and geography." Although other subjects have value, too, these five remain the heart of the academic curriculum of U.S. schools.

Of the five reports we have published, Dr. Lerner's report is, upon first reading, the most bullish. Among the thirty-six jurisdictions with elementary/secondary science standards fit for appraisal, he found six that deserve "A" grades and seven that earn "B's." Good grades for more than a third of the states!

Yet that sounds good mostly because our expectations in such matters have fallen so low. Here's another way to look at the results: Dr. Lerner conferred nine failing grades and seven "D's": three more than won honors. Seven states earned "C's." The average grade for all the standards he appraised is C-minus. And fourteen states either do not have state science standards or did not make them available in timely fashion to Dr. Lerner, so we have no way of knowing how well or poorly they are doing in setting high standards for science education in the elementary/secondary years. In fact, we can only be confident from this analysis that six of our fifty states have first-rate science standards.

Hurrah for Arizona, California, Hawaii, Indiana, New Jersey, and Rhode Island. And shame on all the others!

For when it comes to academic standards, as Dr. Lerner remarks, even a "B" ought not be deemed satisfactory. In a properly organized education system, standards drive everything else. If they are only "pretty good," then "pretty good" is the best the system is apt to produce by way of student learning. No state should be satisfied with such a result. Hence no state should be satisfied with less than world-class standards in a core academic subject such as science.

First-rate standards, moreover, are not that difficult to develop, even when science is their subject. Indeed, this field's very universality makes the task easier. Sound models exist—nationally, in other states, and in other countries. If any subject has the same essentials everywhere, after all, it's science. I can think of no sound reason why what is expected of teachers and children in biology or chemistry should be different in Tennessee (which got an "F" from Dr. Lerner) than in Indiana. Indeed, it should be approximately the same as what is expected in Singapore and Germany, too. A case can be made that academic standards in history or literature or art may be expected to vary from state to state, culture to culture, and country to country. But surely that is not true of science (or mathematics).

How close is the connection between standards and actual achievement? That depends on many factors, including how the standards are used within a larger accountability system (if any). I looked for a pattern that would connect Dr. Lerner's results with states' performance on the 1996 National Assessment of Educational Progress (NAEP) in eighth-grade science. I couldn't find much of one, except that a slight majority of states given "D" or "F" in the Lerner analysis also showed poorly on NAEP. In many jurisdictions, however, the standards have not had time to gain much traction—and in some there is no real accountability system that is apt to give them any. There are, moreover, a number of fine schools and outstanding teachers that manage to do a good job with or without state standards.

But that's not good enough for the United States in 1998. It's not good enough that our eighth-graders fare worse than our fourth-graders on international assessments of science. It's not good enough that so few of our states have praiseworthy science standards to serve as goals, benchmarks, and accountability gauges. It's not good enough that how much and how well U.S. youngsters are expected to learn in this core discipline depend so heavily on where they live and what schools they wind up in.

That, to me, is the central message of Dr. Lerner's report. And he has done an outstanding job of preparing it. His twenty-five criteria for judging state standards in this domain are a model for any such analysis. (Indeed, for a state that is starting from scratch to write or rewrite its science standards, those criteria would be a fine place to begin.) His appraisal of individual state standards against those criteria was systematic, careful, and rigorous. His five expert consultants played key roles in both stages of the analysis—and broadened the disciplinary base beyond Dr. Lerner's own specialty of physics. We are sincerely grateful to them.

Besides his teaching responsibilities at Cal State, Long Beach, Dr. Lerner is the author of two university-level physics textbooks and numerous other publications in condensed-matter physics, the history of science, and science education. He was a major author and editor of the content sections of the Science Framework for California Public Schools, one of the standards documents reviewed in the following pages. He is also a contributing editor to *The Textbook Letter*, which evaluates middle- and secondary-school texts in science and other subjects, and a member of the National Faculty for the Humanities, Arts, and Sciences. He has earned our admiration and our gratitude.

In addition to published copies, this report (and its companion appraisals of state standards in other subjects) is available in full on the Foundation's web site: http://www.edexcellence.net. Hard copies can be obtained by calling 1-888-TBF-7474 (single copies are free of charge). The report is not copyrighted and readers are welcome to reproduce it, provided they acknowledge its provenance and do not distort its meaning by selective quotation.

For further information from the author, readers can contact Dr. Lerner by mail at the Department of Physics and Astronomy, California State University, Long Beach, 1250 Bellflower Boulevard, Long Beach, CA 90840; by fax at 562-985-7924; or by e-mail at lslerner@csulb.edu.

The Thomas B. Fordham Foundation is a private foundation that supports research, publications, and action projects in elementary/secondary education reform at the national level and in the vicinity of Dayton, Ohio. Further information can be obtained from our web site or by writing us at 1015 18th Street N.W., Suite 300, Washington, D.C. 20036. (We can also be e-mailed through our web site.) In addition to thanking Dr. Lerner and his advisors, I would like to take this opportunity to express my personal thanks to the Foundation's program manager, Gregg Vanourek, as well as staff members Irmela Vontillius and Michael Petrilli, for their many services in the course of this project, and Robert Champ for his editorial assistance.

Chester E. Finn, Jr. President
Thomas B. Fordham Foundation
Washington, D.C.
March 1998

EXECUTIVE SUMMARY

The writing and rewriting of standards have been a significant part of the recent national enthusiasm for school reform and improvement. Assessment is a key to accountability, which has been a central theme in school reform. Standards—detailed expectations set for students at various grade levels—are the necessary basis on which examinations and other assessment instruments must be based. Furthermore, well-written standards can function as a roadmap for the subject area at hand for parents, teachers, school administrators and curriculum specialists, textbook writers and publishers, policy makers, and the general public.

Good science standards are of particular importance because they serve as the first step toward remedying the lamentable—one is tempted to say shameful—lack of science literacy among the general public.

Good science standards are of particular importance because they serve as the first step toward remedying the lamentable—one is tempted to say shameful—lack of science literacy among the general public. This study, one of five subject-area studies sponsored by the Thomas B. Fordham Foundation, evaluates the science standards of 36 states. A few states delegate the setting of standards to local authorities; some state standards are still in early draft stages and are thus unavailable; a few state standards are either idiosyncratic or so brief as to make evaluation impossible; and a few were simply unavailable. Nevertheless, the standards of more than two-thirds of the states form a basis for a reliable appraisal of the present state of affairs.

The standards documents were evaluated according to 25 criteria falling into five major categories:

- Purpose, expectations, and audience
- Organization
- Coverage and content (the most extensive category)
- Quality, and
- Negative criteria

While the application of these criteria is a complex and detailed process, the general principles are simple. A good standards document is clearly written and intelligible to all those who may reasonably have an interest in reading it, and it can readily serve as a basis for writing assessment instruments. It is well-organized. It covers the sciences thoroughly (at a level appropriate to the students) and correctly, in such a way as to make the structures of the sciences clear. It makes strong but realistic demands on the students. It does not attempt to peddle pseudoscience as the real thing, and it does not foster an antiscientific, antitechnological, or anti-intellectual world view.

Each state document was rated on each criterion on a scale from 0 (unsatisfactory) to 3 (perceptive and thoughtful meeting of the criterion.) On the basis of the numerical scores thus derived, percentages were calculated and letter grades (A-F) were assigned.

The results, criterion-by-criterion, are presented in Table 1, together with the total scores, percentages, and letter grades. Six states (17%) achieved A's, seven (19%) achieved B's, seven achieved C's, seven D's, and nine earned F's.

Now, B is not a bad grade but it should not satisfy those responsible for writing the standards document. In an ideal world, all states would achieve A's. That ideal, moreover, is far from unattainable. It is truly regrettable that so many states did so poorly (C or below), especially in view of the many good models available.

The overall average performance is mediocre and very disappointing. Using the common procedure of assigning the value 4 to an A, 3 to a B, and so on, we calculate a national grade-point average of 1.8—that is, C-minus.

All the standards documents—even those rated A—have room for improvement. Because most of the documents take the form of lists, the tight theoretical structures of the sciences tend to be slighted. The lists are useful as a basis for drafting examinations or outlining textbook coverage, but they should be accompanied by unifying essays. Many documents attempt to achieve the desired unity by use of "themes," with highly varied success. But as a general rule, the overarching theories that are the skeletons of the sciences are perceptible only by implication even in the best-organized documents, and are invisible in many of the others.

Some subjects are inadequately treated or even omitted in the documents of many states. Among them are energy, evolution (especially human evolution), modern astronomy, and the role of scientific revolutions.

Good standards are not a magic solution to the problem of improving science teaching and learning in our schools. Nevertheless, improved standards are essential to academic progress, and we may hope that this analysis will help to call attention to the areas where improvement is needed.

NATIONAL REPORT CARD

State Science Standards (Maximum Score = 75)

State (in alphabetical order)	Raw Score	Percentage	Grade
Alabama	51	68	D
Alaska[1]	—	—	N
Arizona	71	95	A
Arkansas	46	61	F
California	72	96	A
Colorado	59	79	D
Connecticut	70	93	B
Delaware	69	92	B
District of Columbia	—	—	N
Florida	41	55	F
Georgia	50	67	D
Hawaii	72	96	A
Idaho[2]	—	—	N
Illinois	68	91	B
Indiana	74	99	A
Iowa	—	—	N
Kansas	61	81	C
Kentucky	36	48	F
Louisiana	70	93	B
Maine	57	76	D
Maryland	—	—	N
Massachusetts	65	87	C
Michigan	—	—	N
Minnesota	—	—	N
Mississippi	29	39	F
Missouri	64	85	C
Montana	—	—	N
Nebraska	51	68	D
Nevada	—	—	N
New Hampshire	37	49	F
New Jersey	71	95	A
New Mexico	31	41	F
New York[4]	60	80	C
North Carolina	—	—	N
North Dakota	21	28	F
Ohio	—	—	N
Oklahoma	—	—	N
Oregon	67	89	C
Pennsylvania	—	—	N
Rhode Island	71	95	A
South Carolina	56	75	D
South Dakota	—	—	N
Tennessee	43	57	F
Texas	66	88	C
Utah	69	92	B
Vermont	69	92	B
Virginia[4]	49	65	D
Washington	68	91	B
West Virginia	36	48	F
Wisconsin[3,4]	60	80	C
Wyoming	—	—	N
Virgin Islands[1]	—	—	N

State (by rank)	Raw Score	Percentage	Grade
Indiana	74	99	A
California	72	96	A
Hawaii	72	96	A
Arizona	71	95	A
New Jersey	71	95	A
Rhode Island	71	95	A
Connecticut	70	93	B
Louisiana	70	93	B
Delaware	69	92	B
Utah	69	92	B
Vermont	69	92	B
Illinois	68	91	B
Washington	68	91	B
Oregon	67	89	C
Texas	66	88	C
Massachusetts	65	87	C
Missouri	64	85	C
Kansas	61	81	C
New York[4]	60	80	C
Wisconsin[3,4]	60	80	C
Colorado	59	79	D
Maine	57	76	D
South Carolina	56	75	D
Alabama	51	68	D
Nebraska	51	68	D
Georgia	50	67	D
Virginia[4]	49	65	D
Arkansas	46	61	F
Tennessee	43	57	F
Florida	41	55	F
New Hampshire	37	49	F
Kentucky	36	48	F
West Virginia	36	48	F
New Mexico	31	41	F
Mississippi	29	39	F
North Dakota	21	28	F
Alaska[1]	—	—	N
District of Columbia	—	—	N
Idaho[2]	—	—	N
Iowa	—	—	N
Maryland	—	—	N
Michigan	—	—	N
Minnesota	—	—	N
Montana	—	—	N
Nevada	—	—	N
North Carolina	—	—	N
Ohio	—	—	N
Oklahoma	—	—	N
Pennsylvania	—	—	N
South Dakota	—	—	N
Wyoming	—	—	N
Virgin Islands[1]	—	—	N

Grading Scale: A= 95–100%, B = 90–94%, C = 80–89%, D = 65–79%, F = below 65%

1 The information provided in this three-page document was insufficient to support an evaluation.

2 The Idaho *Framework* is not directly comparable to the documents evaluated here. See the main text.

3 Based on draft Standards only, not the *Curriculum Guide*. Inclusion of *Curriculum Guide* (1986) would raise letter grade to B.

4 Scores have been adjusted due to "additional factors." For detailed explanation, see state-by-state evaluations.

TABLE 1. SUMMARY OF RESULTS
(Maximum Score = 75)

State	A: Purpose, Expectations, & Audience	B: Organization	C: Coverage & Content	D: Quality	E: Negatives	Additional Factors	Raw Score	Percentage	Grade
Alabama	8	6	18	10	9	—	51	68	D
Alaska[1]	—	—	—	—	—	—	—	—	—
Arizona	10	9	25	15	12	—	71	95	A
Arkansas	6	6	17	8	9	—	46	61	F
California	10	9	26	15	12	—	72	96	A
Colorado	8	9	18	12	12	—	59	79	D
Connecticut	11	9	23	15	12	—	70	93	B
Delaware	11	9	22	15	12	—	69	92	B
District of Columbia	—	—	—	—	—	—	—	—	—
Florida	3	6	14	7	11	—	41	55	F
Georgia	7	5	16	11	11	—	50	67	D
Hawaii	12	9	24	15	12	—	72	96	A
Idaho[2]	—	—	—	—	—	—	—	—	—
Illinois	10	9	22	15	12	—	68	91	B
Indiana	12	9	26	15	12	—	74	99	A
Iowa	—	—	—	—	—	—	—	—	—
Kansas	9	8	19	13	12	—	61	81	C
Kentucky	4	4	10	7	11	—	36	48	F
Louisiana	11	9	23	15	12	—	70	93	B
Maine	10	8	14	13	12	—	57	76	D
Maryland	—	—	—	—	—	—	—	—	—
Massachusetts	10	9	21	13	12	—	65	87	C
Michigan	—	—	—	—	—	—	—	—	—
Minnesota	—	—	—	—	—	—	—	—	—
Mississippi	5	4	7	5	8	—	29	39	F
Missouri	9	8	21	14	12	—	64	85	C
Montana	—	—	—	—	—	—	—	—	—
Nebraska	8	7	12	12	12	—	51	68	D
Nevada	—	—	—	—	—	—	—	—	—
New Hampshire	4	2	12	7	12	—	37	49	F
New Jersey	12	9	23	15	12	—	71	45	A
New Mexico	4	5	6	4	12	—	31	41	F
New York	8	6	16	9	12	9	60	80	C
North Carolina	—	—	—	—	—	—	—	—	—
North Dakota	1	3	5	0	12	—	21	28	F
Ohio	—	—	—	—	—	—	—	—	—
Oklahoma	—	—	—	—	—	—	—	—	—
Oregon	11	8	21	15	12	—	67	89	C
Pennsylvania	—	—	—	—	—	—	—	—	—
Rhode Island	12	9	23	15	12	—	71	95	A
South Carolina	9	6	18	12	11	—	56	75	D
South Dakota	—	—	—	—	—	—	—	—	—
Tennessee	7	6	14	6	10	—	43	57	F
Texas	10	9	20	15	12	—	66	88	C
Utah	11	9	22	15	12	—	69	92	B
Vermont	10	9	24	14	12	—	69	92	B
Virginia	5	6	9	12	12	5	49	65	D
Washington	11	8	22	15	12	—	68	91	B
West Virginia	4	4	12	6	10	—	36	48	F
Wisconsin[3]	8	7	16	9	12	8	60	80	C
Wyoming	—	—	—	—	—	—	—	—	—
Virgin Islands[1]	—	—	—	—	—	—	—	—	—

Grading Scale: A= 95–100%, B = 90–94%, C = 80–89%, D = 65–79%, F = below 65%

1 The information provided in this three-page document was insufficient to support an evaluation.

2 The Idaho *Framework* is not directly comparable to the documents evaluated here. See the main text.

3 Based on draft Standards only, not the *Curriculum Guide*. Inclusion of *Curriculum Guide* (1986) would raise letter grade to B.

TABLE 2. PURPOSE, EXPECTATIONS, AND AUDIENCE

(Category A: Maximum Score = 12)

State	Expectations of Scientific Literacy	Basis for Assessment	Clarity, Completeness, Comprehensibility	Expectations for Written & Oral Work	Subtotal
Alabama	2	3	1	2	8
Alaska	—	—	—	—	—
Arizona	2	3	3	2	10
Arkansas	2	1	1	2	6
California	3	2	3	2	10
Colorado	3	2	2	1	8
Connecticut	3	3	3	2	11
Delaware	3	3	3	2	11
District of Columbia	—	—	—	—	—
Florida	2	0	0	1	3
Georgia	2	3	0	2	7
Hawaii	3	3	3	3	12
Idaho	—	—	—	—	—
Illinois	3	3	3	1	10
Indiana	3	3	3	3	12
Iowa	—	—	—	—	—
Kansas	3	2	3	1	9
Kentucky	2	1	0	1	4
Louisiana	3	3	3	2	11
Maine	3	2	3	2	10
Maryland	—	—	—	—	—
Massachusetts	3	2	2	3	10
Michigan	—	—	—	—	—
Minnesota	—	—	—	—	—
Mississippi	1	1	1	2	5
Missouri	3	2	3	1	9
Montana	—	—	—	—	—
Nebraska	3	3	1	1	8
Nevada	—	—	—	—	—
New Hampshire	1	2	1	0	4
New Jersey	3	3	3	3	12
New Mexico	1	0	0	3	4
New York	3	2	1	2	8
North Carolina	—	—	—	—	—
North Dakota	0	0	1	0	1
Ohio	—	—	—	—	—
Oklahoma	—	—	—	—	—
Oregon	3	3	3	2	11
Pennsylvania	—	—	—	—	—
Rhode Island	3	3	3	3	12
South Carolina	3	2	2	2	9
South Dakota	—	—	—	—	—
Tennessee	3	1	1	2	7
Texas	3	3	3	1	10
Utah	3	3	3	2	11
Vermont	3	3	2	2	10
Virginia	3	1	1	0	5
Washington	3	3	3	2	11
West Virginia	3	0	0	1	4
Wisconsin	3	1	3	1	8
Wyoming	—	—	—	—	—
Virgin Islands	—	—	—	—	—

Note: See Criteria, Section III, for the precise meaning of the abbreviated table headings.

TABLE 3. ORGANIZATION
(Category B: Maximum Score = 9)

State	Clusters of 4 Grades or Fewer	Consistency with Scientific Theory	Sound Theoretical Basis	Subtotal
[redacted]	3	1	2	6
Alaska	—	—	—	—
[redacted]	3	3	3	9
Arkansas	3	1	2	6
[redacted]	3	3	3	9
Colorado	3	3	3	9
[redacted]	3	3	3	9
Delaware	3	3	3	9
[redacted]	—	—	—	—
Florida	3	2	1	6
[redacted]	3	1	1	5
Hawaii	3	3	3	9
[redacted]	—	—	—	—
Illinois	3	3	3	9
[redacted]	3	3	3	9
Iowa	—	—	—	—
[redacted]	3	3	2	8
Kentucky	3	1	0	4
[redacted]	3	3	3	9
Maine	3	3	2	8
[redacted]	—	—	—	—
Massachusetts	3	3	3	9
[redacted]	—	—	—	—
Minnesota	—	—	—	—
[redacted]	3	0	1	4
Missouri	3	3	2	8
[redacted]	—	—	—	—
Nebraska	3	2	2	7
[redacted]	—	—	—	—
New Hampshire	0	1	1	2
[redacted]	3	3	3	9
New Mexico	3	1	1	5
[redacted]	3	1	2	6
North Carolina	—	—	—	—
[redacted]	3	0	0	3
Ohio	—	—	—	—
[redacted]	—	—	—	—
Oregon	3	2	3	8
[redacted]	—	—	—	—
Rhode Island	3	3	3	9
[redacted]	3	1	2	6
South Dakota	—	—	—	—
[redacted]	3	1	2	6
Texas	3	3	3	9
[redacted]	3	3	3	9
Vermont	3	3	3	9
[redacted]	3	[illegible]	1	[illegible]
Washington	2	3	3	8
[redacted]	3	[illegible]	1	[illegible]
Wisconsin	3	2	2	7
[redacted]	—	—	—	—
Virgin Islands	—	—	—	—

Note: See Criteria, Section III, for the precise meaning of the abbreviated table headings.

TABLE 4. COVERAGE AND CONTENT
(Category C: Maximum Score = 27)

State	Experimental Evidence, Classical Experiments	Clear Terminology, Rigorous Definition	Stringent Criteria for Data	Progressive Mastery of Graphs	Theory & Experiment	Basic Principles	Ability to Grasp Abstractions	Methodology	Science & Technology	Subtotal
Alabama	1	2	2	3	1	2	3	2	2	18
Alaska	—	—	—	—	—	—	—	—	—	—
Arizona	3	3	2	3	2	3	3	3	3	25
Arkansas	3	1	3	1	2	1	2	2	2	17
California	3	3	3	2	3	3	3	3	3	26
Colorado	1	1	1	2	2	3	3	3	2	18
Connecticut	3	2	2	2	2	3	3	3	3	23
Delaware	3	2	3	2	2	2	2	3	3	22
District of Columbia	—	—	—	—	—	—	—	—	—	—
Florida	2	1	2	1	1	2	2	2	1	14
Georgia	2	3	1	2	1	1	3	1	2	16
Hawaii	2	2	3	3	2	3	3	3	3	24
Idaho	—	—	—	—	—	—	—	—	—	—
Illinois	2	1	3	2	2	3	3	3	3	22
Indiana	3	3	3	3	2	3	3	3	3	26
Iowa	—	—	—	—	—	—	—	—	—	—
Kansas	2	1	2	2	2	2	2	3	3	19
Kentucky	1	0	1	1	0	1	3	1	2	10
Louisiana	3	2	2	2	2	3	3	3	3	23
Maine	1	1	1	2	2	3	1	1	2	14
Maryland	—	—	—	—	—	—	—	—	—	—
Massachusetts	3	2	2	3	1	2	2	3	3	21
Michigan	—	—	—	—	—	—	—	—	—	—
Minnesota	—	—	—	—	—	—	—	—	—	—
Mississippi	1	0	1	1	1	0	0	2	1	7
Missouri	2	2	1	2	3	2	3	3	3	21
Montana	—	—	—	—	—	—	—	—	—	—
Nebraska	1	1	1	1	1	1	2	2	2	12
Nevada	—	—	—	—	—	—	—	—	—	—
New Hampshire	2	0	2	1	1	1	1	2	2	12
New Jersey	3	2	3	2	2	2	3	3	3	23
New Mexico	1	0	1	1	1	0	1	0	1	6
New York	2	1	1	2	1	2	2	2	3	16
North Carolina	—	—	—	—	—	—	—	—	—	—
North Dakota	1	0	1	0	0	1	1	0	1	5
Ohio	—	—	—	—	—	—	—	—	—	—
Oklahoma	—	—	—	—	—	—	—	—	—	—
Oregon	2	2	3	2	2	2	3	2	3	21
Pennsylvania	—	—	—	—	—	—	—	—	—	—
Rhode Island	3	3	3	2	2	2	3	2	3	23
South Carolina	2	1	2	2	1	1	3	3	3	18
South Dakota	—	—	—	—	—	—	—	—	—	—
Tennessee	1	3	0	1	1	0	2	3	3	14
Texas	3	3	1	2	2	3	2	2	2	20
Utah	2	2	2	2	2	3	3	3	3	22
Vermont	2	3	3	2	2	3	3	3	3	24
Virginia	2	1	0	1	0	2	1	1	1	9
Washington	3	2	2	2	2	3	3	3	2	22
West Virginia	2	0	1	1	1	1	2	1	3	12
Wisconsin	2	1	2	1	1	1	3	2	3	16
Wyoming	—	—	—	—	—	—	—	—	—	—
Virgin Islands	—	—	—	—	—	—	—	—	—	—

Note: See Criteria, Section III, for the precise meaning of the abbreviated table headings.

TABLE 5. QUALITY
(Category D: Maximum Score = 15)

State	Unambiguous & Appropriate	Specific but Flexible	Comprehensive but Not Encyclopedic	Demanding, Cumulative	Demanding, Specific	Subtotal
Alabama	1	3	1	3	2	10
Alaska	—	—	—	—	—	—
Arizona	3	3	3	3	3	15
Arkansas	1	2	1	2	2	8
California	3	3	3	3	3	15
Colorado	2	3	2	3	2	12
Connecticut	3	3	3	3	3	15
Delaware	3	3	3	3	3	15
District of Columbia	—	—	—	—	—	—
Florida	0	2	2	2	1	7
Georgia	2	3	2	2	2	11
Hawaii	3	3	3	3	3	15
Idaho	—	—	—	—	—	—
Illinois	3	3	3	3	3	15
Indiana	3	3	3	3	3	15
Iowa	—	—	—	—	—	—
Kansas	2	3	3	3	2	13
Kentucky	1	1	2	2	1	7
Louisiana	3	3	3	3	3	15
Maine	2	2	3	3	3	13
Maryland	—	—	—	—	—	—
Massachusetts	2	3	3	2	3	13
Michigan	—	—	—	—	—	—
Minnesota	—	—	—	—	—	—
Mississippi	2	0	0	2	1	5
Missouri	2	3	3	3	3	14
Montana	—	—	—	—	—	—
Nebraska	2	2	2	3	3	12
Nevada	—	—	—	—	—	—
New Hampshire	1	1	2	2	1	7
New Jersey	3	3	3	3	3	15
New Mexico	1	1	1	1	0	4
New York	1	3	1	2	2	9
North Carolina	—	—	—	—	—	—
North Dakota	0	0	0	0	0	0
Ohio	—	—	—	—	—	—
Oklahoma	—	—	—	—	—	—
Oregon	3	3	3	3	3	15
Pennsylvania	—	—	—	—	—	—
Rhode Island	3	3	3	3	3	15
South Carolina	3	3	2	2	2	12
South Dakota	—	—	—	—	—	—
Tennessee	0	2	0	2	2	6
Texas	3	3	3	3	3	15
Utah	3	3	3	3	3	15
Vermont	3	2	3	3	3	14
Virginia	3	3	3	2	1	12
Washington	3	3	3	3	3	15
West Virginia	0	2	1	2	1	6
Wisconsin	2	1	2	2	2	9
Wyoming	—	—	—	—	—	—
Virgin Islands	—	—	—	—	—	—

Note: See Criteria, Section III, for the precise meaning of the abbreviated table headings.

TABLE 6. NEGATIVES
(Category E: Maximum Score = 12)

State	Eschew Pseudo-Science, Quackery	Not Race-, Gender-, Ethnic-Specific	Science Not Confused with Technology	Reject Anti-Science, Anti-Technology	Subtotal
Alabama	1	3	3	2	9
Alaska	—	—	—	—	—
Arizona	3	3	3	3	12
Arkansas	0	3	3	3	9
California	3	3	3	3	12
Colorado	3	3	3	3	12
Connecticut	3	3	3	3	12
Delaware	3	3	3	3	12
District of Columbia	—	—	—	—	—
Florida	2	3	3	3	11
Georgia	2	3	3	3	11
Hawaii	3	3	3	3	12
Idaho	—	—	—	—	—
Illinois	3	3	3	3	12
Indiana	3	3	3	3	12
Iowa	—	—	—	—	—
Kansas	3	3	3	3	12
Kentucky	2	3	3	3	11
Louisiana	3	3	3	3	12
Maine	3	3	3	3	12
Maryland	—	—	—	—	—
Massachusetts	3	3	3	3	12
Michigan	—	—	—	—	—
Minnesota	—	—	—	—	—
Mississippi	2	1	3	2	8
Missouri	3	3	3	3	12
Montana	—	—	—	—	—
Nebraska	3	3	3	3	12
Nevada	—	—	—	—	—
New Hampshire	3	3	3	3	12
New Jersey	3	3	3	3	12
New Mexico	3	3	3	3	12
New York	3	3	3	3	12
North Carolina	—	—	—	—	—
North Dakota	3	3	3	3	12
Ohio	—	—	—	—	—
Oklahoma	—	—	—	—	—
Oregon	3	3	3	3	12
Pennsylvania	—	—	—	—	—
Rhode Island	3	3	3	3	12
South Carolina	2	3	3	3	11
South Dakota	—	—	—	—	—
Tennessee	1	3	3	3	10
Texas	3	3	3	3	12
Utah	3	3	3	3	12
Vermont	3	3	3	3	12
Virginia	3	3	3	3	12
Washington	3	3	3	3	12
West Virginia	3	3	1	3	10
Wisconsin	3	3	3	3	12
Wyoming	—	—	—	—	—
Virgin Islands	—	—	—	—	—

Note: See Criteria, Section III, for the precise meaning of the abbreviated table headings.

I. INTRODUCTION

No topic of public discourse in the United States has greater staying power than the condition of the education system. This is hardly surprising, given the universality and extent of exposure to both the benefits and the costs of that system. Ironically and paradoxically, no topic of public discourse seems to be based on less hard information and more unfounded opinion or, at best, anecdotal evidence. In large measure, this paradox arises from what most Americans consider a major strength of their education system—its unique decentralization. It is easy to ask, "How do my local schools measure up to other American schools? How do U.S. schools measure up on a global scale?" Yet decentralization makes such questions hard to answer.

Fortunately, public pressure for accountability has led to a flurry of activity on many levels. In particular, most states have either revised, or written for the first time, sets of standards that are imposed to a greater or lesser degree on local school districts and schools. These standards are by no means uniform in format; they are variously called *Standards, Frameworks,* or sometimes *Curriculum Guides.* There are important differences among these three genres, but they all provide, at least potentially, some basis for measurement of achievement at every level from the individual student to the entire state school system. For convenience, we will use the generic term "Standards" to denote all such documents except where it is necessary to make a distinction.

The first purpose of a set of standards is to give everyone concerned a basis for understanding how the state approaches the crucial question: What do we expect teachers to teach and students to learn in the schools of this state, at each grade level and in each subject? Teachers, administrators, parents, politicians, and citizens all have a need to know, and the standards must be written so that they all can make sense out of what they read.

A second purpose follows immediately from the first. Once a set of standards is in place, the obvious next step is to use it as a basis for constructing evaluative tools. These tools may take the form of statewide examinations at specified grade levels, of adoption criteria for textbooks and other teaching materials, and even of teacher certification requirements. Clearly, if such tools are to be useful, the basic standards document must be of high quality. My purpose here was to assess the quality of the current science standards of as many states as possible; I have succeeded in obtaining copies of 36. That is to say, I have been able to study the standards of almost three-quarters of the states.

Throughout this task, I was fortunate in having the advice of five expert consultants from a wide range of scientific disciplines. The consultants aided in the preparation of the evaluation criteria, checked about half of the state-by-state evaluations in detail, and critically read the report in early- and late-draft forms. Their aid was invaluable, and I thank them here:

- Elizabeth L. Ambos, Associate Professor of Geological Sciences, California State University, Long Beach
- Thomas C. Edholm, Science Teacher, Fresno Unified School District
- Thomas P. Sachse, Curriculum and Assessment Consultant, Center for School Improvement, Region V BOCES; formerly Administrator, Mathematics, Science, and Environmental Education Unit, California State Department of Education
- Michael A. Seeds, Professor of Astronomy and Director of the Joseph R. Grundy Observatory, Franklin and Marshall College
- Ellen Weaver, Professor of Biology Emerita, San Jose State University

This report is the last in a series of five nurtured and published by the Thomas B. Fordham Foundation. The reports evaluate Standards in the pivotal disciplines of English, history, geography, and mathematics as well as science. I am indebted to the Foundation's President, Chester E. Finn, Jr., not only for his support and encouragement but for his generous contribution of superb editorial skills.

II. WHAT IS A STANDARD?

Most of the Standards reviewed here explicitly acknowledge the influence of a number of significant national studies of curriculum.[1] Many Standards are derived in considerable measure from these sources, having adapted them to local needs and viewpoints with varying degrees of success. Other Standards follow the form and spirit of the same models, but with considerable variation in detail. Still others take completely independent approaches.

The great majority of science Standards take the form of lists. For each grade level or, more commonly, each cluster of grade levels, there is a list of expectations, each of which is usually (and somewhat confusingly) called a standard. In most cases, each expectation is accompanied by one or more examples of what a student might do to demonstrate mastery of that quantum of knowledge; these examples are often called "benchmarks." Sometimes the standards for different grade levels are listed in sequence; less often they are listed in parallel columns, each devoted to one grade level or cluster.[2] The latter arrangement makes it easy to see how a given thread of understanding develops as the student matures, but it does not lend itself to lengthier, more detailed standards.

Lists have two virtues. They are relatively easy to construct and modify, and they are easy to understand. They have, however, a subtle disadvantage that is probably more serious for science than for other subject areas. The sciences have strong unifying theoretical structures at every level, from specific subdisciplines through general fields and entire disciplines to all of science. Biology, for instance, is a well-defined science with its own principles, but nothing happens in biological systems that contravenes the laws of chemistry or physics. Unfortunately, lists tend to obscure the profound importance of the theoretical structure of science. This is especially true for the reader who is not a scientist or science teacher. More important, a list may be misinterpreted by some science teachers and textbook writers as encouragement to teach science as a simple list of facts.[3]

The writers of the best Standards are well aware of this difficulty, and have taken various steps to deal with it. Some documents introduce each group of related standards with a short unifying essay. Some go well beyond the sentence or two characteristic of the standards in most documents to provide considerable detail. Many organize the subject matter into cross-disciplinary Themes, with greater or lesser success. In some cases, the standards are so tightly organized that the theoretical structure comes through implicitly—at least to the reader with some experience in the field.

Perhaps the most satisfactory approach is that pioneered by California and used to some degree by a few other states.[4] In place of lists, subject areas are dealt with by means of short essays, typically a few hundred words long. In this format, clusters of related facts and concepts can be threaded together on their theoretical framework. The format can serve as a direct model for textbook writers as well as teachers. The construction of evaluation criteria becomes less obvious; one cannot simply turn a short essay into a multiple-choice test question by changing a few words, as one can do with one- or two-sentence standards. Nevertheless, knowledgeable persons can readily use the materials as a basis for such construction.

III. EVALUATING THE STANDARDS

Because state Standards, once adopted, govern so many aspects of education, the quality of the standards is crucial. This has been clear to many and several comparative evaluations of Standards have been published.[5] Our evaluation differs from the two cited here in significant ways. In contrast to the State Education Assessment Center's *Mathematics and Science Content Standards* (see note 5), which is mainly descriptive rather than evaluative, we are concerned here primarily with quality. And this report will serve as a complement to the American Federation of Teachers' *Making Standards Matter* (see note 5) in the sense that science teachers and scientists have complementary perspectives on science and its teaching. In addition, this report presents the point of view of one who has no official connection with K-12 education.

Because state Standards, once adopted, govern so many aspects of education, the quality of the standards is crucial.

Setting up the Criteria

We began by compiling a set of criteria for evaluation. The criteria employed here are freely adapted from those devised by Sandra Stotsky for use in evaluating state English Standards.[6] In taking the Stotsky criteria as a model, we were motivated by two considerations. The first is consistency; it is clearly advantageous to maintain comparability between the evaluations of the two disciplines. The second is the degree to which we have been impressed by the quality of the Stotsky work.

Of course, science and English are different in many ways, and it was necessary to modify the Stotsky criteria in many ways to take the difference into account. In particular, more stress was placed on

- absence of scientific error
- precision and accuracy
- the laboratory experience
- the importance of facility in mathematical language as well as English speech and writing
- the role of theory, its interaction with experiment, and its role in interpretation and prediction
- absence of things that should not appear in a good Standard, such as pseudoscience, quackery, antiscience/antitechnology views, scientific ethnocentrism, and distorted science history

The Criteria

The criteria employed in the evaluation fall into five categories; there are 25 criteria in all, as follows:

A. Purpose, expectations, and audience

1. The standards document expects students to become scientifically literate, at depths appropriate to their grade levels, beginning with the earliest grades and continuing intensively and consistently through the entire K-12 experience.
2. The document can serve as the basis for clear and reliable statewide assessments of student learning and skills acquisition, both theoretical and practical, appropriate to the grade level.
3. The document is clear, complete, and comprehensible to all interested audiences: educators, subject experts, policy makers, and the general public. Technical terms are explained in nontechnical language.
4. The document expects student written work to be presented clearly in standard English and, where called for, in acceptable mathematical language. It expects student oral presentations to be clear, well organized, logical, and to the point. For both written and oral work, the level of language, English and mathematical, is to be appropriate to the subject matter and to the student's grade level.

B. Organization

1. The standards are presented grade-by-grade or in clusters of no more than three to four grade levels.
2. They are grouped in categories reflecting the fundamental theoretical structures underlying the various sciences, e.g., Newtonian dynamics, mass and energy conservation, cosmological evolution, uniformitarianism, plate tectonics, and biological evolution.
3. They pay proper attention to the elementary skills of simple observation and data gathering, the interpretation of systematic observations, and the design of experiments on the basis of a theoretical framework.

C. Coverage and Content

1. The standards address the experimental and observational basis of the sciences, and provide for substantial

laboratory and/or field experience in the sciences. Replication of important classical experiments is encouraged. The primacy of evidence over preconception is made clear.

2. The standards stress the importance of clear, unambiguous terminology and rigorous definition. Such terms as energy, mass, valence, pH, genotype, natural selection, cell, metabolism, continental drift, magnetic reversal, and cosmic background radiation are defined as rigorously as possible at the grade level concerned.
3. The standards address such issues as data analysis, experimental error, reliability of data, and the procedures used to optimize the quality of raw information. The stringent criteria for acceptance of data are made clear.
4. The standards expect students to master the techniques of presentation and interpretation of tabular and graphical data at increasingly sophisticated levels.
5. The standards address the need for systematic, critical interpretation of experimental/observational data within the framework of accepted theory. The continual interplay between data and theory, and the rejection or remeasurement of data and modification of theory where necessary, are stressed at all grade levels, commensurate with the students' degree of maturity. The nature and role of scientific revolutions, and how or when they occur (or do not occur), are part of the curriculum for students sufficiently advanced to appreciate the issues involved.
6. The basic underlying principles of all the sciences are stressed. Examples include Newton's laws, conservation laws, and the microscopic/macroscopic connection in physics; the evolution of the universe and the structure of its parts (including the solar system) in astronomy; plate tectonics in geology; the roles of mass and energy conservation and the nature of the chemical bond in chemistry; and evolution and the molecular basis of life in biology. At the elementary levels, these principles may be exemplified by such observations as buoyancy, plant tropisms, and the gross structure of cells.
7. The increasing ability of students to grasp abstractions and generalizations is taken into account. The broad, less structured knowledge base laid in the early grades is consistently and methodically built up on the basis of progressively more sophisticated theoretical treatment as the students mature.
8. The standards emphasize the need to set forth the general methodologies of the sciences, but do not oversimplify this need into an artificial package called "*the* scientific method." The underlying commonalities of the sciences, as well as the distinctions among them, are made clear.
9. The standards consider the two-way relationships between science and technology, and between science and broader world views, and the way that science has helped to shape society. The standards stress the fact that science is intellectually satisfying as well as socially useful. A common interest in science can act as a strong unifying force among people who differ widely in other ways.

D. Quality

1. The standards are unambiguous and appropriate; that is, their meaning is straightforward and to the point.
2. They are specific but flexible; that is, they are neither so broad as to be vague nor so narrow as to be trivial.
3. They comprehensively cover basic knowledge, the importance of which is generally agreed upon by the scientific community; they are not, however, encyclopedic.
4. Standards are demanding:
   a. They expect increasing intellectual sophistication and higher levels of abstraction, as well as the skills required to deal with increasingly complex arrays of information, at successively higher educational levels. In light of the tight logical structure of the sciences, it is especially important that the standards also expect the knowledge gained by students to be cumulative, each level building on what has been mastered earlier.
   b. Their overall contents are sufficiently specific and comprehensive to underlie a common core of understanding of science for all students in all the schools of the state. They are sufficiently demanding to ensure that this common core comprises understanding of the basic principles of all the sciences, and of their methodologies.

E. Negatives

The following items should not appear in standards. If they do, they carry negative weights:

1. The standards must not accept as scientific, or encourage, pseudoscientific or scientifically discredited constructs such as quack medical doctrines (e.g., homeopathy, foot reflexology), vaguely defined "energy fields" or "auras," creationism and other nonscientific cosmologies, UFO visits, astrology, or mysterious "life forces."
2. The standards must not imply that scientific principles are race-, ethnic-, or gender-specific, or distort the history of science to promote racial-, ethnic-, or gender-based positions.
3. The standards must not confuse science with technology.
4. The standards must not encourage an antiscientific or antitechnological world-view.

IV. THE RATING SYSTEM

While numbers can never yield a complete assessment of academic standards, the degree to which a standard measures up to each criterion is roughly evaluated by means of a four-point scale:

0: The criterion is addressed not at all or in an unsatisfactory manner
1: The criterion is met spottily or inconsistently
2: The criterion is often or usually met
3: The criterion is met almost always or always, and in a perceptive and thoughtful manner

As a matter of convenience, each numerical score was then recalculated as a percentage of the perfect score, 75. Tentative letter grades were then assigned according to the percentage ranges.

95 – 100%	A
90 – 94%	B
80 – 89%	C
65 – 79%	D
< 65%	F

These numerical evaluations are substantially supplemented by written description and exposition. Because number cannot reflect subtler aspects of a complex document, I adopted the following system. To each standards document I assigned an initial letter grade based entirely on the total numerical score. I then considered additional factors that might change the letter grade, and altered the grade by a maximum of one letter up or down in light of these factors. As it turned out, however, only three upward adjustments were necessary: New York and Wisconsin from D to C, and Virginia from F to D.

V. SIGNIFICANT ISSUES

In the course of the detailed study, I found that several shortcomings were evident in a substantial number of Standards. It is worth discussing them here, so as to avoid unnecessary repetition.

Use of Themes

The sciences are linked by several different classes of unifying factors. Unifying factors are essential not only in doing science but also in learning and teaching science. The most obvious class of such factors is universal laws; the principle of momentum conservation, for example, applies across all sciences. A second class is methodological; while there is no such thing as "*the* scientific method," scientists of all kinds share a strategy of attack on problems that involves the same general principles.

A third, more flexible set of links, dubbed "themes of science," has proved useful in science education in particular, because these links are quite general and help students gain insight into the nature of science in a general way.

What are these themes? I can do no better than to quote from the California *Science Framework*:[7]

> [Themes] could also be called big ideas, overarching concepts, unifying constructs, or underlying assumptions. They are distinct from facts and concepts. A fact is a statement based on confirmed observation and inference, such as the number of electrons in an atom of iron, the date of the discovery of helium, or the descent of birds from dinosaurs. A concept often involves several facts; for example, the concept of continental drift, the need for repeatable observations in constructing science, or how magnets work. Themes are larger ideas; they link the theoretical structures of the various scientific disciplines and show how they are logically parallel and cohesive. Scientific literacy lies not only in knowing facts and concepts but also in understanding the connections that make such information manageable and useful. . . . [The themes] presented here should be regarded as only one way to integrate the overarching concepts of science into a curriculum that spans scientific disciplines. . . . No doubt there are alternative arrangements that would work equally well. The important point is that at least some thematic structure will improve the recitation of disunited scientific facts that has come to pass for science in many current curricula and instructional materials.

Unfortunately, too many state Standards have chosen a set of themes and then presented them as "*the* themes of science." This having been done, the writers find the themes a Procrustean bed into which to force scientific concepts rather than an aid in showing students how helpful conceptual methodological links can be.

Energy

Energy is surely one of the most popular concepts in all science Standards, and the word ranks among the most frequently used in them. Unfortunately, too many Standards never bother to define the term. Clearly, one cannot be over-rigorous in a definition intended for the primary grades. Nevertheless, one can be careful, and sooner or later a rigorous definition must be provided. Georgia, Texas, and the Wisconsin *Curriculum Guide* do a fine job in this area. Georgia, in particular, introduces a limited but correct conceptualization of kinetic energy as early as grade 1. In some Standards, unfortunately, the term is not merely never defined but is badly misused.

Evolution

In his seminal work, *The Structure of Scientific Revolutions*,[8] the philosopher of science T. S. Kuhn makes a distinction between pre- and post-paradigm sciences. Prior to its first scientific revolution, a science has no central organizing theory. Work in the science consists of data gathering, and there is endless dispute among various schools as to which parts of the available data should be regarded as most significant. Progress is slow. The first scientific revolution brings resolution to these problems by providing a universally accepted paradigm; disputing groups characterized by names ending in "-ists" disappear and progress is rapid.

This happened to physics in the 17th century, with the advent of Newtonian mechanics; to chemistry in the 18th, with the advent of Lavoisier's quantitative chemistry; to biology in the 19th century, with the advent of evolutionary theory; and to geology in the 20th, with the advent of plate tectonics.

In biology, a distinction can be made between natural history, the pre-paradigm science, and biology, the post-paradigm science. Unless a curriculum is built around a core of evolutionary theory, the subject is natural history and not biology.

Needless to say, younger students are more adept at accumulating facts than at grasping large abstractions, and it makes sense to introduce the overarching theory of any science in a gradual way. Nevertheless, students should understand the underlying structure of the sciences by the time they are in middle school, and should have reasonably deep insight into the fundamental theories of the sciences by the time they graduate.

Most Standards do a good or satisfactory job of setting forth this basic requirement of science teaching. In most Standards, a long initial section is devoted to the methodology of the sciences. Unfortunately, in some states political rather than pedagogical reasons have interdicted this sound approach as far as the life sciences are concerned. Human evolution, in particular, is ignored. The result has been serious damage to the teaching of both the life sciences—one-third of the total curriculum—and of all the sciences as structured, interconnected fields.

Various states have responded to this political pressure in different ways. Mississippi and Tennessee ignore evolution completely. Arizona, Florida, and South Carolina treat the subject lightly, as if it were peripheral to the science, and studiously avoid use of the "E-word." Georgia and Kentucky use euphemisms—"organic variation" in the former and "change" in the latter. Human evolution is nowhere to be seen, even under the mask of euphemism.

Alabama's approach is the most curious. The front matter of the *Alabama Course of Study* contains, among other unrelated statements, a formula evidently dictated from on high by persons who know little of science: "Explanations of the origin of life and major groups of plants and animals, including humans, shall be treated as theory and not as fact." This misuse of the terms "theory" and "fact" in their nonscientific senses has been commented on extensively elsewhere. Interestingly, however, the Alabama document proceeds to deal with evolution in a light but almost satisfactory fashion, always using euphemisms for the term "evolution." The result is reminiscent of the quantum mechanics texts written in the USSR during the Stalin era, when quantum theory was officially regarded as anti-Marxist. A text would typically begin with a disclaimer, and then treat quantum mechanics in an entirely satisfactory way. The success of this approach depended on the fact that the *apparatchiks* who imposed the disclaimer did not know enough physics to read the body of the text. It is a pity that science teachers in an American state should have to take a similar approach.

Thankfully, the areas of astronomy and geology seem not to have fallen prey to antievolutionary pressures. Even the word "evolution" is freely used in the earth/space science sections of the same curricula that short-change biology.

Given the importance of biology, a set of science standards that ignores the spectacular progress of the past century and a half in this science cannot be regarded as satisfactory.

Astronomy

Astronomical knowledge has been exploding over the past few decades. In contrast, K-12 astronomy Standards almost unanimously concentrate 90% or more of their attention to the astronomy of the 17th and 18th centuries. One cannot fault the argument that younger students should be introduced to the solar system first. But too many Standards dismiss almost everything else with a few brief sentences at the grade 9-12 level. And even solar-system astronomy is too often restricted to the seasons, the motions of the planets, and similar subjects. The spectacular discoveries of the past few years—the geology of Mars, the oceans on Titan, the collision of a comet with Jupiter, to name just a few examples—are ignored. There is a need to devote much more time to cosmic background radiation, the life cycles of stars and the Hertzsprung-Russell diagram, the properties of pulsars, quasars, black holes and gravitational lenses, the recent discovery of planetary systems other than our own, and to many other modern topics. And, in light of these discoveries, the history of the universe deserves more than the typical "Debate the current theories on the origin of the universe."

The Nature of Scientific Revolutions

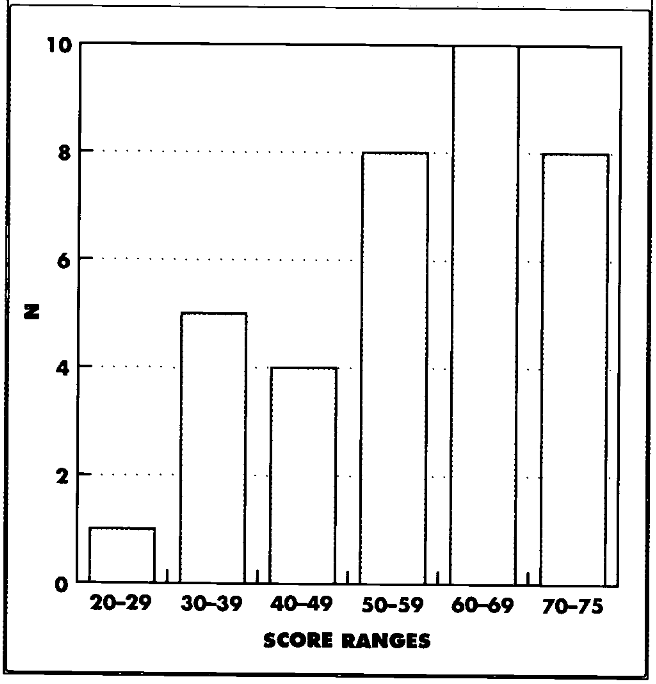
Almost all the standards documents make much of the history and philosophy of science. Much is also made of the importance of leading the student to grasp the underlying methodologies of the sciences, the cumulativeness of scientific knowledge, and the significance of some of the great contributors to that knowledge. Unfortunately, the historical view taken is largely that of a chronicle with minimal interpretation. Most scientists today accept an interpretive picture of the history of science that is more or less consistent with the views set forth by Kuhn in *The Structure of Scientific Revolutions*.[9] At the very least, the concept of the paradigm—the unstated but universally accepted *modus operandi* of the scientist—is widely accepted. Fortunately, the essentials of the Kuhnian view are readily presented to students at the high-school, or even the middle-school, level, and they provide a basis for understanding why and how scientific work goes the way it does. It would be well for Standards to present the history and philosophy of science in the light of this or some other organizing principle.

VI. THE RESULTS

Documents were obtained from or for 38 states and the Virgin Islands. Iowa, Minnesota, and Wyoming leave standards and related matters to school districts and similar local authorities. Pennsylvania is currently writing standards and does not have a document available for study. The North Carolina document, though it was ordered, did not arrive in time to be evaluated. Many states do not have hard-copy Standards available for distribution (most commonly explained by budgetary restrictions) but their documents could be downloaded from the Internet. I was simply unable to obtain materials from the remaining ten states and the District of Columbia.

The results are summarized in Table 1 and displayed in Figure 1. A perfect score is 75. Eight states scored 70 or higher, 10 scored 60-69, eight scored 50-59, four scored 40-49, five scored 30-39, and one below 30 (Figure 1). Alaska and the Virgin Islands have Standards too short to evaluate. The Idaho Standards are deliberately very sketchy, as the details are left to local school districts. As a result, the Idaho document is not comparable to the others discussed here, and was not evaluated.

Figure 1. Distribution of Scores



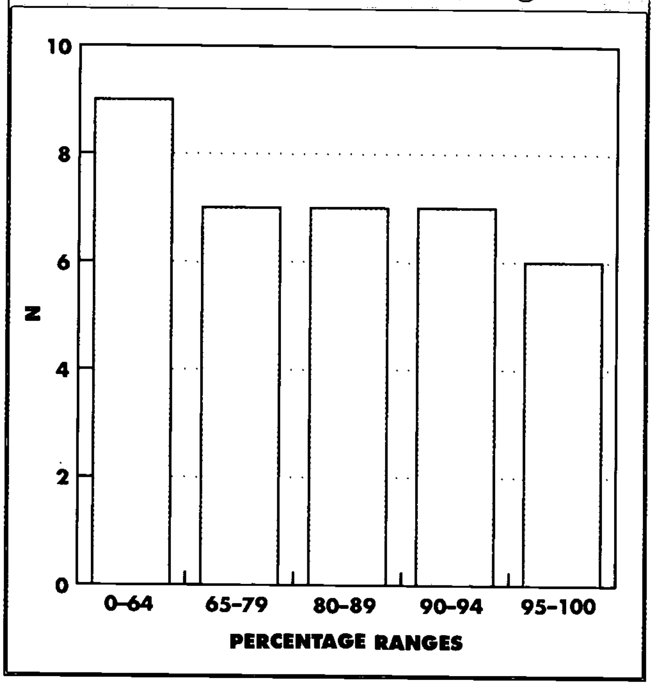
The raw scores were converted into percentages of the perfect score, 75. The results are displayed in Figure 2.

Finally, letter grades were assigned as detailed in Section IV. The grade distribution was as follows:

A:	6	(17%)	AZ, CA, HI, IN, NJ, RI
B:	7	(19%)	CT, DE, IL, LA, UT, VT, WA
C:	7	(19%)	KS, MA, MO, NY, OR, TX, WI
D:	7	(19%)	AL, CO, GA, ME, NE, SC, VA
F:	9	(25%)	AR, FL, KY, MS, NH, NM, ND, TN, WV

The "grade-point average" of the distribution is an unspectacular 1.8—that is, a C-minus, not far from the equally unspectacular minimum grade-point average the NCAA requires of its athletes. A detailed discussion is the subject of Section VII.

Figure 2. Scores As Percentages



How the States Fared in Categories A,B,C,D and E

Criterion A1: Expectations of scientific literacy.

Twenty-seven of the 36 states (75%) scored 3 on this criterion. Their Standards not only state at the outset that scientific literacy is expected but also outline a clear pathway toward that goal. Five states scored 2 and one 1; here the goal was either unstated or unclear, or there was little or no strategy to attain it.

Criterion A2: A basis for assessments.

Eighteen states (50%) scored 3. In some cases, the Standards themselves were a model for assessment; in others, the organization was sufficiently tight and clear to facilitate the development of assessment instruments. The seven state Standards (19%) that scored 2 were generally less clear. New York, for instance, had reasonably well-organized standards, but the examples (which might easily be turned into test items) were often confused or irrelevant to the standards. The six state standards that scored 1 (17%) were vague or disorganized. West Virginia (0) presents a paradoxical case. Although the Standards boldface the items that may appear on tests, they are so chaotically organized as to make genuine assessment of scientific achievement impossible.

Criterion A3: Clarity, completeness, and comprehensibility.

Eighteen states (50%) scored 3. Lower scores (five 2's, eight 1's, and five 0's) reflect varying degrees of vagueness, use of jargon, and failure to define (or misdefinition of) important terms.

Criterion A4: Expectation of well-presented written and oral work.

Eight states (22%) scored 3. Lower scores were mainly due to two factors: lack of proper emphasis on mathematics and failure to expect written work. Seventeen states (47%) scored 2, seven (19%) scored 1, and three (8%) scored 0. It was sometimes difficult to assess this item, especially for the states scoring 3 or 2, because the expectation was expressed in a variety of ways. Sometimes it appeared in a clear, firm statement in the introductory material and sometimes as a repeated expectation throughout the document. It may well be that some states take written expression for granted because it appears in the English standard. This, however, is inadvisable; written work must be required throughout a quality educational experience.

Criterion B1: Presentation of standards in clusters of four or fewer grade levels.

All but two states (94%) did this. Washington's Standards are written with a view to three examinations rather than by grade level. However, the grades at which the exams will be administered have not yet been fixed. New Hampshire makes only two divisions.

Criterion B2: Categories are consistent with the theoretical bases of the sciences.

Nineteen states (53%) scored 3, seven (19%) scored 2, nine (25%) scored 1, and three (8%) scored 0. The states that short-changed evolution theory were at a disadvantage here because they experienced varying incapacities in presenting the life sciences as structured scientific disciplines. Some states, however, simply did not organize the material very systematically.

Criterion B3: The importance of observation, data gathering, and design of experiment on a sound theoretical basis.

Eighteen states (50%) scored 3, eight (25%) scored 2, seven (19%) scored 1, and two (6%) scored 0. There was a fairly close correlation between scores on this criterion and the preceding one. Some states simply did not place sufficient stress on experimentation and its interpretation.

Criterion C1: Importance of experimentation and observation; primacy of evidence; replication of classical experiments.

Twelve states (33%) scored 3, fifteen (42%) scored 2, and nine (25%) scored 1. There was very little encouragement to repeat classical experiments, though some classical experiments were often mentioned in a general way. There is considerable room for improvement in this. All states had something positive to say about experimentation and observation, but in too many cases the emphasis was spotty.

Texas specifies that 40% of science study time be devoted to laboratory work, and clearly describes the need for interpretation. West Virginia laudably specifies 50%, but has nothing to say about the role of experimentation in science.

Criterion C2: Clear use of terminology and rigorous definition.

Only ten states (28%) scored 3; ten scored 2, ten scored 1, and six (17%) scored 0. Clearly, there is room for improvement here. I have already discussed the widespread poor treatment of energy, but many other technical terms are too often misused or poorly defined as well. The use of euphemisms for evolution put a number of states at a disadvantage here; the euphemisms used, though sometimes clever, are unfortunately not scientifically precise.

Criterion C3: The importance of error analysis and evaluation of data reliability, and the stringent criteria for acceptance of data.

Ten states (28%) scored 3, fourteen (39%) scored 2, ten (28%) scored 1, and two (6%) scored 0. This result is perhaps not surprising. Students and teachers alike often find data analysis tedious, and it can easily be slighted. Computers, and even hand-held scientific calculators, can ease the task tremendously. I looked for proper treatment particularly at the upper grade levels, where the issue really must be addressed.

Criterion C4: Expectation of progressive mastery of graphical and tabular presentation and interpretation techniques.

Fifteen states (42%) scored 3, twelve (33%) scored 2, eight (22%) scored 1, and one (3%) scored 0. Only one state neglected this important skill completely, but it was given short shrift more often than one would wish. Most states dealt with the matter well or not at all. It may be that some states take for granted that the matter is adequately handled under the rubric of the mathematics standard. As most teachers know, however, the translation of techniques from pure mathematics to science is often difficult for students.

Criterion C5: The importance of interplay between theory and experiment, and the nature of scientific revolutions.

Twelve states (33%) handled this matter consistently and well, and scored 3. Eight (22%) scored 2, twelve (33%) scored 1, and four (12%) scored 0. Because scientific theory does not fit well into terse statements, a good score usually required either a set of short introductory essays or a narrative format or a strong organization of the lists of standards. Lists fared poorly unless their organization was strong.

There was almost no mention of the role of scientific revolutions in the history of science, though most Standards treated the history of science with more or less completeness in a narrative if not an interpretive mode. More attention needs to be devoted to this matter.

Criterion C6: The basic principles of all the sciences are stressed.

Fifteen states (42%) scored 3, ten (28%) scored 2, eight (22%) scored 1, and three (8%) scored 0. I was impressed by the number of states that introduce Newton's laws, at least in a basic conceptual form, quite early. Arizona, Hawaii, and Texas are exemplary. Unfortunately, some states, including Delaware, Mississippi, New Hampshire, New Jersey, and West Virginia, either neglect these vital laws completely or garble them. Here again the neglect of evolution hamstrings a number of states. Far too often, conservation principles are either garbled or poorly defined; momentum is mentioned only rarely.

Criterion C7: Recognition of the growing ability of students to grasp abstractions.

Twenty-three states (64%) scored 3, eight (22%) scored 2, and five (14%) scored 1. This ability of growing youngsters is generally recognized, and most Standards are written consistently with students' ability.

Criterion C8: Proper treatment of scientific methodology.

Eighteen states (50%) scored 3, ten (28%) scored 2, six (17%) scored 1, and two (6%) scored 0. A few Standards still seemed steeped in the tradition that scientists follow a rigid program in doing research, but the great majority understand the flexibility of scientific methodology. A few states with scores of 2 or 1 did not present the matter clearly or neglected it.

Criterion C9: Relation between science and technology; universal appeal of science.

Twenty-one states (58%) scored 3, eleven (31%) scored 2, and four (11%) scored 1. Only a few Standards confused science and technology, usually not consistently. Almost all Standards made much of the universal appeal of science, often referring to the fact that the paucity of certain groups of people in scientific work in the past was a social handicap to be overcome and not an indication of the talents of those people.

Criterion D1: Standards are unambiguous and appropriate.

Nineteen states (53%) scored 3, six (17%) scored 2, six scored 1, and five (14%) scored 0. Low scores resulted from poor organization, ill-chosen examples, erroneous science, and just plain sloppiness. In several cases, the expectations at the grade 9-12 level were too low.

Criterion D2: Standards are specific but flexible.

A good score on this item appeared to hinge largely on the degree to which the writers understood what they were writing about. Twenty-five states (69%) scored 3, five (14%) scored 2, four (11%) scored 1, and two (6%) scored 0. Low scores resulted from vagueness, excessive use of jargon, and high error frequencies.

Criterion D3: Standards are comprehensive but not encyclopedic.

Nineteen states (52%) scored 3, ten (28%) scored 2, five (14%) scored 1, and two (6%) scored 0. It is difficult to be precise about when comprehensiveness becomes encyclopedic; I looked for complete coverage without exhaustive or pedantic qualities. Low scores were often associated with errors, particularly in physics, and absence of proper treatment of biological principles. In a few cases, astronomy was treated too loosely (see discussion above).

Criterion D4a: Standards are demanding, and expect cumulative mastery.

Twenty-one states (58%) scored 3, twelve (33%) scored 2, two (6%) scored 1, and one (3%) scored 0. Low scores here were associated with poor organization, serious lack of theoretical grounding, or sketchiness.

Criterion D4b: Standards are demanding, and ensure that the statewide common core comprises understanding of the basic principles of all the sciences, and their methodologies.

Nineteen states (53%) scored 3, ten (28%) scored 2, five (14%) scored 1, and two (6%) scored 0. Low scores were associated with poor organization, scientific errors (particularly in physics and chemistry), serious omissions, treatment of individual standards as "factoids," and general neglect of systematic methodology. It is gratifying to note that, on this crucial and summative criterion, 81% of the Standards scored well.

Criterion E1: Standards must not accept as scientific, or encourage, pseudoscientific or scientifically discredited constructs.

The only pseudoscience that presents a problem is creationism, peddled by implication in eight state Standards. Because the courts have repeatedly held that creationism is an expression of religion rather than science, these states have adopted the various strategies discussed in Section V. Although creationism is not explicitly discussed, damage is done to the teaching of the life sciences (and to a lesser degree to the earth and space sciences) by those strategies.

Wisconsin and Rhode Island are unique in dealing directly with pseudoscience in a positive way. Several items in the Wisconsin Curriculum Guide expect the student to consider the reasons why a variety of pseudosciences fail to meet the criteria of scientific enterprises. A few are quoted under "Rhode Island" and "Wisconsin" in Section VIII.

Criterion E2: Standards must not imply that scientific principles are race- ethnic-, or gender-specific, or distort the history of science to accord with such a view.

Only one Standard makes such implications, and that most likely by inadvertence. Most Standards are quite explicit about the universality of the sciences.

Criterion E3: Standards must not confuse science with technology.

Only one Standard possesses this fault, naming a number of technologists as scientists. Most Standards are quite explicit as to the distinction, usually devoting an entire section to the science-technology interaction.

Criterion E4: Standards must not encourage an antiscientific or antitechnological point of view.

All the Standards take quite a positive view of science and technology in general. Two Standards contradict this principle in excessive efforts to appear "green." As a group, the Standards take a reasonably balanced view towards the environmental implications of technological systems; this is surprising in light of the "ecopiety" that permeates many textbooks and other instructional materials.

VII. CONCLUSIONS

There is good news and bad, as the popular saying goes. The good news is that more than one-third of the state Standards scored very good (A) or good (B). The overall averages, though mediocre, are higher than those determined for four other subject areas in companion studies.[6,10] The bad news is that, for all that, the science standards on average are very mediocre indeed. Behind the thirteen leaders is a long procession of successively poorer material, trailing off into uselessness and worse. Many of the trailers demonstrate poor organization and, sad to say, innocence of both the central concepts and details of the sciences.

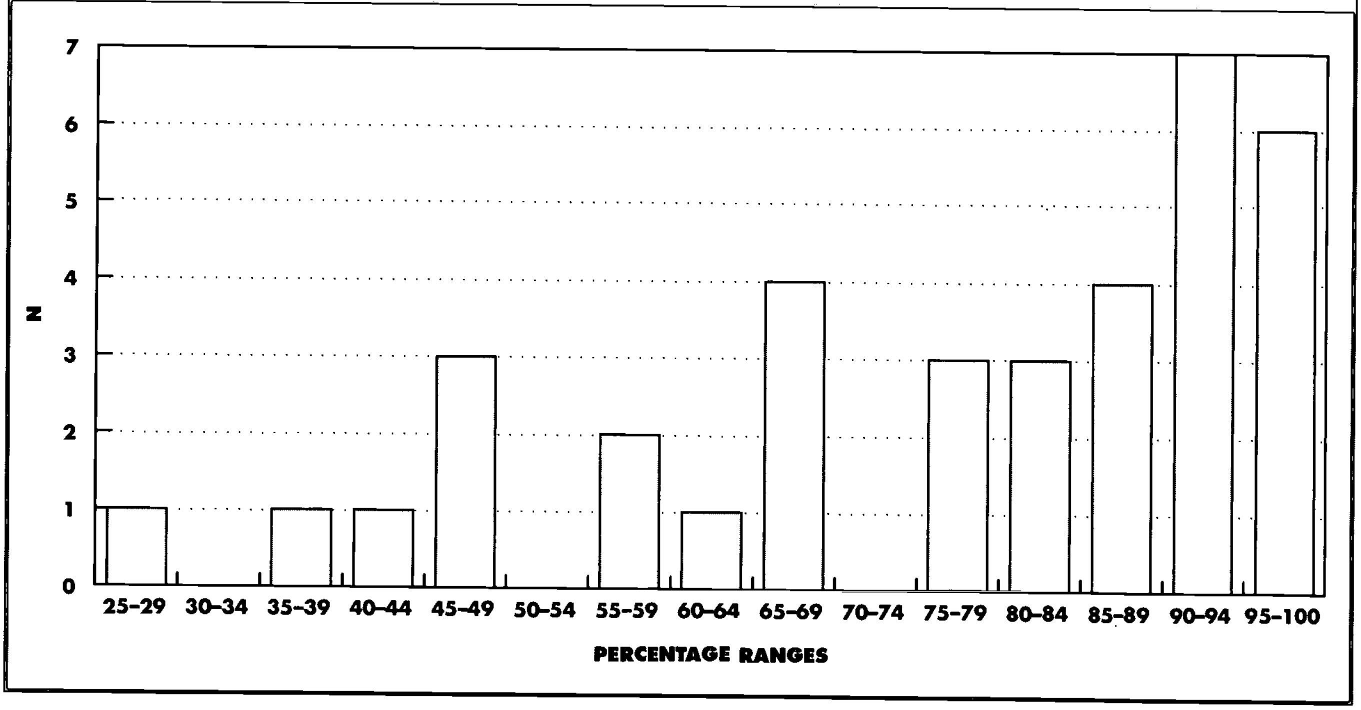
Study after study shows the abysmal condition of scientific literacy among Americans, and quality Standards are the first step—if only the first of many—toward ameliorating that condition.

To what can we attribute the relatively good showings of a significant proportion of the Standards? As one of our expert consultants, Dr. Elizabeth Ambos, has pointed out, a kind of consensus has developed around four models (see note 1) that have been in circulation for some years. Although these models have been the subject of considerable controversy, that controversy has never reached the level of intensity engendered by the rival models in mathematics.[11]

The consensus is evident in the degree to which most of the state Standards have drawn on the models, as to both form and content. In the cases where this has been done with skill and care, the results have been generally good. In some other cases (notably Florida's and West Virginia's Standards) the writers have merely demonstrated a lack of understanding of what they were reading. There is a parallel in the experience of upper-elementary (say, 5th grade) teachers who assign a book report. The submissions are usually not reviews but précis of the assigned book. The better reports approach what one might expect to read in the Reader's Digest; the worst demonstrate lack of reading comprehension.

It is interesting to note that the scores cluster tightly for the one-third of the Standards to achieve grades of A or B; they range from 74 to 68, corresponding to 99%-91%. In contrast, the poor performers range widely, from 67 to 21 (89%-28%.) The spread is made evident in Figure 3, which casts a finer net than Figure 2. This clustering of scores suggests again that there is a consensus as to what students should learn (and to some extent, perhaps, how they should learn it) at least among those Standards writers (and the teachers and experts whom they represent) who are in a position to understand what science and science teaching are about.

Figure 3. Scores as Percentages: Fine Net



It is important to note that Standards set a floor, not a ceiling, on what students are expected to learn. This is dramatically evident in the observation that New York students typically win about half of the annual Westinghouse Science Talent Search awards and honorable mentions; more than half of them usually come from two New York City high schools. And yet the New York Standards are very middling in quality,[12] while California, with a very good Framework and twice the population, hardly ever fields a Science Talent Search finalist.

It is the student without special scientific talents and interests that concerns us here, however. Study after study shows the abysmal condition of scientific literacy among Americans, and quality Standards are the first step—if only the first of many—toward ameliorating that condition.

No state lacks the resources in wealth, talent, and experience that are required to write a set of excellent standards. What is more, there are good models available to facilitate the writing. Given the current national interest in assessment, and in the writing of Standards in particular, there is strong motivation to write better Standards as well. It is my hope that, should I revisit my present task a few years hence, I will have better news to report.

Good standards are not a magic solution to the problem of improving science teaching and learning in our schools. In the primary grades, in particular, there is a crying need to improve the science knowledge of the teachers. In our high schools, only a small fraction of all those who teach physics majored in the subject in college. With a few notable exceptions, science textbooks range from mediocrities to execrable, error-filled horrors. Nevertheless, improved standards are essential to progress, and we may hope that this analysis will help to call attention to the areas where improvement is needed.

VIII. ANALYSIS OF INDIVIDUAL STATE STANDARDS

Alabama

STATE REPORT CARD — Alabama

PURPOSE, EXPECTATIONS, AND AUDIENCE	8
ORGANIZATION	6
COVERAGE AND CONTENT	18
QUALITY	10
NEGATIVES	9
RAW SCORE (out of 75)	51
GRADE	D

The introductory section of the *Alabama Course of Study—Science-Scientific Literacy*[13] entitled "Science Literacy: A Vision for Alabama's K-12 Science Education Program," ends, in complete disjunction with the main body, with this formulaic statement: "Explanations of the origin of life and major groups of plants and animals, including humans, shall be treated as theory and not as fact." The writers of the document have done their best to get around that statement, and in general have done well. The main strategy appears to be avoidance of the word "evolution" in the life-science sections (though it is freely used in the earth and space-science sections). In spite of this avoidance, the ideas of evolution that are indispensable to proper teaching of life science are adequately, if gingerly, introduced as early as 2nd grade. There is distortion in such constructs as "analyze the development of Charles Darwin's theory of evolution,"[14] as though Darwin brought evolution forth fully armed and complete, as Zeus did Athena.

Through grade 8, the standards are set forth grade-by-grade.

The kindergarten program is clear and ambitious. It explicitly notes the need for children at this level to experience real objects, not models or pictures. It expects them to begin graphing information and to observe a wide variety of natural phenomena.

At 3rd-grade level, students are expected to apply probability and fractions, as well as graphing and computation, to scientific problems. They are introduced to the crucial idea that the motion of an object is connected to the presence of unbalanced forces. This idea is expanded steadily, culminating in the grade 9-12 standards: "Describe mathematically the relationships among potential energy, kinetic energy, and work";[15] and "Apply the quantitative relationships among force, distance, work, time, and power."[16]

In general, the intellectual capacities and strengths of children at various stages of development are well expressed in the introductory passages for each grade-level cluster, and are consistently implemented in the materials themselves.

A few examples are not well chosen. The melting of ice cream is used to exemplify a reversible process,[17] but in fact it is not reversible. Telescopes are said to magnify astronomical objects,[18] which is not true for stars and other distant objects. Eighth-graders learn that "heat energy as infrared energy from deep space provides clues to the beginning of the Universe";[19] microwave radiation is the key. The 6th-grade items concerning electricity do not belong to the Energy strand, and it doesn't make much sense to "relate energy and force to work."[20]

Alaska

The three-page *Alaska Content Standards*[21] seem fine as far as they go, but are too brief to evaluate.

Arizona

The rationale for the *Arizona Academic Standards*[22] is clearly presented. In spite of their brevity (31 pages), the science standards are outstanding in their careful definitions and expositions. In particular, there is a fine treatment of energy. Consider the following:

Grades 1–3:	Demonstrate that light, heat, motion, magnetism, and sound can cause changes.[23]
Grades 4–5:	Define energy.[24]
Grades 6–8:	Define the law of conservation of energy.[25]
Grades 9–12:	Identify, measure, calculate, and analyze qualitative and quantitative relationships associated with energy forms and energy transfer or transformation . . . [26]

Newton's laws are explicitly introduced at the grade 6-8 level,[27] an ambitious and laudable initiative. However, the *Standards* could be a little more extensive on planetary science.

Although the word "evolution" seems to be consciously avoided, at least in part on account of political pressure brought by a Board of Education member and her organization, understanding of the process is clearly required and the requirements clearly described. Evolution is not explicitly presented as the organizing principle of the life sciences, but it is interwoven fairly well through much (though not all) of the material.

STATE REPORT CARD

Arizona

PURPOSE, EXPECTATIONS, AND AUDIENCE	10
ORGANIZATION	9
COVERAGE AND CONTENT	25
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	71
GRADE	A

Arkansas

The *Arkansas Science Curriculum Framework*[28] is a minimal document, about 10 pages long. On the level of generalities, it contains some admirable statements:

> Communicate successfully with others about investigations and their explanations.[29]
>
> Understand that the laws of science are universal. Understand that scientific thought is non-dogmatic. Understand that a scientific theory is based on testable evidence that is open to falsification and can be used to predict future events.[30]
>
> Recognize that discrepancies between theory and observation are the result of either inadequate theory or inaccurate observations. Perform error analysis on collected data. Evaluate the historical developments of, and multi-cultural contributions to, the scientific body of knowledge (nature of light, expanding universe, plate tectonics, quantum physics, periodic table, evolution).[31]
>
> Understand that mathematics is the precise language of communication and problem solving in science.[32]

Laudable as these statements are, it is hard to see how they might form a basis for assessment. If the standards were strong on specifics, the generalities might serve a useful purpose in binding ideas together. Unfortunately, the document is weak when it comes to specifics. For example, grade K-4 students are to "explore the relationships between mass/weight, force, and motion,"[33] and "experiment with static and current electricity."[34] But what do these statements mean at the K-4 level? There is similar vagueness throughout.

In following the vogue of assigning broad themes to science, the *Framework* gives the impression that there is only one possible set of themes.[35] The choice of themes is, moreover, idiosyncratic.

Some of the standards don't make sense. What is one to make of the following: "Explain the relationship among mole, chemical bonding, and molecular geometry within chemical compounds"; or "Understand that energy always flows from areas of high energy to areas of low energy (entropy)"?[36]

Biological evolution is treated gingerly, in "Who? Me?" terms, as if the writers didn't quite know how to cope with *Epperson v. Arkansas*. The only two references to it are "describe how biologists might trace possible evolutionary relationships among present and past life forms," and "evaluate scientific theory concerning the origin and subsequent development of living things."[37] In contrast, there is straightforward treatment of geological evolution[38] and cosmology, and even mention of the HR (Hertzsprung-Russell) diagram.[39]

STATE REPORT CARD

Arkansas

PURPOSE, EXPECTATIONS, AND AUDIENCE	6
ORGANIZATION	6
COVERAGE AND CONTENT	17
QUALITY	8
NEGATIVES	9
RAW SCORE (out of 75)	46
GRADE	F

California[40]

The California *Science Framework*[41] is unusual in that the standards are presented in the form of short essays rather than as lists of topics. The approach gives weight to the important concept that the sciences are tightly integrated bodies of knowledge, and not mere lists of things that the student is expected to know. It also gives strong suggestion, by example, as to how a textbook might be constructed. The fundamental organizing principles of all the sciences are explicitly discussed, and the *Framework* is built around them. Unlike lists, these essays cannot be turned into assessment instruments by simple rephrasing. Nevertheless, in the hands of skilled persons they are a firm foundation for writing such instruments. A commission is currently at work developing a set of standards for assessment, based on the *Framework*.

STATE REPORT CARD

California

PURPOSE, EXPECTATIONS, AND AUDIENCE	10
ORGANIZATION	9
COVERAGE AND CONTENT	26
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	72
GRADE	A

Colorado

In a laudable attempt to subsume the science standards under six main headings, the *Colorado Model Content Standards for Science*[42] express those headings in somewhat awkward and unclear terms. Of greatest concern are Standards 2 and 3:

> 2. Physical Science: Students know and understand common properties, forms, and changes in matter and energy.
>
> 3. Life Science: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment.

Too many different things are forced into the Procrustean bed of a single sentence—moreover, a sentence that is required to begin, "Students know and understand. . . ." The standards would be clearer and more useful if they were expressed with primary attention to content rather than form.

The Colorado Standards are typical of too many in their cavalier handling of the concept of energy. The term is used without definition, and sometimes misused, as in "[grade K-4 students can] compar[e] quantities associated with energy movement. . . ."[43] In the same section, a hodgepodge of terms is incorrectly lumped together as forms of energy: "for example, changes in temperature, velocity, potential energy, kinetic energy, conduction, convection, radiation, voltage, current." The following standard is even worse, setting up a concept and then inadvertently undermining it. The section begins, "Students understand that interactions can produce changes in a system, although the total quantities of matter and energy remain unchanged." A little later, this is exemplified for grade 9-12 students as follows: "[Students can identify, describe, and explain] physical and chemical changes involving the conservation of matter and energy (for example, oscillating pendulum/spring, chemical reactions, nuclear reactions." But matter conservation is irrelevant in the first example, is tautological in the second, and is false in the third. Nuclear reactions conserve neither mass nor energy separately, but do conserve relativistic mass-energy.

On the other hand, there is a good treatment of the distinction between static and dynamic equilibrium.[44] Evolution is treated thoroughly in the life sciences. Cosmological and stellar evolution, plate tectonics, and other nonbiological evolutionary processes are also given prominent mention. The concept of the model and the relation between the model and the system it represents are extensively discussed.

STATE REPORT CARD

Colorado

PURPOSE, EXPECTATIONS, AND AUDIENCE	8
ORGANIZATION	9
COVERAGE AND CONTENT	18
QUALITY	12
NEGATIVES	12
RAW SCORE (out of 75)	59
GRADE	D

Connecticut

The Connecticut Standards[45] are currently in the second-draft stage, and the following remarks can only be tentative. High-school biology, chemistry, and physics courses are not included.

While the document is brief, it is easy to read, correct as to facts, and clear in its expectations of students.

I found one serious slip that I hope will be corrected in later drafts. Like many states, Connecticut draws heavily on two publications from the American Association for the Advancement of Science and one from the National Science Teachers Association (see note 1), quoting and paraphrasing in many cases. But whereas Indiana gets the following quotation right: "Scientists' explanations about what happens in the world come partly from what they observe, partly from what they *think* [emphasis added],"[46] the Connecticut Standards read, "[Students will] recognize that scientists' explanations about what happens in the world come partly from what they observe and partly from what they *believe* [emphasis added]."[47] "Belief" is a word scientists treat with great care and use very little in the context of science; science is based on evidence and not belief.

There are a few other errors. Typical is this one: "[Students will] understand that telescopes magnify the appearance of the moon, the planets, and the stars."[48] In fact, stars are not magnified by telescopes; rather, their images are rendered brighter by the greater light-gathering power of the instrument.

Evolution is properly treated as the organizing principle of the life sciences, and it is possible to perceive biological evolution as a part of the overall history of the universe, the solar system, and the earth. For example,

- [Students will] explain how evolutionary relationships among organisms can be inferred from DNA and protein sequences [grades 9-12]

- . . . know that many thousands of layers of sedimentary rock provide evidence for the history of the Earth and its changing life forms [grades 5-8]

Although the Connecticut Standards are of the list type, the tight organization makes the structure of the sciences reasonably clear by implication.

STATE REPORT CARD

Connecticut

PURPOSE, EXPECTATIONS, AND AUDIENCE	11
ORGANIZATION	9
COVERAGE AND CONTENT	23
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	70
GRADE	B

Delaware

The Delaware Standards[49] begin with a well-chosen set of eight standards, each described succinctly but clearly in a one-paragraph essay. Standard Four, *Earth in Space*, gives more prominence to extra-solar-system astronomy than most standards, at least at the grade 9-12 level. However, still more emphasis, beginning at lower grade levels, would be even better.

The standards are neither a list of items nor a detailed essay, but a sort of compromise consisting of descriptions of what is to be learned that are shorter than essays but longer than simple list items. Almost all are accompanied by sample activities. Here are three examples:

- Technology applies knowledge to solve problems and to change the world to suit us better. Technological innovation plays an important role in improving the quality of life. Such innovation involves scientific disciplines as well as other disciplines such as engineering, mathematics, medicine, and economics in order to create practical, cost effective solutions to problems and opportunities. Compare present day technologies (methods and equipment to perform a specific function) to those of the past such as washing machine/washboard, refrigerator/ice box . . . or compare technologies used in this country to those used in other parts of the world (e.g., heavy equipment/elephants, electric stove/cooking over a fire). Discuss the impact these technological differences have had on the quality of life.[50]
- Mechanical energy comes from the motion and/or the position of physical objects. The work done on an object depends on the applied force and on the distance that the object moves. Observe and describe changes in kinetic and potential energy in common activities such as bouncing a ball or swinging on a swing.[51]
- Evolution does not proceed at the same rate in all organisms, nor does it progress in some set direction. Some organisms have remained relatively unchanged for millions of years while others have died out altogether. In addition, some complex organisms have evolved from simple unspecialized forms of life (e.g., green algae to vascular plants), while other species are the result of complex life forms evolving to simple forms (e.g., winged birds to flightless birds). Environmental changes have a strong influence on this whole process. Use specimens, models and illustrations (e.g., vertebrate brain comparisons, fossils, and modern horse anatomy) to develop an understanding of evolutionary change.[52]

The completeness of these short statements, together with their well-organized order, makes it easy to discern the underlying theoretical structure, even though that structure is not set forth in an extended discourse.

The statements are almost always scientifically accurate. A very few slips have crept in. For example, "Momentum allows objects to remain in motion after the applied force is removed."[53] Rather, in the absence of an applied force the momentum remains unchanged. The statement as it stands is a conflation of Newton's first and second laws.

STATE REPORT CARD

Delaware

PURPOSE, EXPECTATIONS, AND AUDIENCE	11
ORGANIZATION	9
COVERAGE AND CONTENT	22
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	69
GRADE	B

Florida

The *Sunshine State Standards*[54] is seriously flawed by a flood of pious dicta couched in jargonistic phrases and meaningless sequences. Consider the following from the introduction:

> All over this country, educators, citizens, and political and business leaders are working toward education reform. An increasingly service-oriented, information-based society that is virtually exploding with expanding knowledge demands that everyone have the opportunity to acquire the necessary skills to succeed in the information age.

Chapter 1 is titled "Visioning," and the first section of Chapter 3 has the remarkable title, "Why is Content Important?"

Sometimes the language is impenetrable. For example, "Through a variety of methods, the need for protection of the natural systems of the Earth is expected"[55] ; or "Although our planet is quite insignificant when viewed as part of the universe, we know its relevance in time and space."[56]; or "Learning emerges from context and connectedness."[57]

There are some serious errors. "[Atoms consist] of a massive nucleus of protons, neutrons, and electrons. . . ."[58] [There are no electrons in the nucleus; they surround the nucleus and

STATE REPORT CARD

Florida

PURPOSE, EXPECTATIONS, AND AUDIENCE	3
ORGANIZATION	6
COVERAGE AND CONTENT	14
QUALITY	7
NEGATIVES	11
RAW SCORE (out of 75)	41
GRADE	F

comprise most of the volume (though very little of the mass) of the atom.] "The nature of science and the nature of inquiry are synonymous."[59] (Whatever meaning is intended, it is not true that all valid inquiry is scientific.) ". . . [E]vidence suggests that the universe contains all of the matter and energy that ever existed."[60] (This is not a matter of evidence but of definition.) "The student knows that as electrical charges oscillate, they create time-varying electric and magnetic fields that propagate away from the source as an electromagnetic wave."[61] (Fine, but the accompanying Sample Performance Description says, "With other students in a small group, [the student] builds an electromagnetic generator. . . ." This conflates electromagnetic radiation with Faradayan electromotive force—a serious error involving basic misunderstanding of the relevant physics.)

The eight major strands are subdivided into 17 standards. Unfortunately, some of the latter are poorly chosen or poorly expressed. For example, under the strand "Energy," the first of two standards is "The student recognizes that energy may be changed in form with varying efficiency."[62] What is presumably meant is that practical energy conversion, particularly in heat engines, is imperfectly efficient in the sense that not all the heat generated can be converted into mechanical energy. But while that is an important engineering and practical concern, it is not an issue of such central scientific importance as to warrant its place as only one of two standards involving energy. Under the strand "Force and Motion," the two standards are not really separate but say the same thing a bit differently. And under "The Nature of Science," the reader finds, "The student understands that most natural events occur in comprehensible, consistent patterns." Does this imply that we understand most natural phenomena, including those we have not yet discovered? Or does it imply the existence of incomprehensible miracles? Or that the Universe has incomprehensible or inconsistent parts? The reader deserves better.

Some of the standards are trivial. Under the strand "Earth and Space," one of the two standards is "the student recognizes the vastness of the Universe and the Earth's place in it." The ambiguous antecedent of "it" aside, there are far deeper statements possible for this major standard that go beyond the fact that the Universe is vast. Much better would be something like this: "The student interprets the structure of the Universe at various scales of size and time and understands the evolutionary process that has led to the present configuration."

On occasion, the Sample Performance Descriptions—which are examples of how a student might demonstrate his understanding of a benchmark, or element of knowledge—are irrelevant to the benchmarks. For example, the grade 6-8 student is meant to "know that equal volumes of different substances may have different masses."[63] To demonstrate this knowledge, the student "determines the mass of a solution, a solute, and a solvent before and after mixing and mathematically compares the mass of the whole with the mass of the parts." This is a useful activity for demonstrating mass conservation, but it does not show that the densities of substances differ. Moreover, "mathematically compares" is a pretty ponderous way of saying that the student adds two mass measurements and compares their sum with a third measurement.

Sad to say, irrelevant or trivial examples and poorly or erroneously stated ideas are common in this document. I made a count in the first three standards, which concentrate on the physical sciences. In 88 benchmarks and their accompanying Sample Performance Descriptions, there are at least 38 errors, irrelevancies, trivialities, confusing statements, and misstatements.

In various contexts, students are expected to build models or dioramas of systems, write skits or "infomercials," carry out public-service projects, and so on. This is all very well, but it is striking that in no case are students ever expected to write essays.

The word "evolution" is carefully avoided. The issue is skirted and such matters as genetic variation and natural selection are treated lightly; biological evolution is certainly not treated as the central principle of the life sciences.

Georgia

The Georgia Standards[64] specify general science expectations grade-by-grade through 6th grade. Life science is presented in grade 7 and earth science in grade 8. The high school curriculum consists of college-preparatory courses in physical science, biology, chemistry, and physics, and a collection of 11 other elective courses.

The importance of correlating science achievement with reading, writing, and mathematical skills is mentioned, at least in a general way, as early as kindergarten. The concept of kinetic energy is introduced in a simple way in grade 1, and potential energy is introduced in grade 3:

> [The student] defines movement as evidence of energy. . . . Recognizes examples of the energy of motion using simple objects, such as balls, toy cars, roller skates, bicycles.[65]

> Identifies and demonstrates examples of energy as potential (such as objects with ability to cause change due to position) or kinetic (such as objects in motion).[66]

The distinction between temperature and heat is made explicit in grade 4. Important evolutionary ideas are introduced in grades 3 and 6[67] (though not the word itself.) Written laboratory reports are required beginning at grade 9.

The grade 9 Physical Science document has an unusually complete discussion of organic chemistry, and the student is expected to distinguish between weight and mass, and to define weightlessness.

Like many Southern states, Georgia has problems with the politics, if not the science, of evolution. In the biology course, the euphemism "organic variation" is used for evolution, yielding such delectable bits as the following:

> [The learner will] describe historical and current theories of organic variation . . . describe how current geological evidences [*sic*] support current theories of organic variation . . . explain that a successful change in a species [*sic*] is most apt to occur when a niche is available.[68]

In the same spirit, the theory of evolution is called "Darwin's theories," as if no one else ever had anything to do with the theory:

> [The learner will] explain the development of Darwin's theories . . . recognize the impact of Darwin's theories on accepted views of change in species through time.[69]

The purpose of this approach, of course, is to insulate the study of science from the inroads of politics. But for all its good intent, it makes it difficult or impossible for all but the most gifted students to understand the profound importance of evolution as the basis of the biological sciences. It also isolates biology from the other historical sciences, geology and astronomy, and thus wounds the student's understanding of the unity of the sciences. The total absence of evolutionary concepts from the Microbiology course, which concentrates on pathogens, makes it impossible to convey an appreciation of the origins of the diseases that from time to time appear as if from nowhere—typhus, AIDS, and the annual strains of influenza. It is impossible, likewise, to make clear in the Ecology course the fundamental fact that an ecosystem bears to space the same relationship that an evolutionary sequence bears to time.

As usual, there seem to be no similar problems in setting forth the Geology curriculum; a few odd cosmological statements do crop up in the Astronomy course.

The college-preparatory Chemistry I and Physics curricula are well-organized and cover the standard material at a depth that will make substantial demands on the student.

Very lengthy and detailed, the Georgia document is of the list genre, each item being exemplified by a brief activity description. The list is reasonably well-organized but its terseness is such as to make grasping the structure of the sciences difficult. The lack of more than a sketchy introductory section makes it difficult to read and interpret the document.

Note added in proof: A revision, dated Novemeber 1997, makes brief but explicit mention of evolution at the grade 9–12 level. Uniformitarianism gets brief mention at the grade 8 level. The depth of treatment is, however, still far from satisfactory. [See http://admin.doe.k12.ga.us/gadoe/qcc.nsf]

STATE REPORT CARD

Georgia

PURPOSE, EXPECTATIONS, AND AUDIENCE	7
ORGANIZATION	5
COVERAGE AND CONTENT	16
QUALITY	11
NEGATIVES	11
RAW SCORE (out of 75)	50
GRADE	D

Hawaii

There are two documents, entitled "Essential Content" and "Performance Standards."[70] While the precise relationship between them is not explicit in the materials available to me, it appears that the former is a brief catalogue of items that students should know while the latter is a more detailed list of both content standards and associated performance standards.

Both documents suffer from the limitations of lists; although they give a detailed account of what elements of knowledge are to be learned, they do not lend themselves to emphasizing the connectedness that is so essential to science. List entries under such categories as "Habits of Mind" are intended to express the importance of this connectedness, and succeed to some extent. Furthermore, the writers of the Hawaii documents clearly knew what they were writing about, and their understanding of the connectedness of scientific knowledge is reflected in the organization of the items.

Some of the items concerning general scientific methodology are exceptionally well thought out; among these are the following:[71]

> Demonstrate honesty by reporting and considering all observations even when these contradict [the students'] ideas.
>
> Demonstrate the value of skepticism by asking many questions and looking for evidence to support or contradict explanations.
>
> Demonstrate tolerance for ambiguity by recognizing that data are seldom compelling and scientific information does not always prove something.
>
> Demonstrate an understanding that technological issues are rarely simple and one-sided.
>
> Demonstrate an understanding that, at present, all fuels have advantages and disadvantages so that society must consider trade-offs among them.
>
> Judge theories by how well they mesh with other theories, how [wide] a range of observations they explain, how well they explain observations, and how effective they are in predicting new findings.

But how the student is to "demonstrate" these achievements is an unanswered question. A supplementary set of assessment criteria is much to be desired.

There are a few goofs. The theory of (biological) evolution is to be applied to the origin of life on earth.[72] In fact, the purpose of this theory is to explain the processes by which life proliferated subsequent to its origin. And I could not make sense of this: "Demonstrate an understanding that an object in motion can only be described in relation to a reference point of another object (i.e., objects near the earth will fall to the ground unless they are held up by something)."[73] Nor could I agree that electricity and light are forms of energy that humans use but other living things do not.[74]

Important scientific ideas are introduced early, but at appropriate depth. For example, graphing of linear motion and the connection between motion and unbalanced force (an entree to Newton's second law) are introduced for the first time at grades 4-6, and subsequently explored in greater depth. The grade 4-6 student is expected to "demonstrate that a magnetic field surrounds an electric current and may pass through non-magnetic material."[75] The intimate connection between geology and biology is likewise introduced at this level: "Demonstrate the use [of] the stratification of rocks as a record of changes to show the evolution of living and non-living things over time."[76] At grades 7-8 there is this explicit item: "Demonstrate an understanding that there are no fixed steps called 'the scientific method' for conducting a scientific investigation."[77]

The importance of communication is explicitly recognized, if rather vaguely set forth. Students in grades 7-8 are expected to "analyze, evaluate, and discuss findings with clarity in oral, written, or graphic format."[78] This is fine as far as it goes, but students will be more likely to carry out these desirable activities if the expectation is much more detailed.

STATE REPORT CARD

Hawaii

PURPOSE, EXPECTATIONS, AND AUDIENCE	12
ORGANIZATION	9
COVERAGE AND CONTENT	24
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	72
GRADE	A

Idaho

The *Idaho Science Framework*[79] is organized grade-by-grade through grade 8; a brief, rather general section serves to cover the various areas studied in grades 9-12. As a result, it is quite articulate on generalities, as these examples show:

- All students will understand the empirical nature of science as one method of knowing about the universe. Science questions all things, rejects the labeling of statements as unalterable, and opens itself to continual scrutiny and modification.[80]

- Mathematical skills and reasoning are especially important in developing . . . habits of the mind in science.[81]

In exemplifying achievement of these goals, the *Framework* draws upon all the sciences for vignettes. But the intent is to leave most decisions as to actual subject matter coverage to localities. Thus, there is no attempt to develop a systematic approach to any particular body of scientific knowledge. Though the Idaho *Framework* is well-written in its way, it is not comparable to the great majority of documents reviewed here, and cannot be evaluated according to the same criteria.

Illinois

The *Illinois Learning Standards*[82] includes, as one of its three major goals, the following: "Understanding the fundamental concepts, principles, and interconnections of the life, physical and earth/space sciences." This explicit recognition of the structured nature of the sciences is laudable. The individual items in the standard are terse but complete, and the corresponding expectations that students are to meet are well-chosen, as are the examples that illustrate them. Most of the expectations are age-appropriate; the only exception I found was one which (perhaps over-ambitiously) expects early-high school students to "explain and predict motions in inertial and accelerated frames of reference."[83] At 10 pages long (plus about five pages of general introductory material covering all subjects), the science Standards is about as short as such a document might be. Within this limit, it appears to be satisfactory.

STATE REPORT CARD

Illinois

PURPOSE, EXPECTATIONS, AND AUDIENCE	10
ORGANIZATION	9
COVERAGE AND CONTENT	22
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	68
GRADE	B

Indiana

The *Indiana Science Proficiency Guide*[84] is carefully organized and thorough in its coverage of science learning from kindergarten through high school. Although mathematics is not a principal subject, the importance of mathematics to science is made clear throughout by a strand called "The Mathematical World" which elegantly states many of the salient aspects of mathematics and statistics, especially in their relation to science. The importance of communication in various modes is made clear. For instance, the middle-school student is expected to "organize information in simple tables and graphs . . . read simple tables and graphs produced by others and describe in words what they show . . . understand writing that incorporates circle charts, bar and line graphs, two-way data tables, diagrams, and symbols."[85]

The ethical and social aspects of science are handled in an especially lucid way. The first three of the following excerpts are intended for middle-junior high students; the fourth for high school students:

- Some matters cannot be examined usefully in a scientific way. Among them are matters that by their nature cannot be tested objectively and those that are essentially matters of morality. Science can sometimes be used to inform ethical decisions by identifying the likely consequences of particular actions, but cannot be used to establish that some action is either moral or immoral.[86]

- Until recently, women and racial minorities, because of restrictions on their education and employment opportunities, were essentially left out of much of the formal work of the science establishment; the remarkable few who overcame these obstacles were likely even then to have their work disregarded by the science establishment.[87]

- Rarely are technology issues simple and one-sided. Relevant facts alone, even when known and available, usually do not settle matters entirely in favor of one side or another. That is because the contending groups may have different values and priorities. They may stand to gain or lose in different degrees, or may make very different predictions about what the future consequences of the proposed action will be.[88]

- By the 20th century, most scientists had accepted Darwin's basic idea. Today that still holds true, although differences exist concerning the details of the process and how rapidly evolution of species takes place. People usually do not reject evolution for scientific reasons but because they dislike its implications, such as the relation of human beings to other animals, or because they prefer a biblical account of creation.[89]

The *Indiana Science Proficiency Guide* treats such touchy subjects as evolution (including human evolution), reproductive and mental health, ethics, and environmental issues in a forthright, accurate, and dispassionate manner. More generally, the *Guide* is a model of clarity, accuracy, and completeness. A student who fulfills the requirements set forth will have received an excellent education.

A companion document to the *Science Proficiency Guide*, entitled *Indiana High School Science Competencies,*[90] sets forth standards for the traditional college-preparatory courses in biology, chemistry, earth/space science, and physics. This document is explicitly aimed at setting forth expected competencies rather than the curricula intended to achieve these competencies, and is intended to furnish a basis for assessment. Its purpose, however, is not identical with that of the *Science Proficiency Guide;* it aims much more at specific skills and, while it achieves its stated purpose, we do not review it here.

STATE REPORT CARD

Indiana

PURPOSE, EXPECTATIONS, AND AUDIENCE	12
ORGANIZATION	9
COVERAGE AND CONTENT	26
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	74
GRADE	A

Kansas

The *Kansas Curriculum Standards*[91] for Science places much emphasis on the importance of effective communication. In an introductory passage, written, mathematical, oral, and data-retrieval skills are stressed, as are skills related to working effectively with others. These general considerations are made specific, for example, in such standards as this one for grade 9-12 students:[92]

> Communicates a high level of scientific understanding using oral language, written language, mathematics, statistics, symbols, tables, graphs and technology.

Most of the standards are accompanied by examples of how a student might demonstrate achievement of the standard. In general, the examples are well-chosen and clear. There are some exceptions. Here is a glaring one for grades 6-8, in which the effort to be exhaustive appears to have pushed the writers into several kinds of error:

> [The student] communicates scientific understandings using oral language, written language, mathematics, symbols, tables, graphs, visual aids, and/or technology.
> (Example: Verbal [the writers mean *oral*]—explains why increasing the number of light bulbs in a series circuit decreases the current flowing through them; written—in a journal, writes a paragraph summarizing thoughts about the word "greenhouse" and its relationship to climate; technological—creates a hypercard stack of five cards using graphics to illustrate how electrical circuits work; using a pH probe and a computer, determines the pH of substances such as household ammonia, vinegar, tap water, dissolved Alka-Seltzer, and lemon juice; makes a chart of the results; symbolic—writes a formula relating "B" to "h" where "B" = height a ball bounces and "h" = height from which the ball drops.)[93]

The examples begin well enough; a good explanation of the light-bulb effect will reveal understanding of series circuits. But the journal assignment, which asks for a one-paragraph "thought" on greenhouses, would do far better to require an essay on the function of glass in a greenhouse and the analogous function of such greenhouse gases as CO_2 in the earth's atmosphere. "Creating a hypercard stack of [exactly?] five cards using graphics" may demonstrate the student's knowledge of computer skills and his artistic talent, but I cannot imagine how he could cover the entire subject of "how electrical circuits work." The act of pH determination will doubtless demonstrate the student's ability to use an instrument, but will he understand at this grade level what pH—the negative of the base-10 logarithm of the hydrogen ion concentration—implies? I doubt it. And finally, deriving the formula for the bouncing ball—the definition of what physicists call the coefficient of restitution—is well beyond the capabilities of the middle school student.

In spite of these occasional lapses, the Kansas *Standards* is for the most part clear, well organized, and to the point.

STATE REPORT CARD: Kansas

PURPOSE, EXPECTATIONS, AND AUDIENCE	9
ORGANIZATION	8
COVERAGE AND CONTENT	19
QUALITY	13
NEGATIVES	12
RAW SCORE (out of 75)	61
GRADE	C

Kentucky

The Kentucky *Core Content for Science Assessment* document is marred by a well-intentioned but not very successful attempt to fit the sciences into an interdisciplinary relationship with other areas of knowledge, as outlined in a companion document.[94] The result is a dense laundry list of items that students are expected to know, surrounded by jargon that obscures the internal structure of science itself. Theory is slighted, and definitions of important terms are nearly absent. Such projects as "communicate scientific discoveries by creating an original product or performance using music, visual arts, drama or dance," or "listen to Holtz's [*sic*] The Planets [and] compare the scientific and musical elements, create movement sequences illustrating the musical or scientific ideas," are not likely to do much to deepen the student's insight into science, the arts and humanities, or the connections between them.

Evolution is skirted and euphemized under such titles as "Change." No student following these guidelines will receive much help in integrating his understanding of the life sciences under their main organizing principle.

Both documents also contain far too many typographical errors.

STATE REPORT CARD: Kentucky

PURPOSE, EXPECTATIONS, AND AUDIENCE	4
ORGANIZATION	4
COVERAGE AND CONTENT	10
QUALITY	7
NEGATIVES	11
RAW SCORE (out of 75)	36
GRADE	F

Louisiana

The *Louisiana Science Framework*[95] is a carefully organized document. It begins with a brief discussion of general educational concerns, and continues with a brief but fine section entitled "Nature of Science," which discusses the nature of scientific theory and the methods of science in a particularly lucid way.

The main body of the *Framework* is a 35-page list of benchmarks by which student achievement of the standards can be assessed. The list is carefully drawn, complete, and grade-appropriate.

The *Framework* is slightly marred by the incursion of cliché and jargon, mainly in the introductory section. The Glossary at the end unfortunately contains some silliness: "benchmark: specify what students should know and be able to do"; "understanding: Power to understand. . . ." On the positive side, the definition of energy is correct if a bit overbroad.

Biological evolution is discussed explicitly and appropriately, especially in the upper grades. It does not, however, take its proper place as the central organizing principle of the life sciences. The evolution of the universe, the solar system, and the earth are well set forth.

All in all, a carefully written and useful document.

STATE REPORT CARD

Louisiana

PURPOSE, EXPECTATIONS, AND AUDIENCE	11
ORGANIZATION	9
COVERAGE AND CONTENT	23
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	70
GRADE	B

Maine

Maine's very long *Curriculum Framework for Mathematics and Science*[96] contains two sections relevant to the present study. Section I is an 11-page introduction. Section II, Curriculum Standards, is 91 pages long, but most of it is concerned with extensive statements of principles. The matter of main interest here—content—comprises 17 pages.

Maine takes the mixed essay/list approach of prefacing each list of content standards with a short integrative essay. It is relatively easy to follow structural strands through the standards, which are well-organized and suited to their grade levels. This is especially true of the life-science standards. However, the content standards are not very specific, especially in physics.

There are some weaknesses. Energy is never properly defined, though it appears as a main theme. Some of the standards are much too vague to be useful. For example,

- Compare and contrast historical and quantum physical models of the atom.[97]
- Understand factors that affect chemical reactions.[98]

There is a very fine standards document hidden in here, crying to get out. What is needed, given the generally good overall organization, is much more attention to details.

STATE REPORT CARD

Maine

PURPOSE, EXPECTATIONS, AND AUDIENCE	10
ORGANIZATION	8
COVERAGE AND CONTENT	14
QUALITY	13
NEGATIVES	12
RAW SCORE (out of 75)	57
GRADE	D

Massachusetts

The *Massachusetts Science & Technology Curriculum Framework*[99] has an unusually detailed Learning Standard concerning the development of the modes of student learning over the grades. Unfortunately, some of the subject-specific material is garbled. In the following quotations from the *Framework*, the italicized passages are examples of how the student might demonstrate the preceding skill.

> Twelfth graders study . . . the causes of electron movement to produce light . . . and the uses of the electromagnetic spectrum and namometer [*sic*], e.g., red-shift or using lasers to study seismological activity.[100]

> Demonstrate that things that give off light may also give off heat. *For example, students explore and describe ways in which heat is produced by mechanical and electrical machines, and friction.*[101]

There is some elegant material, as well. The following conceptually excellent example is unfortunately couched in clumsy language:

> Explore and describe that [*sic*] the mass of a closed system is conserved. *For example, if a wet nail is put in a jar and the lid closed, the nail will rust (oxidize) and increase in mass but the total mass in the contents of the jar will not.*[102]

Massachusetts has adopted the view that the sciences should be taught in a unified manner, at least through grade 10. I am inclined to agree with this approach in principle, but it is fraught with difficulties that are apparent in the *Framework*. There is much discussion of the need for interdisciplinary cooperation among teachers of complementary backgrounds, as is of course desirable. Unfortunately, things tend to get fuzzy when the details are addressed. One grade 8-12 school, for example, chose to exploit its coastal location by exploring the sciences from a maritime point of view. The school found that the weather, in particular, furnished a fruitful field of interaction. But one teacher, recording her experiences, seems to have discovered that her new-found skills in using the Internet allowed her to collect large amounts of weather data and to use her knowledge to make weather predictions. All of this is very well, but it does not really address the issue of learning the basic sciences that truly underlie meteorology. One might have wished, for example, that she had spent more time learning about the gas laws, about the adiabatic lapse rate and its effect on precipitation, or about the role of the Coriolis force in creating cyclonic systems. The exercise in data gathering and predicting on the basis of empirical experience is fine as far as it goes, but in the upper grades one wants to see much more probing into basic theory as the students' level of sophistication rises above the pure data-gathering stage.

STATE REPORT CARD

Massachusetts

PURPOSE, EXPECTATIONS, AND AUDIENCE	10
ORGANIZATION	9
COVERAGE AND CONTENT	21
QUALITY	13
NEGATIVES	12
RAW SCORE (out of 75)	65
GRADE	C

Mississippi

The *Mississippi Science Framework*[103] is divided into two major sections. The first lists competencies grade-by-grade through grade 8, with a laudable incrementation of sophistication with increasing age. Each grade lists roughly a dozen competencies, which are expanded upon and exemplified in the second, longer section entitled "Course Outlines."

Unfortunately, the competencies are in the form of a laundry list that fails to suggest either any connectedness among the ideas of science or any theoretical foundation. This chaos is exacerbated by the fact that Mississippi schools offer no fewer than 19 high school-level science courses—eight in the life sciences, seven in the physical sciences, two in environmental sciences, one in geology, and one in aerospace studies.

Many of the courses, moreover, are severely flawed; some are essentially worthless. Chemistry I, Chemistry II, and Organic Chemistry are all offered, but not one mention is made of either mass or energy conservation. The nine life-science courses are innocent of any organizing principles. Not only is evolution never mentioned, but there is hardly a hint as to the basis for the diversity of life or its history. The astronomy course is purely descriptive and devoted mainly to the solar system and the classical constellations; no attempt is made to deal with cosmological, stellar, or even solar-system evolution. The only astronomers mentioned are Ptolemy, Copernicus, Kepler, and Newton, and the only physical laws that warrant even a passing glance are Newton's laws of motion and of universal gravitation. The presentation is essentially eighteenth-century. There is little of the astronomical progress of the nineteenth century, and the only twentieth-century technique even mentioned in passing is radio-astronomy.

The organizing principles of geology are treated only marginally better. The single reference is a timid "Describe the theories *or hypotheses* associated with plate tectonics, continental drift, and earthquakes"[104] [emphasis added]. This is followed by another hint: "Describe the methods and tools used in dating rocks and fossils." Such denigration of the firmly established theory of plate tectonics is unacceptable in teaching science.

STATE REPORT CARD

Mississippi

PURPOSE, EXPECTATIONS, AND AUDIENCE	5
ORGANIZATION	4
COVERAGE AND CONTENT	7
QUALITY	5
NEGATIVES	8
RAW SCORE (out of 75)	29
GRADE	F

Missouri

The Missouri Standards[105] laudably stress the importance of written communication at every level. In the overall "Show-Me Standards," Goal 2.1 states, "Students will demonstrate . . . across all content areas the ability to plan and make written, oral, and visual presentations for a variety of purposes and audiences."[106] This is followed, in the "Communication Arts" standards, by Standard CA1: "Students . . . will acquire . . . knowledge of and proficiency in speaking and writing standard English (including grammar, usage, punctuation, spelling, capitalization)." It would be better, of course, if these principles were elaborated upon in the detailed specifications that follow.

An introductory essay clearly outlines the logical and theoretical framework in which the specific goals of science learning are couched. Though it suffers somewhat from cliché and jargon ("moving into the 21st century," "minds-on, hands-on") it ably sets forth the rationales, methods, and goals of science.

In parallel columns, specifications are given for "What All Students Should Know," "What All Students Should Be Able to Do," and "Sample Learning Activities." The connections among these three are well thought out, and the examples, in particular, are apposite.

Too frequently, however, the document suffers from vagueness and a tendency to skip over things. One quotation will demonstrate both of these weaknesses. In grades 5-8,

> . . . all students should know that various statistical procedures are used to determine characteristics of sets of data as well as to determine the validity of experimental results. Sample learning activity: Use computer software to analyze data from a class experiment using various statistical procedures.[107]

Now, "a class experiment" and "various statistical procedures" are far too vague to be useful. What characteristics must a class experiment have to make it amenable to a statistical procedure? Which one? Are middle-school students in a position to decide which one (or more) is appropriate? Worse, however, is the approach. The people who wrote the computer software doubtless knew a great deal about the theory that underlies the procedures embodied in their software. But the student is put in a position where he knows less than the computer does! This merely adds to the many influences that encourage young people to be dependent on technology they do not understand.

Other Sample Learning Activities are also questionable. How are grade 5-8 students to "design and construct a planetarium," and how will that help them to understand that "the universe is so large that its distances are expressed in special units"? And, granted that students should know that "the force of gravity determines the orbital patterns [*sic*] of celestial objects," how are they to confirm this knowledge if they "use ball bearings with different strengths of magnets to simulate planetary orbit paths"?[108] Anybody who actually tries this is in for a big surprise!

The fundamentals of the physical and life sciences are generally well presented, in spite of the weakness of the sample activities. In the astronomical and geological sections, there could be more stress on the fundamentals.

STATE REPORT CARD

Missouri

PURPOSE, EXPECTATIONS, AND AUDIENCE	9
ORGANIZATION	8
COVERAGE AND CONTENT	21
QUALITY	14
NEGATIVES	12
RAW SCORE (out of 75)	64
GRADE	C

Nebraska

Nebraska has published its mathematics and science frameworks as a single document.[109] A single well-written introduction serves both. For the most part, however, the two areas are considered separately. We concentrate here on the 60-page science section.

Following a brief but cogent introduction which includes an excellent discussion of "Developmentally Appropriate Practices,"[110] the Standards list the usual items in a systematic and reasonably accurate way. A short summary list is followed by expanded treatment in short-essay form. There are a few goofs. For instance, I am at a loss to know how secondary students are to "predict evolutionary cycles."[111] And I do not know what it means to say "without a constant input of energy into a system, entropy occurs."[112] Gregor Mendel is given as an outstanding example of the application of mathematics to science,[113] but in fact his mathematics was very simple and his statistics (as recent studies have shown) consisted largely of fudging results. Sewall Wright, with his critical role in the development of population genetics, would have been a much better example.

There are numerous Lamarckian notions; e.g., "The learner will . . . investigate and communicate how a species adapts to its environment."[114] And how is a student to "create an organism to survive in a given ecological region"?[115]

More generally, energy is mentioned frequently throughout the document, but no attempt is made to define it. And, given the close connection implied in the publication of joint mathematics-science standards, it is disappointing to see how little mathematical or statistical analysis is incorporated into the science standard. An addendum devoted to the matter[116] is unfortunately not very specific. Biological evolution, though mentioned from time to time, is not given its proper place in the study of the life sciences. There is no mention of human evolution at all. Finally, little if any attention is devoted to the importance of communication of scientific ideas in written words and mathematical language.

STATE REPORT CARD

Nebraska

PURPOSE, EXPECTATIONS, AND AUDIENCE	8
ORGANIZATION	7
COVERAGE AND CONTENT	12
QUALITY	12
NEGATIVES	12
RAW SCORE (out of 75)	51
GRADE	D

New Hampshire

New Hampshire's brief (31-page) framework[117] is quite coarse-grained, being divided into levels K-6 and 7-10, in spite of the term "K-12" in its title. The work of grades 10-12 is mentioned only in passing. New Hampshire law provides for the development of assessment instruments at grades 6 and 10, and the framework is intended to aid in the ongoing development of these instruments.[118] Most persons will probably hold the view that this time scale is too coarse to deal with the complexities of the development of children's intellectual strengths. Nevertheless, the New Hampshire standards have some virtues. There are some insightful and useful observations; for example, "Although scientists reject the notion of attaining absolute truth and accept some uncertainty as part of nature, students should understand that most scientific knowledge is valid at any given time."[119]

The tendency of the Standards is to defer most theoretical understanding of the natural world to grades 11-12. For example,

> In middle/junior high school life science, the emphasis should be understanding oneself as a human being. Issues focusing on health, nutrition, environmental management, and human adaptation are appropriate for middle school students. . . . General biology in the high school should emphasize biological knowledge in a social/ecological context. . . . Advanced level courses in high school biology should be taught in the context of a discipline emphasizing its structure, its modes of inquiry, its theoretical underpinnings, and its career opportunities.[120]

Little attempt is made to elaborate on the fundamental principles of the sciences. Students are expected to understand the concepts of energy and entropy,[121] but no attempt is made to define or develop them. Newton's laws of motion are dealt with only by implication.[122] An attempt is made to ameliorate this lack of theoretical foundation in Standard 6 ("Unifying Themes and Concepts") but it is not very satisfactory.

STATE REPORT CARD

New Hampshire

PURPOSE, EXPECTATIONS, AND AUDIENCE	4
ORGANIZATION	2
COVERAGE AND CONTENT	12
QUALITY	7
NEGATIVES	12
RAW SCORE (out of 75)	37
GRADE	F

New Jersey

The science standards comprise a long and very detailed section of the *Core Curriculum Content Standards*.[123] For the purposes of this work, we have concentrated our attention on the following chapters of the document: Chapter 2, Part I: "The Science Standards"; Chapter 7, "Science Process Standards"; and Chapter 8, "The Content Standards."

Much is made of the importance of mathematics as a tool in science, as here:

> From the earliest grades, students should find science and mathematics virtually indistinguishable. Beginning with counting, young students will progress quickly to making simple measurements (introducing them to units), which will lead in turn to collecting and displaying data. In the middle and upper grades, students should consistently be asked to use mathematics to analyze and interpret experimental results, determining relationships among variables, and deriving mathematical expressions that describe physical phenomenon [*sic*]. At the most challenging level, they should begin to appreciate the importance of a mathematical model as a valid representation of an otherwise unobservable entity.[124]

It may go too far to call science and mathematics "indistinguishable," and "unobservable" is not the *mot juste* in the last sentence, but the sentiment is laudable.

Much of the length of Chapter 8, the core of the document, is attributable to extensive descriptions of "Learning Demonstration Activities." For the most part these are well chosen and well described. But there are slips. For example, a fairly standard demonstration of the contagion process is represented as modeling the immune system as well, which it does not.[125] A visit to a pet shop is said to provide "living examples of most vertebrate groups."[126] Whether that is true or not depends, of course, on what is meant by "groups." An activity intended to demonstrate Newton's first law does not really do so.[127]

A particularly well-described learning activity concerns the Big Bang for grades 9-12.[128] Care is taken to discuss some of the essential underlying physics that must be understood before the student can acquire an appreciation for the Big Bang. These include the idea of blackbody radiation, the concept of photons, and the Olbers paradox.

The tight theoretical structure of the sciences is well represented. In particular, evolution is presented at the core of the life sciences; some elementary ideas are introduced explicitly at the earliest grades.

STATE REPORT CARD

New Jersey

PURPOSE, EXPECTATIONS, AND AUDIENCE	12
ORGANIZATION	9
COVERAGE AND CONTENT	23
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	71
GRADE	A

New Mexico

The New Mexico science standards[129] are very brief (19 pages) and consist entirely of tabular material listing standards and the benchmarks to be used in assessing their achievement. In common with the Standards for other areas, they "clearly state that proficiency in English is of the highest importance." The overall Standards for science does, however, provide for "supporting the use of a student's primary or home language, as appropriate, for teaching and learning while the student acquires proficiency in English."[130] We must presume that the acquisition process is described in detail elsewhere. The six principles set forth as the basis for science include two, unfortunately, that suppose the existence of "a special investigative approach called *the* scientific method."[131]

The first seven pages of standards and benchmarks, comprising nearly 40% of the whole, are so abstract as to be empty. Students are, for example, to "demonstrate an understanding of prediction and its uses,"[132] "design and develop models,"[133] and "discriminate between the effects of constancy and change as properties of objects and processes,"[134] but there is not a clue as to the system to which these efforts are to be applied.

Most of the remaining material constitutes a potpourri of bits and pieces of knowledge in the physical, life, and earth/space sciences. The bits and pieces, taken individually, are pretty standard fare; in the absence of any unifying argument they are not very useful. In the final section, "Technology and the History of Science," students are expected to "describe the kinds of problems people have solved through scientific investigations,"[135] "explain how the benefits of science and technology are enjoyed by some groups and not by other groups,"[136] and "model changes in the direction of scientific inquiry based on all modifications of previous scientific research."[137]

In sum, the New Mexico Standards are of very little use.

STATE REPORT CARD

New Mexico

PURPOSE, EXPECTATIONS, AND AUDIENCE	4
ORGANIZATION	5
COVERAGE AND CONTENT	6
QUALITY	4
NEGATIVES	12
RAW SCORE (out of 75)	31
GRADE	F

New York

New York has published a combination *Learning Standards for Mathematics, Science, and Technology*[138]—probably not a bad idea. The three areas are dealt with individually, but in parallel columns where that is appropriate.

Each of the many detailed benchmarks is followed by an example. While the benchmarks are mainly clear and appropriate, far too many of the examples are poorly chosen, as the following sampling suggests:

- As an example of how intermediate students should conduct a proper scientific inquiry—"develop explanations of natural phenomena in a continuing, creative process"—they are expected to study the disparity between the amount of solid waste that is, and the amount that could be, recycled. But disposal of solid waste is not a natural process, and in any case it is mainly a technological, not a scientific problem. More to the point, the disparity between the quantity that is recycled and that which could be recycled is a socioeconomic issue and is not relevant to science in any direct way. A poor example has been chosen for a content-specific item, in a pious attempt to demonstrate "greenness."[139]

- "Knowledge of the impacts and limitations of information systems is essential to its [*sic*] effective and ethical use . . . Students describe the uses of information systems . . . understand that computers are used to store personal information[,] demonstrate ability to evaluate information. This is evident, for example, when students look for differences among species of bugs . . . and classify them according to preferred habitat."[140] Come again?

- "The Earth and celestial phenomena can be described by principles of relative motion and perspective." Whatever this means, it is difficult to see the connection with the example that follows: "Conduct a long-term weather investigation, such as running a weather station or collecting weather data."[141]

- To demonstrate the variety of forms of energy, intermediate students are to "build an electromagnet and investigate the effects of using different types of core materials, varying thicknesses of wire, and different circuit types."[142] This is a fine activity, but has no direct connection with energy. And just what "different circuit types" did the writers have in mind?

- "Individual organisms and species change over time."[143] What does this mean? Does it refer to the change in an organism as it ages or encounters environmental changes? What does it mean to say that a species changes? In the appended example—"investigate the acquired effects of industrialization on tree trunk color and those effects on different insect species"—what is meant by an acquired effect and how is the student to proceed? This attempt to introduce the study of evolutionary processes fails because the writers either did not understand or could not communicate their understanding of those processes.

- Students are expected to explore the role of reproduction and development in the continuity of life by "apply[ing] a model of the genetic code as an analogue of the genetic code in human populations."[144] What is a model of the genetic code and how is it to be applied? How is a teacher to interpret this?

Some examples, especially at the high-school commencement level, are too low-level. For example, the student is expected to explain complex astronomical phenomena by "creat[ing] models, drawings, and demonstrations to explain changes in day length, solar insolation, and the apparent motion of planets," or to "explain the mechanisms and patterns of evolution" by "determin[ing] characteristics of the environment that affect a hypothetical organism and explore how different characteristics of the species give it a selective advantage."[145]

There are some good examples: Students "use the atomic theory of the elements to justify their choice of an element for use as a lighter than air gas for a launch vehicle"; one may presume that by *launch vehicle* is meant a research balloon, not a rocket.

Standard 6—"Interconnectedness: Common Themes"—is very well done. This standard covers such ideas as model building, magnitude and scale, stability, and change. Elementary students are to study the concept of models in terms of toy cars, building-block structures, and road maps. They are introduced to scaling laws by studying the relation between height and shoe size.[147]

STATE REPORT CARD

New York

PURPOSE, EXPECTATIONS, AND AUDIENCE	8
ORGANIZATION	6
COVERAGE AND CONTENT	16
QUALITY	9
NEGATIVES	12
ADDITIONAL FACTORS	9
RAW SCORE (out of 75)	60
GRADE	C

A section entitled "Samples of Student Work" is intended to exemplify the output of students at various levels and various proficiencies as they progress toward meeting the standard. The section is apparently in an early stage, and will doubtless be refined. At present, it is a good start toward a laudable goal. Likewise, a draft "Curriculum Resource Guide" is an excellent beginning toward providing conceptual and exemplary materials intended to guide students toward meeting the raised expectations specified by the Regents.

Overall, the New York document is a curious mixture of generally well-written standards and poorly chosen, often confusing, erroneous, or irrelevant examples. It is as though two different groups wrote the document. The C grade assigned represents a compromise between the good and the bad.

North Dakota

The "North Dakota Science Framework"[148] consists almost entirely of a list of empty generalities; e.g., "The student demonstrates the ability to . . . generate questions about the world based on observation[149] . . . recognize[s] that science can provide enjoyment as a leisure activity[150] . . . recognize[s] what constitutes data."[151] Even when content is touched upon, it is in the vaguest manner: "The student demonstrates the ability to . . . identify the phases of matter[152] . . . compare[s] and contrast[s] cause and effect relationships in physical, biological, and chemical systems."[153] A companion document, the *Elementary Science Curriculum Guide, K-6*,[154] provides a little more specificity. It contains 20 pages of lists of such items for the teacher as "investigate rocks," "demonstrate that air can support objects," "discuss why animals are important," "investigate microscopic objects," and "recognize the difference between mass and weight." In my view, the documents are essentially useless. In an attempt to search for more specific material, I obtained several teachers' guides.[155] Although these contain some more specific information, they are curriculum guides and lab/demonstration manuals rather than standards.

STATE REPORT CARD

North Dakota

PURPOSE, EXPECTATIONS, AND AUDIENCE	1
ORGANIZATION	3
COVERAGE AND CONTENT	5
QUALITY	0
NEGATIVES	12
RAW SCORE (out of 75)	21
GRADE	F

Oregon

The Oregon science standards are currently under development. This discussion is based on two draft documents[156] and should be regarded as tentative. The standards will be reviewed and updated every two years; then next revision is supposed to be available for the 1998-99 school year. At present, the grade 6, 8, and 10 benchmarks are in a reasonably complete if tentative state; relatively little work has been done on the grades 3 and 12 benchmarks.

Oregon's goal is to test every student at the end of grades 3, 5, 8, and 10. Science tests will be administered at the ends of grades 5, 8, and 10 beginning in the 1998–99 school year. By 2002–03, students achieving the 10th grade standards will be awarded a Certificate of Initial Mastery (CIM); by 2004–05, students achieving the 12th grade standards will be awarded a Certificate of Advanced Mastery (CAM). These programs are under active development in selected schools. Associated with these certificate programs are a Proficiency-Based Admission Standards System (PASS) based on admission standards for four-year public colleges, to be in place by 2001, and a diagnostic tool called Proficiencies for Entry into Programs (PREP) intended to predict the likelihood of success in a two-year institution, projected for 1999.

The standards and benchmarks are generally well-organized. Mathematics is well-integrated into the benchmarks at appropriate places. The importance of written communication receives considerably less attention. One might wish for a more complete treatment of extra-solar-system astronomy, and for assignment of a more central role to evolution in the life sciences.

Because the standards are strongly goal-oriented, they tend to revolve about items which may appear on tests. For all its advantages, this tends to short-change the broad organizational principles so important to the sciences. Nevertheless, one may infer from the systematic lists that the writers knew what they were talking about. It would be well to provide more guidance on organizational principles to the classroom teacher.

STATE REPORT CARD

Oregon

PURPOSE, EXPECTATIONS, AND AUDIENCE	11
ORGANIZATION	8
COVERAGE AND CONTENT	21
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	67
GRADE	C

Rhode Island

The *Rhode Island Science Framework*[157] is an ambitious document, more than 300 pages long. Drawing explicitly on the benchmarks of *Project 2061*, the *Framework* elaborates on assessment, themes, and processes. Some of the elaborations are interesting and unique:

- Describe in an essay how life would be different in the 1990s in Rhode Island without Route 95.[158]
- What would happen if you dropped a ball in Australia? Dropped it while flying in an airplane?[159]
- Compare the astrological signs of the students with the actual constellations in the sky at the time of their birth. Have students keep a journal of daily horoscopes which they compare, ex post facto . . . with actual events. Have them draw conclusions after a month of such data collection.[160]

There are some errors. Students are to perform flame tests as a technique of elemental analysis, and are then assessed as to their ability; for example, "Given a star's color and suitable reference materials . . . identify the likely predominant elements."[161] However, the overall color of stars is accounted for by their temperature and not their chemical composition; they are primarily blackbody radiators.

Students are expected to acquire a substantial degree of knowledge of such important matters as DNA sequences and the amino acids for which they code, cell differentiation, and the selectivity of cell membranes. The science is real and specific, and includes considerable laboratory experience.

As in many other high-quality standards of the list type, the unity of science must be inferred from the plethora of individual benchmarks and other items.

STATE REPORT CARD

Rhode Island

PURPOSE, EXPECTATIONS, AND AUDIENCE	12
ORGANIZATION	9
COVERAGE AND CONTENT	23
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	71
GRADE	A

South Carolina

South Carolina has published a pair of closely related documents, a *Science Framework*[162] and *Standards*.[163] The Framework is well-organized and easy to read. The importance of communication—in words, graphics, and mathematics—is recognized in the introductory material[164] if not stressed in the main body of the document. The major fault of the *Framework* is a tendency to deal in overbroad generalities. For example, grade 6-9 students "should know and be able to . . . investigate planetary bodies, major constellations, galaxies and other objects in the solar system and universe."[165] Grade 9-12 students should "describe the nature of gravitational, electrical, and magnetic forces."[166]

There are also some scientific misunderstandings. Students are to be able to "identify the conversion of the matter form of mass into the energy form of mass."[167] Unfortunately, this statement has no physical meaning.

South Carolina short-changes its students by treating biological evolution gingerly, skirting the subject without mentioning the word. A similar delicacy affects earth science to a lesser extent.

The section entitled "The Nature of Science," is a one-page list of some of the attributes of scientists. Much more needs to be done.

The *Standards* does expand to some extent on the specifications of the *Framework*, but not always satisfactorily. For example, the grade 6-9 investigation of planetary bodies, etc., is expanded in only two sentences: "Identify major constellations and star groupings visible in the northern hemisphere," and "Describe ways in which information about the universe is obtained and measured."[168] This is still much too vague to be useful. The grade 9-12 item concerning forces is expanded into seven items. But each of these is still far too broad to enable a student to demonstrate a real competence; e.g., "Investigate and analyze magnetic fields"; "Construct complex electrical circuits."[169]

It is unfortunate that the division into grade levels does not coincide in the two documents. The *Framework* uses grades PreK-3, 3-6, 6-9, and 9-12 (the overlap itself being a source of ambiguity); the *Standards* uses PreK-3, 4-6, 7-8, and 9-12.

STATE REPORT CARD

South Carolina

PURPOSE, EXPECTATIONS, AND AUDIENCE	9
ORGANIZATION	6
COVERAGE AND CONTENT	18
QUALITY	12
NEGATIVES	11
RAW SCORE (out of 75)	56
GRADE	D

Tennessee

The *Tennessee Science Framework*[170] is very clear on some important concepts concerning science that are too often glossed over or even ignored. Four are worth quoting:

- The content of the science curriculum must be composed of significant and accurate scientific concepts and reflect thoughtful coordination across science domains and with other curricular areas.[171]

- Young people build critical thinking skills and scientific habits of mind when they are allowed to become scientists rather than simply studying science.[172]

- The process of science follows no single pathway but involves imagination, inventiveness, experimentation and logic, and evidence to support results.[173]

- One example can never be used to prove that something is true, but sometimes a single example can prove that something is not true.[174]

Attention is paid to the importance of communication of scientific information in writing. It would be better if this point were made consistently, but there are remarks at the grades 3-5[175] and 9-12 levels.[176]

One may also take issue with some statements in the *Standards*. Many appear to be the result of sloppy editing. For example, "The collection of data requires the most accurate degree of precision."[177] Beyond the offense it gives to the nonspecialized eye, this statement ignores the distinction that scientists make between precision and accuracy. Worse, it is not true; the precision required of data depends on the purpose of the measurement being made, and scientists are just as sensitive to excessive precision as to inadequate precision. Surface area, mass, and volume are said to vary "exponentially" with linear dimensions,[178] but the truth is that they vary according to a power law.

Far too many benchmarks simply don't make sense. Here are just a few:

- Mathematical statements can be used to describe the magnitudes of change one quantity has on another.[179]

- The cellular organelles, internal biochemical processes, and involved interactions can be described using appropriate models.[180]

- Mathematical symbols and anthropological concepts can represent the principles of Mendelian inheritance and population genetics.[181]

- Matter and energy are interchangeable. The rate and degree of change depends on the availability of matter and energy and the duration of the interaction.[182]

- Interdependence conveys a need for all organisms within the environment to develop a natural, uninhibited, rate of change.[183]

- Some changes in organisms may be predicted using genetic inheritance and other theories of system change.[184]

- Logical connections can be found among different parts of mathematics.[185]

What do these statements mean?

The word *energy* is used loosely in various contexts throughout the *Framework*, but is never defined. Newton's laws are essentially ignored, even at the "Physics" level, and there are many vague and inaccurate statements in the Physical Science and Physics categories.

Most embarrassing of all, however, is the fact that the treatment of biology in Tennessee seems not to have changed since the notorious "Monkey Trial" of 1925. Biological evolution is not merely euphemized, as is a widespread practice in Southern states, but it is entirely absent. Moreover, geological evolution is slighted and cosmological evolution completely ignored.

STATE REPORT CARD

Tennessee

PURPOSE, EXPECTATIONS, AND AUDIENCE	7
ORGANIZATION	6
COVERAGE AND CONTENT	14
QUALITY	6
NEGATIVES	10
RAW SCORE (out of 75)	43
GRADE	F

Texas

The *Texas Essential Knowledge and Skills* or *TEKS*[186] is a very detailed document. It is divided into subchapters for elementary, middle, and high schools and for advanced courses, health science technology, and technology education/industrial technology. The elementary and middle school subchapters are further subdivided into grade-by-grade sections.

While the detail will undoubtedly be useful to classroom teachers, textbook publishers, and others, an overall discourse is lacking, giving the document the flavor of an extended shopping list rather than a guide to the teaching of the highly structured discipline of science. Textbook publishers in particular are likely to be misled by this approach (as many have been in the past), and this is especially significant because Texas (with California and Florida) is heavily influential in the development of textbooks.

Within the limits of this approach, *TEKS* is well-organized, logical, largely error-free, and carefully graded according to demanding but realistic expectations concerning the intellectual development of growing children.

Some of the expectations are striking. For example, conservation principles are subtly introduced at the 4th grade level:

> The student knows that change can create recognizable patterns. The student is expected to . . . illustrate that certain characteristics of an object can remain constant even when the object is rotated like a spinning top, translated like a skater moving in a straight line, or reflected on a smooth surface, and use reflections to verify that a natural object has symmetry.[187]

The best science combines deep insight with a childlike vision of the world, as this excerpt illustrates.

At the 6th grade level the student is introduced to the key ideas of Newtonian mechanics, and, most laudably, is expected to "define matter and energy."[188] In 7th grade the student is explicitly introduced to Newton's first law of motion, and is expected to understand the distinction between kinetic and potential energy. Newton's second law is introduced to 8th graders.[189] This sort of systematic development is followed in other scientific areas as well. For example, the student's vision of the heavens is expanded from the solar system to the cosmic scale in eighth grade.

The importance of laboratory experience is made clear. The high-school science standards, for example, all specify that at least 40% of class time be spent in field or laboratory work.

The modern perspective is especially clear in the description of the astronomy course.[190] Far too many astronomy courses, even at the college level, devote most of their attention to solar-system astronomy. *TEKS* makes clear the importance of dealing with the universe as a whole, including the evolution of the universe, the structure of galaxies, and the life cycles of stars, as well as more local matters.

TEKS would have scored B if its list format had not obscured such general principles as the importance of written and oral expression, of error analysis, of students' growing abilities in various areas, of the significance of scientific methodology, and of the connections between science and technology.

STATE REPORT CARD

Texas

PURPOSE, EXPECTATIONS, AND AUDIENCE	10
ORGANIZATION	9
COVERAGE AND CONTENT	20
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	66
GRADE	C

Utah

The *Elementary Science Core* covers grades K-6; the *Secondary Science Core*[191] covers grades 7-8, a "Ninth Grade Integrated Science Course" entitled Earth Systems, and six high school courses: the traditional college-prep biology, chemistry, and physics courses, two additional courses entitled Agricultural Biology and Human Biology, and one called Physics: Principles of Technology.

The *Elementary Science Core* describes objectives grade-by-grade. The arrangement is fairly standard; each grade description is introduced with a one-paragraph essay followed by a list of standards, each with subsidiary objectives, and each objective exemplified by several indicators.

Mathematics as a tool of science is explicitly introduced in 1st grade, though it is not mentioned again until grade 6. Connections with social studies are introduced in grade 4. As early as grade 3, students are challenged to "describe the relationships between active volcanos and related geological features"[192]—an innovative introduction to plate tectonics at an early age. The exceedingly varied biomes of Utah—past and present—are introduced at grade 4,[193] as is the richly varied and economically important geology of the state:

- Discuss the value of rocks and minerals to Utah's economy. . . . Identify the modern and historical importance of minerals and mining.

- Collect and analyze data about Utah's fossils and infer how fossils are formed. . . . Make inferences about origin of fossils. . . . Predict where fossils might be found, based on inferences.

- Explain how Utah fossils can be used to draw inferences about Earth's history. . . . Formulate hypotheses about the geological history of Earth from study of fossils and compare then to accepted scientific theories. . . . Research what scientists have learned about the history of the Earth from fossils.[194]

These are ambitious but realistic expectations for 4th graders; explicit discussions of plate tectonics follow in 5th grade.[195]

The processes of science are well-presented. In 9th grade, for instance, the student is expected to "distinguish between [*sic*] theory, law, evidence, fact, and superstition."[196]

Occasionally, there is a bit of silliness. For example, "Describe similarities and differences in the production of heat, light, and sound. . . . Describe the significance of the roles heat, light, and sound have played on [*sic*] different cultures."[197] Or, under "Microorganisms," "Describe in [the students'] own terms how a microscope works."[198] To the best of my knowledge, there is only one explanation of how a microscope works, and it involves an understanding of the function of lenses.

The college-prep courses are outlined in detail, in depth, and systematically. For the biology course, typical examination questions are supplied.

STATE REPORT CARD

Utah

PURPOSE, EXPECTATIONS, AND AUDIENCE	11
ORGANIZATION	9
COVERAGE AND CONTENT	22
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	69
GRADE	B

Vermont

Vermont's *Science, Mathematics, and Technology Standards*[199] takes the form of a relatively brief listing of objectives and associated benchmarks. The integration of the three areas into a single Standards has been carried out well. In particular, the idea that the use of mathematical language is essential to the practice of science is well-presented—as far as it goes:

> Illustrate mathematical models of a physical phenomenon.[200]
>
> Use physical and mathematical models to show how, in a system, input affects output.[201]
>
> Quantitatively apply ideal gas laws.[202]

It is too bad that these fine generalities were not fleshed out with specifics.

The integration of evolution into the life sciences ranks among the best of any state Standards. Beginning at the preK-4 level, the dynamic nature of life forms the center of biological investigations. The intimate linkage among the astronomical, geological, and biological sciences is made very clear, as is the basis of these sciences on physical and chemical laws. Technology is well-integrated with the sciences and mathematics.

STATE REPORT CARD

Vermont

PURPOSE, EXPECTATIONS, AND AUDIENCE	10
ORGANIZATION	9
COVERAGE AND CONTENT	24
QUALITY	14
NEGATIVES	12
RAW SCORE (out of 75)	69
GRADE	B

Virginia

The Virginia *Standards*[203] is remarkable in its completeness, given its brevity (23 pages). For each grade, K-6, and for each of the three standard middle-school and three standard high-school courses, it lists items that the students are expected to "investigate and understand." The list is complete, competent, and systematic. Each section is preceded by a short one-paragraph description of the emphasis to be found in the list that follows. No benchmarks accompany the standards; that is, there are no examples of how the student might demonstrate mastery of a topic.

No attempt is made to sketch broad ideas or theoretical structures. The document is best compared to a cookbook intended for professional chefs who know the territory and need nothing more than brief directions to create unfamiliar dishes. It will thus be of the greatest use to the experienced teacher; novices may not find it very useful.

The D grade assigned reflects the lack of detail, as a consequence of which many of the criteria are met only to a limited degree.

STATE REPORT CARD

Virginia

PURPOSE, EXPECTATIONS, AND AUDIENCE	5
ORGANIZATION	6
COVERAGE AND CONTENT	9
QUALITY	12
NEGATIVES	12
ADDITIONAL FACTORS	5
RAW SCORE (out of 75)	49
GRADE	D

Washington

Science is the subject of pages 67 through 84 in the Washington *Manual*.[204] The overall expectations are outlined in a two-page summary which lists five major goals, each of which has between three and six subdivisions. The arrangement is not unusual except in the way it makes a fundamental distinction between communication in ordinary language and communication in the language of mathematics. The former is expressed clearly in Requirement 4: "The student uses effective communication skills and tools to build and demonstrate understanding of science. To meet this standard, the student will . . . use writing and speaking skills to organize and express science ideas."[205] In contrast, mathematics is relegated to a sort of interdisciplinary grab bag in Requirement 5: "The student understands how science knowledge and skills are connected to other subject areas and real-life situations. To meet this standard, the student will use mathematics to enhance scientific understanding."[206] The other subdivisions of Requirement 5 say similar things about science and technology, history, society, and the workplace.

Leaving aside the invidious distinction made between science and real life, it seems a pity to treat mathematics, the essential language of the sciences, in this manner.

Each of the subdivisions is associated with three sets of benchmarks. Except for language skills and mathematics, Washington has reached no decision yet concerning the grade levels at which the benchmarks are to apply. However, "Benchmark 1 can be thought of as related to grades 4-5, and Benchmark 2 as related to grades 7-8. Assessment at Benchmark 3 is tied to the Certificate of Mastery . . . generally the 10th grade."[207]

The list that constitutes the main body of the *Manual* is succinct, well-organized, appropriate to the grade levels, and complete. It contains considerably more information than the formally comparable Virginia list. In particular, the theoretical underpinnings of the individual items are made reasonably clear probably as clear as can be expected in the absence of an essay format. Two examples will suffice:[208]

[The student will]	Benchmark 1	Benchmark 2	Benchmark 3
1.4 Recognize the components, structure, and organization of systems and the interconnections within and between them.	Recognize that fossils are remains of plants and animals that lived long ago.	Understand how the theory of biological evolution accounts for the diversity of species and the change of species over time.	Understand how the theory of biological evolution accounts for the similarities and differences among living things and provides a scientific explanation of the fossil record.
2.4 Understand the relationship between evidence and scientific explanation.	Know that ideas in science change as new scientific evidence arises.	Understand that terms such as "hypothesis," "law," "principle," and "theory" are used to describe various types of scientific explanation; that they are supported by evidence; and that they are subject to change if new evidence arises.	Understand that scientific principles, theories, and laws are logically consistent, abide by rules of evidence, are open to question and modification, are based on historical and current scientific knowledge, and are invented by acts of imagination, intelligence, and logic through scientific investigation.

STATE REPORT CARD

Washington

PURPOSE, EXPECTATIONS, AND AUDIENCE	11
ORGANIZATION	8
COVERAGE AND CONTENT	22
QUALITY	15
NEGATIVES	12
RAW SCORE (out of 75)	68
GRADE	B

I am a little concerned, however, by the use, throughout the Standards, of the word "understand" in the context exemplified in the table above. Assessment is much easier if the student is expected to *demonstrate* some sort of skill. It is difficult to be sure what he "understands." However, the statements above are readily converted into expectations of demonstrations. For example, Benchmark 2 for Standard 2.4 could easily be rewritten as

> demonstrate how terms such as "hypothesis," "law," "principle," and "theory" can be used to describe various types of scientific explanation; use an example to show how they are supported by evidence and how they are subject to change if new evidence arises.

In my evaluation, I have assumed that the use of "understand" is an unfortunate convention rather than a commitment.

West Virginia

STATE REPORT CARD

West Virginia

PURPOSE, EXPECTATIONS, AND AUDIENCE	4
ORGANIZATION	4
COVERAGE AND CONTENT	12
QUALITY	6
NEGATIVES	10
RAW SCORE (out of 75)	36
GRADE	F

West Virginia[209] presents its science standards grade-by-grade through grade 10. In grades 9 and 10, students take courses named "Coordinated and Thematic Science (CATS) Nine and Ten"; graduation requires one additional course from a list including traditional biology, chemistry, and physics, technical chemistry, environmental earth science, human anatomy and physiology, technical physics, and AP courses. It is not clear how the college-bound student who wishes to take biology, chemistry, and physics—to say nothing of AP courses—is to be accommodated.

The form of the standards document is familiar; for each grade, a short description of general expectations is followed by a list of expected achievements.

From kindergarten on, students are expected to devote 50% of their science study time to laboratory work—a very desirable requirement if properly implemented. Students are expected to use graphs and calculations in scientific inquiries beginning at 2nd grade.[210]

There are some oddities and slips. For example, grade 2 students are to study the lives of scientists. The persons suggested are Thomas Edison, Jacques Cousteau, Alexander Graham Bell, and Rachel Carson, none of whom was primarily a scientist.[211] Given the importance of clarifying the differences between science and technology, this confusion is not a good start. And if one is to "recognize that science changes over time,"[212] it is inappropriate to give such examples as "earth features changed shape, variations of birds appeared, plants of long ago became coal"; these represent quite another sort (or rather several sorts) of change.

Beginning at grade 3, items that may be expected on examinations are boldfaced. The intent is a good one in the sense that it clarifies the evaluation process. However, it has the disadvantage of implying that lightfaced items are less important. Every teacher, after all, dreads the question, "What are we responsible for on the test?"

The lists of items are extensive and reasonably complete. However, the organization tends to the chaotic. Consider, for example, the following (quite typical) sequence of items at grade 6:

> 6.63 review fundamental earth science concepts including celestial relationships, air has mass and exerts pressure—*systems*
>
> 6.64 recognize that stars are different temperatures and ages—*systems*
>
> 6.65 identify and investigate Earth's resources (e.g., use and abuse, energy sources, how man's utilization affects the environment)—*changes*
>
> 6.66 probe atmospheric conditions (e.g., composition, interactions)—*changes*
>
> 6.67 summarize the forces and results of plate tectonics—*changes*

Quite aside from the fogginess of some of the individual items, it is far from clear how they are to be connected to one another in the context of a theoretical framework. Integration of the sciences is one thing; scrambling is quite another.

Newton's laws are mangled:

Illustrate qualitatively and quantitatively Newton's Laws of Motion (e.g., F=m x a, D=v x t, p=m x v, simple machines, W=f x d)—*models*[213]

Only one of these statements (more properly, $F = ma$) is one of Newton's three laws—the second. The definition of momentum, $p = mv$, is closely related to the second law as well. But none of the other statements in this grab-bag is one of Newton's laws, and the first and third laws are completely missing.

Similarly if less seriously, the ideal gas laws are misrepresented.[214] The document is riddled with errors of this sort. And what is to be made of this hodgepodge of an item, which is bold-faced and thus subject to examination?

9.55 review of foundational concepts including refraction, speed, distance, time, Newton's Laws, simple machines tables and graphs, heat absorption, energy transformations, and air pressure—*systems*

Finally, there is an odd dissonance in the treatments of the college-prep biology, chemistry, and physics courses. The standards for the chemistry course are exceedingly detailed, and involve a substantial amount of quite advanced material (e.g., calculating the Gibb's [*sic*] free energy of a system.) But the standards for biology and physics are very general and sketchy. In particular, all the content of the physics course is condensed into six two-line standards.[215]

Wisconsin

Wisconsin is currently rewriting its standards; this analysis is based on a draft.[216] To the extent necessary, the information in the draft Standards is supplemented by reference to the *Curriculum Guide*.[217]

Pages 43 through 61 of the Standards are devoted to science. To a great extent, the individual standards are quite general and address the methodology and social context of science. As is true of all states, Wisconsin adopts the view that a major purpose of science education is to prepare students for participation in public life by equipping them with the ability to evaluate and criticize issues having scientific or technological content. One standard puts this particularly well:[218] "Students will . . . evaluate popular press, television, internet, scientific journal articles, or technology issues using the criteria of accuracy, degree of error, sampling, treatment of data, among others, in these evaluations."

Only about 10 pages are devoted to specific subject matter, and so the standards are somewhat sketchy. This appears to be deliberate, as language in the draft places responsibility for detailed curriculum in the hands of local districts. There is much more detail, however, in the *Curriculum Guide*.

There is room for criticism. As in many other standards, the term *energy* is used loosely and never properly defined. An 8th-grade standard[219] expects students to "Use commonly accepted definitions of energy," but no attempt is ever made to define energy precisely. This is exacerbated by the absence of any direct reference to the laws of motion.

There are some technical errors as well. A 4th-grade standard[220] expects students to distinguish between "substances that are touched—matter, and substances that cannot be touched—forms of energy, light, heat, electricity, sound, and magnetism." But "substance" is usually reserved for forms of matter, and is not used for energy or fields. Moreover, not all substances can be touched. An 8th-grade standard[221] asks students to investigate "light, heat, radio waves, magnetic fields, electrical [*sic*] fields, and sound waves as they interact in common situations . . . with each other." But the items in this grab-bag of items do not in general interact with each other, especially in common situations, except possibly in the presence of matter. Moreover, heat is not a definite entity, and cannot be treated as such.

The *Curriculum Guide* is both more specific and more accurate. Laudably, the idea that "energy can be classified as kinetic or potential" and the assignment to "show how kinetic energy is continually being transformed into potential energy and vice versa as a pendulum swings" are introduced as early as grades 3-6.[222]

STATE REPORT CARD

Wisconsin

PURPOSE, EXPECTATIONS, AND AUDIENCE	8
ORGANIZATION	7
COVERAGE AND CONTENT	16
QUALITY	9
NEGATIVES	12
ADDITIONAL FACTORS	8
RAW SCORE (out of 75)	60
GRADE	C

Some of the "Nature-of-Science" items are unique—even offbeat—and very interesting. Here are a few:

- Try to find evidence of development in science between the 5th and 13th centuries. . . . Explain the result of this search.[223]

- Scientists are restricted to using evidence that can be collected directly or indirectly from nature. Imagined or distorted data must be rejected. . . . List the benefits of the study of phrenology, astrology. . . . Describe the problems encountered in U.F.O. research.[224]

- Compare the decisions a scientist must make to those of a person selling a popular product.[225]

- Discuss the problems scientists might encounter in trying to study extrasensory perception.[226]

- Try to find an example of an accepted event or happening that has no natural cause.[227]

Mathematics is given strong emphasis as a tool essential to scientific work, especially at the high-school level. Students are expected to achieve fairly sophisticated levels in measuring, estimating, graphing (including spherical coordinates), using algebra and statistics, interpreting, and modeling.[228]

Observation and experimentation are stressed. Here are some outstanding activities:

- Study the populations of plants on a bank of a new road-cut. Compare to the bank of an older road.[229]

- Compare aerial photographs and topographic maps of areas with very different landscapes to find evidence of the effect of climate, rock type, and structure on geologic history.[230]

- Use collision carts loaded with different masses to measure momentums [*sic*] before and after head-on collisions.[231]

The *Standards* is still in the process of development. One hopes that the final document will draw more heavily on the older, very fine *Curriculum Guide*.

Virgin Islands

The Virgin Islands *Standards* is currently available only as a two-page second-draft outline. A much more detailed document is to be developed during the 1997-98 school year.

ENDNOTES

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2. The most common choice of clusters is K-3, 4-6, 7-9, and 10-12, but there is much variation.

3. Presentation of a science as a list of "factoids" is a far-too-common fault of the present generation of science textbooks.

4. *Science Framework for California Public Schools, Kindergarten Through Grade Twelve*, California Department of Education, 1990.

5. See *Mathematics and Science Content Standards and Curriculum Frameworks* (Washington, D.C.: Council of Chief State School Officers State Education Assessment Center, 1997); and *Making Standards Matter* (American Federation of Teachers, 1997), and earlier annual editions.

6. Sandra Stotsky, *State English Standards: An Appraisal of English Language-Arts/Reading Standards in 28 States*, Fordham Report 1(1), Washington, D.C.: Thomas B. Fordham Foundation, July 1997.

7. *Science Framework for California Public Schools*, p. 26.

8. T. S. Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. (Chicago: Univ. of Chicago Press, 1970).

9. Kuhn, op. cit.

10. Ralph A. Raimi and Lawrence S. Braden, *State Mathematics Standards*, Fordham Report 2(3), March 1998; David Warren Saxe, *State History Standards*, Fordham Report 2(1), February 1998; Susan Munroe and Terry Smith, *State Geography Standards*, Fordham Report 2(2), February 1998.

11. ibid., 19 ff. A controversy over science content and pedagogy broke out in California in late 1997, when two groups with conflicting philosophies competed for the role of consultant to the standards-writing commission. The controversy seems to have been resolved by the contra-Solomonic expedient of merging the two groups.

12. Note, however, that the New York Standards would have rated much higher if they had not been marred by poor examples. See the detailed discussion of the New York Standards in Section VIII.

13. *Alabama Course of Study—Science-Scientific Literacy*, Alabama State Department of Education, Bulletin 1995, No. 4.

14. ibid., p. 91.

15. ibid., p. 107.

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21. *Alaska Content Standards*. Downloaded from http://www.educ.state.ak.us/Content/Standards/Science.html.

22. *Arizona Academic Standards: Arizona Student Achievement Program*, Arizona Department of Education, 1997.

23. Standard 5SC-F2, p. 20.

24. Standard 5SC-E3 PO1, p. 22.

25. ibid.

26. Standard 5SC-P3, 23. This passage is based on but much improved over the *National Science Education Standards*. (See note 1.)

27. Standard 5SC-E5 PO1-3, p. 23.

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29. Standard 1.1.7, grades K-4.

30. Standards 1.1.8, 1.1.9, 1.1.11, grades 5-8.

31. Standards 1.1.25, 1.1.26, 1.1.27, grades 9-12.

32. Standard 2.1.15, grades 9-12.

33. Standard 3.1.8.

34. Standard 3.1.12.

35. Standard 2.1.18: Understand the broad themes of science: systems, change, interactions, models, scale, and adaptation.

36. Standards 3.1.30, 3.1.35.

37. Standards 4.1.17 (grades 5-8) and 4.1.23 (grades 9-12).

38. Standards 5.1.11-13 (grades 5-8) and 5.1.26 (grades 9-12).

39. Standards 5.1.31, 5.1.32, grades 9-12.

40. The reader should bear in mind the fact that the author of this analysis made substantial contributions to the California *Science Framework*, and the objectivity of his comments on the *Framework* should be assessed in the light of this fact.

41. See Note 4.

42. *Colorado Model Content Standards for Science*. Downloaded from http://www.cde.state.co.us/sci.htm.

43. ibid., Standard 2.2.

44. ibid., Standard 2.3, grades 9-12.

45. "Science Curriculum Framework," August 7, 1997: Second Draft for Review and Comment, Connecticut State Department of Education, Division of Teaching and Learning. I am grateful to Science Consultant Steve Weinberg for making the draft available.

46. *Indiana Science Proficiency Guide*, item 2.2, 32.

47. Second unnumbered page of *Content Standard 1: The Nature of Science.*

48. *Content Standard 10: The Universe*, grades K-4.

49. Downloaded from http://www.dpi.state.de.us/standard/science/sstand.html through /sseig912.html.

50. Standard 1, grades 4-5, "Science, Technology, and Society."

51. Standard 3, grades 6-8, "Force and Motion."

52. Standard 7, grades 9-12, "Evolution."

53. Standard 3, grades 9-12, "Force and Motion."

54. *Florida Curriculum Framework-Science-PreK-12 Sunshine State Standards and Instructional Practices*, State of Florida, 1996.

55. ibid., p. 35.

56. ibid., p. 36.

57. ibid., p. 39.

58. ibid., p. 34.

59. ibid., p. 38.

60. ibid., Standard SC.B.2.4.1, p. 66.

61. ibid., Standard SC.B.1.4.4, p. 62.

62. The citations in this paragraph are all from pp. 40-41.

63. ibid., Benchmark SC.A.1.3.6, p. 48.

64. *Quality Core Curriculum.* Remarks in the introduction suggest that the K-8 material was written in the late 1980s. The Georgia Standards Table of Contents was downloaded from http://tanabi.gac.peachnet.edu/WRAP,26,651,3098,0,69,0.srch; other sections are immediately accessible from that site.

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66. ibid., grade 3, item 6.

67. ibid., grade 3, item 21b; grade 6, item 18.

68. Biology, Objective 9.

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81. ibid., Standard I.

82. *Illinois Learning Standards,* 1st ed., Illinois State Board of Education, July 25, 1997.

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84. *The Indiana State Proficiency Guide*, Indiana Department of Education, 1995.

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86. ibid., Item 2.1, p. 57.

87. ibid., Item 2.3, p. 58.

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89. ibid., Item 8.8, p. 119.

90. *Indiana High School Competencies*, Indiana Department of Education, 1995.

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103. *Mississippi Science Framework*, Mississippi Department of Education, 1996.

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117. *K-12 Science Curriculum Framework*, New Hampshire Department of Education, 1995.

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141. ibid., p. 30, Standard 4 — Science, Physical Setting, elementary level.

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160. ibid., p. 3D-23, The Human Organism—Learning, grade 9-12.

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177. ibid., Standard 1.4b, grades 6-8, p. 6.

178. ibid., Standard 2.1e, Physics, p. 14.

179. ibid., Standard 1.5a, grades 6-8, p. 7.

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182. ibid., Standard 2.5a, Physics, p. 25.

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225. ibid., Example Activity 3.511, grades 7-9, p. 135.

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229. ibid., Example Activity 2.134, grades 10-12, p. 156.

230. ibid., Example Activity 2.172, grades 10-12, p. 157.

231. ibid., Example Activity 2.351, grades 10-12, p. 159.

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