Evolution in State Science Tests & Standards
Many States Include Evolution Questions on Assessments
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Evolution Theory Well Represented in Leading High School Textbooks
Textbooks—teachers’ road maps through the curriculum—generally do a respectable job of covering evolution, according to experts who have reviewed the books, though the thick volumes tend to be weaker in describing the theory’s relevance across the many areas of science. Education Week, Dec. 7, 2005.

Treatment of Evolution Inconsistent
State standards for academic content vary enormously in how well they cover the topic of evolution, with many of those documents either ignoring or giving scant treatment to the core principles of that established scientific theory, an Education Week analysis shows. Education Week, Nov. 9, 2005.

Research Brief: Evolution in State Science Education Standards
EPE Research Center, November 2005.
None Surveyed Addresses ‘Intelligent Design’ on Tests

Many States Include Evolution Questions on Assessments

BY SEAN CAVANAGH

State science tests differ greatly in what they expect students to know about evolution, with some asking no questions about the theory and others including more than a dozen items related to it, an Education Week review has found.

Responses from more than 20 states to a survey last year by the National Center for Improving Science Education, in Arlington, Va. “Science is based on observations concerning natural phenomena. Belief systems do not. They may be legitimate for people who hold those beliefs, but they’re not science." Ms. Raizen recently co-chaired a committee that directed the revision of the biology blueprint for the National Assessment of Education Progress, perhaps the most closely scrutinized exam in the country, which influences many state assessments.

For its review, Education Week sent a list of questions to 29 states that, as of last school year, reported that they had science tests at the elementary, middle, and high school levels that were aligned with their state standards. The review focused on high school exams, the level at which all states have testing materials, typically taught in the greatest depth.

Of the 22 states that responded to the survey, 17 indicated they had at least one question that specifically mentioned evolution on the most recent exam, three states said they had none; one state, Kentucky, declined to answer the question; and another, Tennessee, said it was unlikely the term showed up in a question.

States tend to be protective of testing materials, mostly to ensure that the process remains tamper-proof. Thus, some states declined to say how many test items were connected to evolution.

Of those states that provided specifics, the number of questions on their high school science assessments that cited “evolution” as it pertains to biological changes in species ranged from zero to seven.

When asked how many questions related to evolution generally, without mentioning the word, some state officials said their tests included no such items, while others, such as New York and Utah, said they had as many as a dozen questions on the topic.

Test Deadlines Coming

In some ways, the contrasting approaches on evolution reflect different approaches in science testing overall.

Some of the states with the greatest number of evolution-related items give subject-specific tests in biology. Likewise, states with fewer of those questions test students across a broad range of scientific fields, such as physics and chemistry.

In addition, the total number of test questions varies with the No Child Left Behind law requiring states to test students in science. The No Child Left Behind law requires states to have science assessments on the topics that the law identifies, which include evolution.

In Leading High School Textbooks

Evolution Theory Well Represented In Leading High School Textbooks

BY SEAN CAVANAGH

Textbooks—teachers’ road maps through the curriculum—generally do a respectable job of covering evolution, according to experts who have reviewed the books, though the thick volumes tend to be weaker in describing the theory’s relevance across the many areas of science.

Leading textbooks strongly present major evolutionary ideas, experts say, despite being jammed with information to comply with the academic standards of so many different states—a concern across science.

“If you look at the major textbooks on the market, they all have one, two, or three chapters on evolution,” said Rodger W. Bybee, the executive director of the Biological Sciences Curriculum Study organization, in Colorado Springs, Colo., which develops textbooks and other instructional materials.

Despite scientists’ concerns about the recent resurgence of criticism over the teaching of evolution, most textbook publishers say, in fact, “strengthened empirical arguments” in presenting the theory in recent years, in response to criticism that the textbooks were weak or nonexistent in it. He expects those efforts in the coverage of evolution to continue.

A 2000 study by the American Association for the Advancement of Science in Washington found that high school biology books were strong in presenting basic facts in evolution and other major scientific concepts. But those facts were too often presented in isolation, that analysis found, rather than in ways that described evolution’s influence throughout science.

“Kids need to understand why the scientific community supports evolution, and why it’s important,” said Jo Ellen Roseman, who directed the study and is also the director of Project 2061, an AAAS venture to improve learning in science, mathematics, and technology.

She attributed textbooks’ weaknesses in coherence partly to the tendency of the authors—primarily college professors—talking over concepts that seem obvious to them, but might not be to precollege students.

Sticking to Science?

Publishers and other textbook experts say major science books avoid discussing “intelligent design,” a purported alternative to the theory of evolution, because the mainstream scientific community does not regard it as legitimate science. Yet one widely used textbook, Glencoe’s 2004 edition of Biology: The Dynamics of Life, describes intelligent design and other views in a section titled “Biology and Society.” The concept is described as a belief, not a scientific theory.

April Hattori, a spokeswoman for the Glenview, Ill.-based McGraw-Hill, a division of the New York City-based McGraw-Hill Education, said the book makes no other reference to intelligent design. Overall, it treats evolution as a “unifying concept” in science, she said, which the publisher recognizes is backed by the vast majority of the scientific community.

At the same time, some private schools have shown an increased interest in science textbooks that discuss either creationism or intelligent design, said Derek J. Keenan, a vice president of the Association of Christian Schools International, in Colorado Springs. His organization represents 3,700 U.S.-based religious schools, many of which use Christian-themed science texts alongside those favored by the mainstream scientific community. Those schools often seek textbooks through Christian-oriented publishers, such as A Beka Books, in Pensacola, Fla.

A Close Reading

Textbooks have come under inspection in a closely watched federal lawsuit on creationism. The Dover, Pa. school board last year was found to be exposing students to intelligent design, is written by Kenneth R. Miller, a Brown University biology professor, and Joseph S. Levine, a longtime science writer. During the trial, Mr. Miller was questioned by a school board lawyer about a heading on one section of the book titled “Strengths and Weaknesses of Evolutionary Theory.”

Mr. Miller testified that the authors added that wording to conform with Texas state standards, which call for students to critique various scientific theories and hypotheses. The Dover policy says students should be exposed to “alternative” views in evolution, which “gaps/problems” in evolution, in Mr. Miller’s book, the lawyer implied, seemed to justify such criticism.

The professor, however, said the headline was taken out of context. Intelligent-design advocates, he said in an interview, “will try to take that (language) and make something out of it.” Virtually any textbook discussion of evolution, he noted, could be scrutinized in the same way.

Mr. Miller has heard criticism that one of his previous biology texts was long on evolution facts and short on coherence across subjects. Not so with Biology, he said, which tries to make those connections. In fact, the author joked that a Dover school board member’s complaint that his book was “laced with Darwinism” could apply describe his work.

“There,” Mr. Miller said, “should be a quote on the back cover of my book.”
sessions in place at three grade levels—3, 5, 6-9, and 10-12—by the end of the 2007-08 academic year, and to have standards in those subjects in place by this school year. According to a recent survey by the Council of Chief State School Officers, 42 states have science tests in place at the three levels, though not all are aligned with their standards.

Experts on science testing were not surprised by the broad differences in how states treat evolution. Those disparities could be attributed not only to the different ways in which exams are structured, they said, but also to the dissimilarities in which state standards cover the theory.

“It’s impossible to put an absolute number on what is the right number of questions to include about evolution,” said Meryl Bertenthal, a former program officer at the congressionally chartered National Research Council, who has studied state science testing. “The emphasis and the depth [will be] similar to the state standards. You’re not likely to see questions that are not aligned with the standards.”

A related Education Week analysis, published last month, showed that state standards documents vary greatly in their coverage of evolution, with many ignoring core concepts and evidence connected to the theory. (See Education Week, Nov. 9, 2005.)

Alabama’s high school science assessment, which covers many science topics, does not include the term evolution, according to state officials’ survey responses. Yet references to the theory are found in underlying language throughout the state’s standards. The exam, however, is based on specific items in the standards that are highlighted as central concepts, said Gloria Turner, the state’s director of assessment, and evolution is not one of them.

“We assessed the content standards as they were written,” she said.

‘Can’t Cover Everything’

In the past year, efforts to promote alternatives to evolution, or raise questions to teaching, have played out in more than 30 states, according to the Oakland, Calif.-based National Center for Science Education, which monitors those fights.

One of the most visible battles has played out in the 3,600-student Dover, Pa., district, where the school board in 2004 approved a policy requiring that students be introduced to intelligent design. A federal lawsuit on the policy awaits a judge’s ruling. (See Education Week, Nov. 16, 2005.)

Another equally visible fight occurred in Kansas, where state school board members last month included more criticism of evolution in state science standards.

The effect of those changes is unclear. Kansas’ high school science test usually has four to six questions on evolution, out of 60 overall, and only those items would likely be affected, if state board members decided to revise their areas to reflect the new standards, said Alexa Posny, the state’s deputy education commissioner for learning services. “If you were to remove all those questions, you would have to remove that concept more generally,” she said. That state, however, is in the process of developing a new test to meet requirements of the No Child Left Behind Act, state officials said. The exam is one option.

Field testing of Ohio’s 38-question test, next administered in 2008, are multiple-choice. Ms. Posny was not sure how state officials might structure a multiple-choice question about criticism of evolution. “It would be a challenge,” she said.

South Dakota also does not mention evolution specifically on its high school test, though officials said two questions related to the concept more generally. That state, however, is in the process of developing a new test to meet requirements of the No Child Left Behind Act, state officials said. That test is based on Ohio’s state standards, which were revised in 2002 after an extended debate, to encourage critical analysis of evolution and broad coverage of the theory overall. Deborah Owens Fink, an Ohio state school board member who supported those standards, was surprised that the concept did not appear on the state test. But she and other state officials noted that an original bank of potential questions included several evolution items. Those queries were eventually pared down to include randomly selected questions at various difficulty levels.

“If you only have 38 questions,” Ms. Fink said, “you can’t cover everything.”

**Treatment in NAEP**

While most states included only a few test items about evolution, that treatment is similar to the approach used on one of the most heavily scrutinized precollege tests in the country, the National Assessment of Educational Progress. On the 2005 version of the science NAEP, 12th graders were quizzed about four items that referred specifically to evolution and five others that covered related concepts, making up 4 percent of the 209 total questions.

NAEP also provides a glimpse of how well students performed when questioned about evolution. Fifty-one percent of the 12th graders correctly answered a question about sexual and asexual reproduction in animals.

In Utah, a state that reported having about 15 evolution-related items on its high school exam, 61 percent and 66 percent of students reached the “proficient” level on two different parts of the state biology test most directly related to evolution, while 67 percent who scored proficient on the overall exam. Students there are required to take at least two high school science tests; the biology exam is one option.

Utah officials have no inclination to include questions about intelligent design or other alternative views on their exam.

“Those things don’t belong in science,” said Brett Moulding, the state’s director of curriculum.

**Top-Down Mandates**

Several experts on science education and testing said they fully expected that states were not testing students on views critical of evolution. They noted that pre-collegiate science teachers, who generally want evolution taught, often play a major role in shaping the content of tests.

“For the vast majority of biologist teachers out there, there’s no controversy here. There’s no close call,” said Bruce A. Fuchs, the director of the office of education at the National Institutes of Health, an arm of the federal government. He speculated that any future efforts to promote alternatives to evolution in science testing were “likely to be forced in from the top,” if at all, “rather than coming from teachers.”
Mapping Evolution

States vary enormously in how thoroughly they cover the theory of evolution in their science standards. Some avoid the term entirely; others, describe, in great detail, the theory, the evidence supporting it, and what separates it from what scientists say is a nonscientific belief.

Evolution is the cornerstone and the building block of modern biology. It should be the centerpiece of modern biology education

Wayne W. Carley
Executive Director
National Association of Biology Teachers

Evolution was dropped from the state science standards in 1996 and reinstated in 1999. The Illinois Learning Standards for Science scored poorly in the analysis. Without employing the term “evolution,” they specify that students should be able to “describe processes by which organisms change over time,” using evidence from the fossil record and other sources. The other three states use similar substitute language.

IN THE NEWS

By Sean Cavanaugh

State standards for academic content vary enormously in how well they cover the topic of evolution, with many of those documents favoring creationism over the theory described by Charles Darwin. The lack of consistency in treatment to the core principles of that established scientific theory, an Education Week analysis found.

Nearly all the science standards reviewed at least mention the theory advanced most famously by Charles Darwin, giving scant treatment to the core principles of that established scientific theory, an Education Week analysis found.

Evolution was dropped from the state science standards in 1996 and reinstated in 1999. The Illinois Learning Standards for Science scored poorly in the analysis. Without employing the term “evolution,” they specify that students should be able to “describe processes by which organisms change over time,” using evidence from the fossil record and other sources. The other three states use similar substitute language.

One Word Missing

In its review, Education Week found four states—Florida, Illinois, Kentucky, and Oklahoma—that do not mention the term “evolution,” as it pertains to biological changes in species, anywhere in the body of their science standards. The Illinois Learning Standards for Science scored poorly in the analysis. Without employing the term “evolution,” they specify that students should be able to “describe processes by which organisms change over time,” using evidence from the fossil record and other sources. The other three states use similar substitute language.

Gwen Pollock, the principal state science education coordinator in Illinois, said that despite omitting the term from the standards, state officials in no way were suggesting that students shouldn’t master the concept. She also noted that Illinois officials have produced separate documents, known as “performance descriptors,” that do mention evolution specifically. Those documents are meant to provide
teachers and students with more detail about the material they will face on statewide assessments, Mr. Foltz said. “There is accountability through the statewide assessment, and they want to provide test scores.” Ohio officials were “very confident” that students were learning about evolution.

Science Content Weak?

*Education Week*’s findings echo some of the conclusions of earlier studies of state standards and evolution. A 2000 study by the Washington-based Thomas B. Fordham Foundation found that roughly two-thirds of states did at least a satisfactory job of explaining evolution in their standards, but that their overall performance ranged from “excellent” to “disgraceful.”

Paul R. Gross, a professor emeritus of life sciences at the University of Virginia in Charlottesville, is leading a new *Fordham* study of state science standards, to be released soon, which includes a look at evolution language. He said his research was indicating that most state standards treated evolution “reasonably well,” though their quality varied greatly.

Mr. Gross also suggested that singling out evolution as a weak spot in state standards is misleading, because those documents lack academic depth across many areas. “The handling of evolution is disappointing,” he said, “but the handling of science content overall is disappointing.”

Other states besides Illinois are also relying on secondary documents to describe evolution in greater detail than in the state standards themselves. Wisconsin’s Model Academic Standards for Science Instruction didn’t fare well in *Education Week*’s analysis, with descriptions of evolution that failed to provide detail comparable with the NSERs concepts. But Wisconsin officials are writing a new “assessment framework” that will describe evolution and other concepts in greater detail, said Shelley A. Lee, the state’s science education consultant. Wisconsin has also issued a statement describing evolution as a “fundamental and important” concept in science and has warned that attempts to teach religious belief in science classes will be “very bad” in its overall treatment of assessment, “is being revised to include the term itself. “It’s obvious to me—we support the teaching of evolution,” said Lisa Gross, a spokeswoman for the Kentucky education department. “But using the specific term, she maintained, is less crucial than “teaching students how to learn.”

But Ellen Roseman, the director of Project 2061, a long-standing enterprise at the AAAS to promote literacy in science, mathematics, and technology, dismissed efforts to describe evolution while dodging the term itself. “Change over time”—that’s not evolution,” Ms. Roseman said. “We expect that students who graduate from high school will be able to read the term ‘evo’ in the newspaper and know what it is.”

Glenn Branch, the deputy director of the National Center for Science Education, an Oakland, Calif., organization that opposes the teaching of intelligent design and creationism in science classes, agreed. “It conveys the idea that there’s something menacing the e-word,” Mr. Branch said of omitting the term. “It doesn’t do students a service to not use standard scientific terminology.”

Besides setting clear expectations for students, he added, standards serve another function: They are authoritative documents to which state documents teachers can rely on when confronted with outside pressure to teach creationism or intelligent design. “Teachers who face irate parents can point to the state standards,” Mr. Branch said. “Secondary Battleground”

Several state officials explained the lack of detail about evolutionary theory by saying that standards should provide relatively broad learning goals for students—and secondary documents, more detailed language. “State standards are more global statements,” said Dixie Stack, the director of curriculum in Maryland, which did relatively well in the *Fordham* review. Her state also offers a more detailed treatment of evolution in a curriculum document outside of the state standards. “We develop curriculum for teachers to know what students are expected to know about those global statements,” she said.

Mr. Carley of the biology teachers’ association, said that approach could work. “There are multiple layers at which evolution can expand or contract,” he said. “As long as it expands, that’s OK.”

But Mr. Branch of the center for science education warned that such supplemental documents were beginning to emerge as a “secondary battleground” in debates over evolution. Ohio’s state board of education, after a prolonged debate, approved revised science standards in 2002 that do not advocate intelligent design. That document is “not bad” in its overall treatment of evolution, Mr. Branch argued, and it scored well in *Education Week*’s overall analysis. Yet after the furor subsided, Ohio officials in 2004 approved an additional science lesson plan titled “Understanding That Evolution Is a Fact.” That document drew objections from many state and national science organizations. One state that scored well in *Education Week*’s review, Rhode Island, relied extensively on the AAAS science standards in crafting its document. Closely following that model gave educators and others the detail they needed to shape classroom lessons, said Linda A. Jzyk, a science and technology specialist for the state. “The more specificity we can provide, the better for all,” she said. “It helps the teacher in their daily practices, and [it] helps districts in shaping their curriculum.”

Evolution Concepts

*An Education Review* show that state science standards are uneven in their treatment of evolution. The analysis looked at how well 41 states covered 10 concepts related to evolution identified in the 1996 National Science Education Standards.

**General Concept**

- Biological adaptation and survival
- Natural selection
- Fossil record reflects changing life forms
- Environmental changes affect survival
- Similarity among diverse species
- Mechanisms of evolution
- Classification systems reflect evolutionary relationships
- Variable effects of genetic change
- Common ancestry of species
- Time frame of biological evolution

**NSES Language**

- Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.
- Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common, most of the species that have lived on the Earth no longer exist.
- Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for increase in numbers; (2) the genetic variability of offspring due to mutation and recombination of genes; (3) a finite supply of the resources required for life; and (4) the ongoing selection by the environment of those offspring better able to survive and leave offspring.
- Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.
- Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism’s offspring.
- Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry.
- The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.

**States With Matching Content (out of 41)**

- 39
- 36
- 34
- 32
- 27
- 22
- 22
- 21
- 20
- 6
SCIENCE, EDUCATION, AND EVOLUTION

A large majority of scientists view the theory of biological evolution as accepted knowledge that has firmly withstood generations of empirical scrutiny and analysis. The core tenets of the theory are considered beyond serious dispute and represent a bedrock upon which the architecture of the modern life sciences have been built. Although a largely settled issue within scientific circles, encounters between evolution and the general public, politics, and the educational establishment in the United States have often been unsettling.

Starting most prominently with the fabled Scopes trial in 1925, critics of the theory have repeatedly opposed the teaching of evolution in the public schools. In a more contemporary example of such a challenge, between 1999 and 2001, the Kansas state board of education removed (and subsequently reinstated) references to biological evolution from the state’s academic standards. In 2002, Ohio inserted language into its academic standards that effectively contests the scientific standing of evolution by calling on students to “describe how scientists continue to investigate and critically analyze aspects of evolutionary theory.”

That passage from Ohio’s standards is immediately qualified by a disclaimer noting that the preceding statement does not constitute a mandate to either teach or test on “intelligent design.” This alternative explanation contends that certain biological processes and structures are so complex that they could not be a product of the mechanisms delineated by the theory of evolution. Intelligent design instead proposes that the development of life on Earth bears the mark of an outside designer or pre-existing intelligence. This counter explanation has gained currency among critics of evolution in recent years and lies at the heart of a federal trial currently under way in Harrisburg, Pa. In that proceeding, parents from the nearby town of Dover are seeking to overturn a school district policy that requires high school students to be introduced to the concept of intelligent design in addition to evolutionary theory.

Two approaching milestones in the federal No Child Left Behind Act related to science education have increasingly occupied the attention of the education and policy communities. Under the federal law, all states are required to have science education standards in place by the end of the 2005-06 school year. By the 2007-08 school year, states must also initiate annual assessments in science at the elementary, middle, and high school levels. In light of these developments, the academic content identified by states as core scientific knowledge for students to learn will soon carry even greater importance for the nation’s schools.

This report describes the results of a systematic analysis of state science education standards conducted by the Editorial Projects in Education Research Center in conjunction with Education Week. We obtained information on the science education standards in 41 states from an extensive electronic database and devised a rigorous study methodology for analyzing the evolution content of those standards. In so doing, we were able to determine the extent to which the science standards in each state aligned with the treatment of evolutionary theory outlined in one influential and widely respected national standards document – National Science Education Standards, published by the National Research Council in 1996.

Our findings show that all of these state offer at least some minimal amount of attention to the theory of evolution or its attendant concepts, despite the fact that several states do not explicitly mention the word “evolution” in their standards. As described in detail below, considerable variation can be found in the extent to which different state standards capture key concepts related to evolution. Similarly, while certain basic aspects of evolution are covered by nearly all of these states, markedly fewer states’ standards include statements pertaining to more subtle or potentially controversial elements of the theory.

METHODOLOGY

In this study, we perform a systematic and objective analysis of state academic standards in science education in order to characterize the extent to which these documents cover the theory of biological evolution. Studies of this kind typically adopt one of two general methodological approaches.
Some reviews of academic standards, for example, rely on an expert-driven process. Under this model, an individual reviewer (or team) with expertise in a particular content-knowledge area first develops a set of review criteria delineating concepts or features of interest. This rubric is then used to evaluate a series of standards documents in order to generate a score or grade for each set of standards. Expert-driven reviews of academic standards can provide very useful insights into the nature of content-knowledge expectations. If not carefully implemented, however, the results of such investigations can be swayed by the biases of the reviewers. The potential for bias can be minimized by taking such steps as providing explicit statements describing the study’s conceptual orientation and its analytic rubrics or using multiple reviewers. When employing the latter measure, the issue of inter-rater reliability should also be taken into consideration.

In the present study, we have pursued an alternative approach to analyzing academic standards that might be described as a benchmarking strategy. This methodology starts by identifying an existing statement of academic content knowledge. This external standard then becomes a benchmark against which other sets of standards are compared. The objective here is to determine how closely a given set of standards aligns with the content of another particular document that serves as the benchmark. These types of studies are heavily reliant on the validity of the standards selected as the point of reference. Disputed or controversial benchmarks could call into question the results of such an investigation. For the present study, we have adopted the National Research Council’s National Science Education Standards (NSES) as our objective benchmark. Highly respected within both scientific and educational communities, the NSES document outlines a vision of scientific literacy and includes standards describing what students should know and be able to do at particular grade levels.

From the NSES, we derive a set of concept statements describing core evolutionary principles. These benchmark concepts are then compared with the content of state-adopted academic standards in order to determine the extent to which the content in the states’ standards aligns with the treatment of biological evolution in the NSES. As the following step-by-step description of the study methodology indicates, we utilize an extensive electronic database of academic standards and a standardized set of procedures and decision rules. These measures help to minimize the possibility that subjective judgments will affect the results of the analyses, thereby strengthening confidence in the findings.

Step 1: Identifying Evolution Benchmark Concepts

Published in 1996, the NSES is a highly regarded and widely-cited statement of the content knowledge that students should be expected to learn in K-12 science education. In fact, a number of states have looked to this document as a model when developing their own academic standards in science. In consultation with outside experts in science and science education, we identified 10 statements from NSES that describe core concepts related to the theory of biological evolution. These statements, listed in Exhibit 1, span an array of topics that many experts would consider to reflect essential knowledge about evolution.

A potential critique that might be offered of this study lies in the choice of NSES as a point of reference for our analysis. For instance, it might be argued that another set of reference standards could have generated a different set of core evolution concepts and, therefore, different analytic results. Cognizant of this possibility, we also examined the treatment of evolution found in Benchmarks for Science Literacy, published by the American Association for the Advancement of Science (AAAS) in 1993. Like NSES, the AAAS document enjoys a strong reputation and has also been used as a guide in the development of state science standards. We found very close correspondence between the coverage of evolutionary theory in both NSES and Benchmarks. In fact, all 10 of the core evolution concepts from NSES examined in this study also appear in the AAAS document. This finding suggests that the results of our analysis are not unduly dependent on the choice of NSES as our benchmark, which provides validation for the methodology used in this study.

Step 2: Linking Evolution Concepts to the Standards Database

The systematic analysis of evolution-content coverage performed in this study is made possible by an extensive database of academic standards documents maintained by Align to Achieve Inc. (A2A). This Standards Database comprehensively catalogs the content of science standards documents created by the states, the National Research Council, and national organizations, and selected countries. For more information: www.aligntoachieve.org
Evolution in State Science Education Standards

Editorial Projects in Education Research Center

Council (i.e., NSES), and several other professional organizations (e.g., AAAS). Every set of standards contained in the database has been divided into numerous (typically several hundred) individual entries, each of which contains a discrete standard, benchmark, or statement of scientific-content knowledge. Some state standards present content knowledge in outline form while others describe this content using more extended passages of prose. So depending on the ways in which a particular standards documents is organized, database entries can range in length from a short phrase to an entire paragraph.

Entries in the A2A database are organized using a heuristic tool known as the “Compendix,” an extensive index of distinct scientific concepts, each of which is identified by a unique three-part code known as a “triplet.” The triplet system of the Compendix catalogs scientific concepts in much the same way as the Dewey Decimal system would be used to catalog holdings in a library collection. In addition to its focal statement of academic-content knowledge, each Compendix entry also provides a set of vocabulary terms related to that particular concept.

When benchmark statements derived from a standards document (e.g. NSES or a state’s academic standards) are added to the Standards Database, each entry is assigned a triplet code that refers to the corresponding scientific concept from the Compendix. The state benchmark is also indexed

EXHIBIT 1: EVOLUTION CONCEPTS FROM NSES

<table>
<thead>
<tr>
<th>Evolution Concept Label</th>
<th>A2A Triplet Code</th>
<th>NSES Benchmark Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common ancestry of species</td>
<td>4.3.4</td>
<td>Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry.</td>
</tr>
<tr>
<td>Classification systems reflect evolutionary relationships</td>
<td>4.4.1</td>
<td>Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.</td>
</tr>
<tr>
<td>Variable effects of genetic change</td>
<td>5.4.4</td>
<td>Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism’s offspring.</td>
</tr>
<tr>
<td>Fossil record reflects changing life forms</td>
<td>9.3.1</td>
<td>Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the earth no longer exist.</td>
</tr>
<tr>
<td>Biological adaptation and survival</td>
<td>9.3.2</td>
<td>Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.</td>
</tr>
<tr>
<td>Changes in the environment</td>
<td>9.3.3</td>
<td>Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival.</td>
</tr>
<tr>
<td>Natural selection</td>
<td>9.4.2</td>
<td>Like other aspects of an organism’s biology, behaviors have evolved through natural selection. Behaviors often have an adaptive logic when viewed in terms of evolutionary principles.</td>
</tr>
<tr>
<td>Similarity among diverse species</td>
<td>9.4.3</td>
<td>Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.</td>
</tr>
<tr>
<td>Mechanisms of evolution</td>
<td>9.4.4</td>
<td>Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.</td>
</tr>
<tr>
<td>Timeframe of biological evolution</td>
<td>9.4.5</td>
<td>The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.</td>
</tr>
</tbody>
</table>
using a subset of relevant concept vocabulary terms. A database entry might be indexed against more than one Compendix triplet code if the standard statement captures multiple concepts (a common occurrence with longer entries). For the purposes of illustration, Exhibit 2 depicts an A2A database entry from NSES related to evolution. The first portion of the entry contains the content of the benchmark statement as it appears in the NSES document. The second part of the entry describes the Compendix benchmark that corresponds to this evolution principle (including the triplet key, Compendix text, and related concept vocabulary).

As the description above suggests, the Compendix is the common language of the A2A database and the device used to systematically catalog the multitude of entries from state and professional standards documents. The triplet codes can also be used to perform a crosswalk. That is, we can align the content captured across multiple sets of standards by means of their shared triplet codes. The first step in this crosswalk process involves identifying the Compendix triplet codes assigned to the 10 NSES concept statements on evolution. This was accomplished using the publicly accessible database search on the Align to Achieve Web site. For reference purposes, Exhibit 1 above lists the triplet codes corresponding to the focal evolution concepts. Using these triplets, we can proceed with the two-stage electronic search process that will enable us to identify the state standards or benchmarks corresponding to these evolution concepts from NSES.

**Step 3: Triplet Search of the A2A Database**

As mentioned previously, the A2A Standards Database systematically catalogs academic standards that have been adopted by the states or published by professional organizations in four core-subject areas. It should be noted that the database does not contain draft versions of state standards or supplementary documents such as curricular guides that have not been officially adopted as standards by the appropriate state authority (e.g., board of education or legislature). At present, the database houses K-12 science education standards from 41 states, in addition to NSES and the AAAS Benchmarks documents.

State academic standards themselves are in a nearly constant state of evolution, with revised documents periodically adopted to replace earlier versions. This reality of the standards-development and -adoption process has two implications for the present study. First, there are several instances where the A2A database contains multiple documents for a given state, representing different revisions of the standards adopted at different points in time. When such a situation was encountered, we selected the more recent version of the standards for analysis. Second, it is possible that the science standards available for a given state in the A2A database could have been superseded by a more recent version. In light of approaching No Child Left Behind mandates, it is also reasonable to anticipate a major wave of state revisions and adoptions for science standards in the near future.

Although keeping up-to-date in a rapidly changing field can be extraordinarily difficult, we can at least provide the reader with additional information about the standards documents analyzed for this study. Exhibit 3 lists the title of each of these standards documents, along with the year in which those standards were adopted by the state.
## EXHIBIT 3: STANDARDS REVIEWED

<table>
<thead>
<tr>
<th>State</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>2001</td>
<td>Alabama Course of Study: Science</td>
</tr>
<tr>
<td>Arizona</td>
<td>1997</td>
<td>Arizona Academic Standards: Science</td>
</tr>
<tr>
<td>Arkansas</td>
<td>1999</td>
<td>Arkansas Science Curriculum Framework Revised 1999</td>
</tr>
<tr>
<td>California</td>
<td>1998</td>
<td>Science Content Standards for California Public Schools, Kindergarten Through Grade Twelve</td>
</tr>
<tr>
<td>Colorado</td>
<td>1995</td>
<td>Colorado Model Content Standards for Science</td>
</tr>
<tr>
<td>Florida</td>
<td>1999</td>
<td>Grade Level Expectations for the Sunshine State Standards: Science</td>
</tr>
<tr>
<td>Georgia</td>
<td>2004</td>
<td>Georgia Science Performance Standards</td>
</tr>
<tr>
<td>Hawaii</td>
<td>1999</td>
<td>Hawaii Science Content Standards</td>
</tr>
<tr>
<td>Idaho</td>
<td>2001</td>
<td>Idaho Achievement Standards K-12 in Science</td>
</tr>
<tr>
<td>Illinois</td>
<td>1997</td>
<td>Illinois Learning Standards for Science</td>
</tr>
<tr>
<td>Indiana</td>
<td>2000</td>
<td>Indiana's Academic Standards 2000 for K-12 Science</td>
</tr>
<tr>
<td>Kansas</td>
<td>2001</td>
<td>Kansas Science Education Standards</td>
</tr>
<tr>
<td>Kentucky</td>
<td>1998</td>
<td>Kentucky Science (Primary, Intermediate, High School)</td>
</tr>
<tr>
<td>Louisiana</td>
<td>2003</td>
<td>Louisiana Science Grade-Level Expectations</td>
</tr>
<tr>
<td>Maine</td>
<td>1997</td>
<td>Learning Results for Science and Technology</td>
</tr>
<tr>
<td>Maryland</td>
<td>2000</td>
<td>Maryland State Content Standards</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>2001</td>
<td>Massachusetts Science and Technology/Engineering Curriculum Framework</td>
</tr>
<tr>
<td>Minnesota</td>
<td>2004</td>
<td>Minnesota Academic Standards Science K-12</td>
</tr>
<tr>
<td>Mississippi</td>
<td>2001</td>
<td>Mississippi Science Framework</td>
</tr>
<tr>
<td>Montana</td>
<td>1999</td>
<td>Montana Standards for Science</td>
</tr>
<tr>
<td>Nebraska</td>
<td>1998</td>
<td>Nebraska Science Standards</td>
</tr>
<tr>
<td>Nevada</td>
<td>1998</td>
<td>Nevada Science Content Standards Grades 2, 3, 5, 8, and 12 and Grade Level Indicators for Kindergarten and Grades 1, 4, 6 and 7</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>1995</td>
<td>K-12 Science Curriculum Framework</td>
</tr>
<tr>
<td>New Jersey</td>
<td>1998</td>
<td>New Jersey Core Curriculum Content Standards for Science</td>
</tr>
<tr>
<td>New Mexico</td>
<td>2003</td>
<td>New Mexico Science Content Standards, Benchmarks, and Performance Standards</td>
</tr>
<tr>
<td>North Carolina</td>
<td>2004</td>
<td>North Carolina Science Standard Course of Study and Grade Level Competencies</td>
</tr>
<tr>
<td>North Dakota</td>
<td>2002</td>
<td>North Dakota Science Content Standards and Benchmarks</td>
</tr>
<tr>
<td>Ohio</td>
<td>2002</td>
<td>Ohio Science Academic Content Standards</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>2002</td>
<td>Oklahoma’s Priority Academic Student Skills (PASS) for Science</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>1995</td>
<td>Science Literacy for ALL Students: The Rhode Island State Science Framework</td>
</tr>
<tr>
<td>South Dakota</td>
<td>1999</td>
<td>South Dakota Science Standards</td>
</tr>
<tr>
<td>Tennessee</td>
<td>2001</td>
<td>Tennessee Science Curriculum Standards</td>
</tr>
<tr>
<td>Texas</td>
<td>1997</td>
<td>Chapter 112. Texas Essential Knowledge and Skills for Science</td>
</tr>
<tr>
<td>Utah</td>
<td>2002</td>
<td>Utah K-6 Elementary Science Core Curriculum; 2003 Utah Secondary Science Core Curriculum</td>
</tr>
<tr>
<td>Vermont</td>
<td>2000</td>
<td>Vermont’s 2000 Framework of Standards and Learning Opportunities</td>
</tr>
<tr>
<td>Virginia</td>
<td>2003</td>
<td>Science Standards of Learning for Virginia Public Schools</td>
</tr>
<tr>
<td>Washington</td>
<td>1998</td>
<td>The Essential Academic Learning Requirements in Science</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>1998</td>
<td>Wisconsin Model Academic Standards for Science</td>
</tr>
<tr>
<td>Wyoming</td>
<td>2003</td>
<td>Wyoming Science Content and Performance Standards</td>
</tr>
</tbody>
</table>

Align to Achieve offers a variety of online-search functions that can be utilized to explore the standards database. Two separate search processes were employed in the present study.

In the first stage, we performed an electronic search to identify state standard entries that were assigned one of the Compendix triplets corresponding to the 10 core evolution concepts from NSES. So in effect, 410 separate queries were performed – one for each of the 10 triplet codes in each of the 41 states with standards in the A2A database. To facilitate this process, Align to Achieve provided the researchers with access to an administrative database.

For a given state and triplet, this query could generate multiple “hits” (cataloged statements indexed against the triplet), one hit, or no hits. It should be noted that the indexing of entries in the A2A database by triplet codes is concept-dependent, not vocabulary-dependent. So a state need not use the same terminology as NSES (or the Compendix) to describe a particular evolution concept in order to generate a hit in this search.

### Step 4: Keyword Search of the A2A Database

The A2A Standards Database was constructed by analysts who reviewed state (and other) standards documents, subdivided these documents into discrete benchmark-sized entries, and indexed each entry using one or more Compendix triplet codes and a set of concept vocabulary terms. Particularly when entries contain compound statements capturing multiple closely-related concepts, the matter of indexing a particular entry may not be entirely straightforward. In order to accommodate any possible ambiguity that might have arisen in the indexing of standards as the database was being compiled, we performed a secondary search to complement the triplet-based search described above.

This second query involved a keyword search of the A2A database. For each of the 10 focal evolution concepts, we identified from one to three key terms or phrases related to that particular aspect of evolutionary theory. Exhibit 4 lists these keyword search terms, with the underlined portion of the term representing the exact search string used. Like the initial triplet search, this procedure generated a set of hits – state benchmarks containing the relevant keyword term. The hits from the two search stages were then pooled together for further examination in the final stage of our analysis.
Step 5: Vetting “Hits” from Electronic Searches to Identify “Matches”

Mechanistic search processes, such as those described above, are useful to the extent that they provide a way to conduct an automated, systematic query. However, such searches are also necessarily limited by the functional parameters of the search engine and the organization of the underlying database. As a result, it is possible – often inevitable – that some false hits will be generated. For instance, the Compendix index that organizes the A2A Standards Database often consists of statements that are more extensive than those appearing in the NSES or state benchmark entries. A Compendix statement related to evolution could, therefore, be cataloged according to multiple elements or subconcepts. Not all of these subconcepts will be relevant for our analysis.

Consequently, it is necessary to vet each individual hit from the electronic searches in order to determine whether it matches the evolution concept actually being targeted. A vetting rule or guideline was developed and applied for each of the 10 focal evolution concepts. These rules (reported in Exhibit 4) provide a transparent and uniform method for determining whether a mechanical “hit” generated by our search actually constitutes a “match” in terms of the content of the statement.

SUMMARY OF FINDINGS

Using the methodology described above, we performed an alignment analysis focusing on the evolution content of science education standards. That is, we determined the extent to which the science standards of a particular state captured the 10 core evolution concepts derived from NSES.

<table>
<thead>
<tr>
<th>Evolution Concept Label</th>
<th>A2A Triplet</th>
<th>Keyword Search Terms</th>
<th>Vetting Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common ancestry of species</td>
<td>4.3.4</td>
<td>evolutionary relationship common ancestry kinship</td>
<td>Benchmark notes common ancestry or evolutionary relationships among species (which may display surface dissimilarities).</td>
</tr>
<tr>
<td>Classification systems reflect evolutionary relationships</td>
<td>4.4.1</td>
<td>classification evolutionary relationship</td>
<td>Benchmark makes connection between biological classification systems and the evolutionary relationships among species. Link to classification can also be described in terms of degree of kinship, common descent, or common ancestry of species.</td>
</tr>
<tr>
<td>Variable effects of genetic change</td>
<td>5.4.4</td>
<td>value of characteristic mutation genetic change</td>
<td>Benchmark describes that genetic changes can have variable effects that relate to organism or species success.</td>
</tr>
<tr>
<td>Fossil record reflects changing life forms</td>
<td>9.3.1</td>
<td>fossil</td>
<td>Benchmark references the fossil record and changes in life forms over time (e.g., extinction, emergence of new species, or diversification of life).</td>
</tr>
<tr>
<td>Biological adaptation and survival</td>
<td>9.3.2</td>
<td>biological adaptation survival</td>
<td>Benchmark cites biological adaptation or survival. Benchmark does not need to mention evolution explicitly to receive credit.</td>
</tr>
<tr>
<td>Changes in environment</td>
<td>9.3.3</td>
<td>extinction environment survival</td>
<td>Benchmark relates changes in the environment to the process of extinction, survival, or adaptation.</td>
</tr>
<tr>
<td>Natural selection</td>
<td>9.4.2</td>
<td>natural selection</td>
<td>Benchmark references or describes natural selection. Credit for match awarded even for brief reference or citation of term “natural selection.”</td>
</tr>
<tr>
<td>Similarity among diverse species</td>
<td>9.4.3</td>
<td>diversity similarity common descent</td>
<td>Benchmark establishes clear connection between evolution and similarities among species.</td>
</tr>
<tr>
<td>Mechanisms of evolution</td>
<td>9.4.4</td>
<td>natural selection</td>
<td>Benchmark explicitly elaborates on the theory of evolution by citing or describing relevant mechanisms related to natural selection (e.g., environmental pressures, variation within species, adaptation, survival). At least one such mechanism must be cited. Credit not awarded for simply citing the term “natural selection.”</td>
</tr>
<tr>
<td>Timeframe of biological evolution</td>
<td>9.4.5</td>
<td>billion</td>
<td>Benchmark explicitly describes the time of the evolution of life forms as occurring over billions of years.</td>
</tr>
</tbody>
</table>
A detailed state-by-concept table presenting the results of our analysis appears in Exhibit 5. States are ranked by alignment score, indicating the number of NSES-derived evolution concepts covered in their respective standards.

We find that all of the 41 state standards examined in this analysis contain some content related to the theory of biological evolution. That is, each set of state standards contains language that aligns with at least one of the focal evolution concepts. Based on these results, we can conclude that none of these states completely excludes the topic of evolution from their standards. However, despite the fact that most experts consider evolution theory to be an essential element of science education, our findings reveal a
tremendous range in the extent of coverage that the various state standards afford to this topic.

No state scored a zero. However, the number of concepts reflected in the state standards ranges from a low of one to a high of 10. In the two states at the low end of the spectrum (New York, North Dakota), for example, coverage of evolution is limited to a single topic – the process of biological adaptation as it pertains to the survival of organisms and reproductive success. Another pair of states score matches for only two concepts. Standards in Kentucky likewise address the subject of adaptation, along with fossil-record evidence for evolution. In Montana, standards reference natural selection and the evolutionary relationships that underlie biological-classification systems.

At the opposite end of the scale, a “perfect” alignment score was received by four states – Arizona, Indiana, New Mexico, and Ohio. The science standards in these states capture all 10 of the focal evolutionary concepts. Most states, of course, fall somewhere between these extremes. In the average state, science education standards cover just over half (six) of the core topics identified from the NSES.

The particular combination of concepts covered by the states displays some variation, even among those receiving similar scores. An examination of the results reveals some interesting patterns (see Exhibit 6). For instance, some evolution concepts are covered in nearly all states, while others are included in the standards of only a handful of states. Among the evolution concepts examined, the topic of biological adaptation (triplet 9.3.2) was the most frequently encountered, appearing in the science standards of 39 out of 41 states analyzed. Over 30 states also provided some treatment of three other core concepts: natural selection as evidence of changing and evolving life forms (9.3.1); and the connection between environmental changes and the survival of species (9.3.3).

By contrast, fewer than half of the 41 state standards noted that evolution provides a basis for understanding that the common ancestry of different species accounts for their underlying similarities (4.3.4). Only six state science standards documents concretely describe the timeframe over which life forms have been shaped by evolution, a period of roughly 3.5 billion years. It should be added that some states offered vaguer references to evolution occurring over a “long” period of time, which our analysis did not credit as a match with the NSES standard. These latter findings are noteworthy because the age of the Earth and the length of time life has existed have been points of contention between proponents of evolutionary theory and “young earth” creationists. The latter adhere to a literal interpretation of the Bible, which would place the age of the Earth at about 6,000 years.

A separate keyword analysis was performed to determine whether states use the term “evolution” in the context of describing the biological process of change in organisms and species over time. This particular usage of the term is intended to distinguish statements related to the biological theory of evolution from those describing the history of the universe or geological processes. A number of states also employ the term “evolution” in the latter context. We found that only four states among the 41 analyzed did not mention the word “evolution” (or a related form such as “evolve”) in their standards: Florida, Illinois, Kentucky, and Oklahoma. In place of the term “evolution,” the standards in these states typically substituted an alternative word or phrase, such as “changes over time,” “diversity of species,” or “genetic diversity.” Two of these states (Florida, Oklahoma) nevertheless received alignment scores in the average range (7 and 5 respectively), despite the fact that their standards do not mention the word “evolution.”
This finding underscores an important methodological point mentioned earlier. Namely, the procedures used to catalog in the A2A database are not heavily dependent on the use of specific terminology. The critical factor underlying the state alignment scores is simply the representation of the respective evolution concept within the standards documents, in some form or another. In most cases, credit could be earned for having an aligned concept even by a very briefly worded state benchmark, provided that the relevant concept or term was cited in the appropriate context. Therefore, the methodology applied in this study does not inherently discriminate between outline-style standards that consist of short statements (sometimes a single word or phrase) and standards organized around longer passages of text.

**Conclusion**

This study offers one perspective on a critical but complex educational issue. Indeed, the teaching of evolution has often sparked controversy and has repeatedly become entangled in heavily politicized disputes. The current investigation should be viewed as a first step down a fruitful avenue along which researchers can continue to investigate the ways in which the theory of biological evolution has been incorporated in state science education standards. It would be interesting, for example, for analysts to return to this issue again once the states have implemented or revised their science standards as required by the federal NCLB legislation.

The present study has been careful to avoid making normative or qualitative statements about the treatment of evolution in state standards. We have assessed whether or not states address particular intellectual components of evolutionary theory in their standards. But we have offered no speculation as to whether, in a more subjective sense, a particular state’s coverage of these topics is either good or bad, adequate or inadequate, exemplary or disgraceful. To an analyst concerned with making such judgments, examples of all of the above could be found among the various state standards.

This observation raises a final issue that is worth mentioning briefly in closing. The alignment score received by a given state’s standards in this study does not necessarily reflect a deliberate attempt by the state to deal with the topic of biological evolution in a more or less thorough manner than other scientific principles. Some states have created highly skeletal standards documents in which scientific concepts are essentially listed like vocabulary words. In such cases, no individual issue receives in-depth treatment. By contrast, other states provide substantive explications of the ideas associated with evolution as well as a variety of other central issues in science. So it is important to reiterate that a low alignment score should not be interpreted as an intentional attempt to slight the theory of evolution. Evolution may very well receive equal (if brief) treatment compared with other topics.

There is, however, a broader issue to contemplate in this regard. Namely, one may ask to what extent any set of standards that treats expectations for important scientific knowledge in a highly abbreviated manner can serve as a useful touchstone for the stakeholders in our public schools – the educators who need to develop curricula and instructional strategies, parents who want to know what their children are expected to learn in school, and the public whose well-being in a society that grows more technologically sophisticated by the day will depend on the level of science literacy attained by the next generation.

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