SCIENCE

California

GRADE	SCORES		TOTAL SCORE
A	Content and Rigor	7/7	10/10
	Clarity and Specificity	3/3	

REPORT CARD

Content & Rigor	**6.7**
Scientific Inquiry & Methodology	5
Physical Science	7
Physics	7
Chemistry	7
Earth & Space Science	7
Life Science	7
Clarity & Specificity	**3.0**

Average numerical evaluations

Overview

The California science standards are truly excellent. The standards themselves are reasonably succinct yet quite comprehensive. This is especially true in high school chemistry, where topics are covered that are rarely seen in other K-12 standards documents. The continuity from grade to grade is superb, thanks in part to the introductory commentary and context that the state provides, which relate grade-specific learning to standards that have been covered in earlier grades, and those that will be covered later.

Organization of the Standards

The *Science Content Standards for California Public Schools* include grade-specific content for grades K-8. Grades K-5 cover earth and space sciences, life sciences, and physical sciences, all to varying degrees. Earth and space sciences are then focused on in sixth grade, life sciences in seventh grade, and physical sciences in eighth.

At the high school level, standards are presented by content area (rather than by grade) for physics, chemistry, biology/life sciences, and earth sciences.

Along with the content-specific standards, each grade level or high school content area includes a strand titled "investigation and experimentation," which acquaints students with the scientific method.

Building off the *Science Content Standards* is the *Science Framework for California Public Schools*. This document offers more background and explanation than the standards—including outlines for assessments, for professional development, and for special-education instruction. Specifically relevant to this review, chapters three through five of the *Framework* present detailed explanations of each of the standards, including clarifying examples.

These expansions are well done—almost like an abridged textbook. They are clear, systematic, and free of any really serious errors (though some small mistakes creep in).

Document(s) Reviewed[1]

- *Science Content Standards for California Public Schools*. 1998. Accessed from: http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf
- *Science Framework for California Public Schools*. 2005. Accessed from: http://www.cde.ca.gov/ci/cr/cf/documents/scienceframework.pdf

[1] California's academic content standards have not changed since Fordham's 2005 evaluation. However, the evaluation criteria used here have been updated and improved since 2005. (See Appendix A for a complete explanation of criteria used in this review.) Even through this new lens, California's science grade remained an impressive A. The complete 2005 review can be found here: http://www.edexcellence.net/publicationsissues/publications/sosscience05.html.

Content and Rigor

The authors of the California standards knew what was important to cover and how to set it down in cogent prose. The material is suitably rigorous throughout, with few, if any, gaps.

Scientific Inquiry and Methodology

In our last review, published in 2005, we noted:

> **On science processes, and on history and philosophy of science, California's standards vary delightfully from the norm: They are *brief*, there is no bombast, and they are realistic about the capacities of children for making sense of abstract ideas. Process is stressed where it should be, and in plain and appropriate language. For example: Grade 3: "Repeat observations to improve accuracy, and know that the results of similar scientific observations seldom turn out exactly the same. ...Differentiate evidence from opinion and know that scientists do not rely on conclusions unless they are backed by observations that can be confirmed."[2]**

This still holds. However, these otherwise exemplary standards make no mention of the historical and social aspects of the scientific endeavor from Kindergarten through eighth grade and do so only briefly in high school. There we read, for example, "Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings" and "Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent...and that the theory is sometimes wrong." While there is nothing wrong with this statement, it adds no particular value.

Physical Science

The coverage in physics, chemistry, and astronomy is thorough and logical, particularly in the primary-grade standards. The supporting material generally adds significant value across all grades. For instance, in physics (and to some extent in chemistry) the inclusion of mathematical statements is extensive, beginning in eighth grade.

While the standards are generally error-free and comprehensive, some gaffes occasionally appear in the frameworks. Take, for example, the following statement from the sixth-grade standards:

> **Energy can also be transferred by the movement of matter. For example, the energy supplied by the pitcher's arm transports a pitched baseball to the catcher's mitt. (grade 6)**

This explanation is somewhat garbled. What is important here is the energy transported from the pitcher's arm to the catcher's mitt (the catcher feels it in the impact), not the baseball itself.

Likewise, in eighth grade, students are told that "an experiment by Galileo resulted in the discovery of friction." Galileo discovered many important things, but friction wasn't one of them.

High School Physics

The high school physics standards can easily provide the foundation for an excellent course. Subjects are treated in logical order, with mathematical expressions used as necessary. Particularly remarkable (and, unfortunately, unusual in state science standards) is the excellent treatment of heat and thermodynamics. The treatment of the laws of thermodynamics (especially the first law) and of heat engines are far superior to any we have seen in other state science standards.

Curiously, though, some physics content is presented in the chemistry section, including radioactivity, fundamental particles (quarks, etc.), kinetic theory, and the gas laws.

Ampère's and Faraday's laws are not discussed explicitly, but there is some discussion of electromagnetic induction (changing magnetic fields produce electric fields) and its complement (changing electric fields produce magnetic fields).

A slip that is particularly curious in a California publication is this statement from the *Framework*:

> **The first accelerator was developed in the 1950s in Berkeley, California. (grades 9-12)**

Ernest O. Lawrence and his colleagues achieved fame at Berkeley in the 1930s for the development of the cyclotron, one of the earliest types of particle accelerators. But this statement seems to be the result of conflation of particle accelerators in general and the Bevatron, the first one to achieve energies sufficient to produce antiprotons.

The naming of the electron is attributed, incorrectly, to J. J. Thomson. The electron was actually named in 1891 by the Irish physicist G. Johnstone Stoney on theoretical grounds before it was actually observed.

[2] Paul R. Gross, *The State of State Science Standards 2005* (Washington, D.C.: Thomas B. Fordham Institute, 2005), http://www.edexcellence.net/publications-issues/publications/sosscience05.html.

High School Chemistry*

Chemical bonds are treated extensively and completely in high school, building upon the groundwork laid earlier. As noted above, kinetic theory and the gas laws are covered within the chemistry standards, but are well treated there. In particular, there is an explicit discussion of Boyle's and Charles's laws as special cases of the ideal gas law, with a table to show the conditions under which each is valid. Acid-base chemistry, solutions, and chemical equilibria are among the topics covered with elegance and clarity. For example:

> **Students should be able to compare the three descriptions of acids and bases—the Arrhenius, Brønsted-Lowry, and Lewis acid-base definitions—and recognize electron lone pairs on Lewis dot structures of molecules (see Standard Set 2, "Chemical Bonds," in this section). To calculate pH, students should understand and be able to use base-10 logarithms and antilogarithms and know how to obtain logarithms by using a calculator. Students should become proficient at converting between pH, pOH, [H] and [OH-]. (grades 9-12)**

Earth and Space Science*

Like so many of the California standards, the earth and space science standards are thorough and appropriately rigorous. They're not perfect, however.

One may legitimately carp, for example, at the "explanation" of the Coriolis force. The writers would do better to avoid explanation of complicated topics like this than to give incorrect ones.

The discussion of gravitation in the solar system in fifth grade has some confusing and incorrect statements. We read, "[The Sun's] mass can be calculated from the shapes of the planetary orbits ..." Not true. "Asteroids and comets are small bodies, most of which are in irregular orbits about the Sun." Not unless an eccentric ellipse counts as "irregular."

But these rare confusions are more than balanced by admirable statements, such as this one in sixth grade: "Students know how to determine the epicenter of an earthquake and know that the effects of an earthquake on any region vary, depending on the size of the earthquake, the distance of the region from the epicenter, the local geology, and the type of construction in the region." This example is semi-quantitative, involves practical knowledge, and deals with earthquakes as phenomenon.

Life Science

The life sciences are equally strong. Evolution is well presented as the central organizing principle of the life sciences, with good cross-references to geology, paleontology, and cosmology. Treatment of genetics and population genetics, and the development of contemporary evolutionary biology in the context of the latter, are sound, timely, and clearly written. Fossils and the fossil record are introduced thoughtfully in second, third, and sixth grades. But given the otherwise careful selection of important implications of the main science themes—including the key themes of biology—it is perplexing that human evolution is never explicitly mentioned, though it is clearly implied in the broad sweep of life science content covered.

As one can see from the examples cited above, the California standards are not completely free from error. But these are such minor errors with so little impact on the whole, that we do not hesitate in assigning a perfect score—seven out of seven—to the whole for content and rigor. (See Appendix A: Methods, Criteria, and Grading Metric.)

Clarity and Specificity

Not only are statements set forth clearly and cogently, with very few exceptions, but the entire document shows a solid sense of interconnection. One topic flows into another in transparent fashion, showing that the writers knew their subject matter well. The California science standards easily earn a perfect score of three out of three for clarity and specificity. (See Appendix A: Methods, Criteria, and Grading Metric.)

* Two of our reviewers, Martha Schwartz and Rick Schwartz, contributed to the writing of the California science standards. Therefore, these reviewers abstained from commenting on the documents. Lead reviewer Lawrence Lerner, along with the others on the team, reviewed the chemistry and earth and space science sections in their stead.