EARTH SCIENCE Content Standards for California Public Schools

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Table of Contents

Message from the State Board of Education and the State Superintendent of Public Instruction

In 1983 the report *A Nation at Risk: The Imperative for Educational Reform,* by the National Commission on Excellence in Education (1983), brought squarely to our attention a "rising tide of mediocrity" in our schools. An era of education reform began. The results were somewhat uneven. The reform movement did stimulate important infrastructure improvements: instructional time was increased, high school diplomas came to signify the completion of minimum course requirements, and emphasis was placed on local planning efforts to improve the schools' efficiency and effectiveness. A shortcoming of the movement up to this point has been the lack of focus on rigorous academic standards. The desire to improve student achievement guided the effort, but it lacked a comprehensive, specific vision of what students actually needed to know and be able to do.

Standards are a bold initiative. With the adoption of these content standards in science, California is going *beyond reform*. We are redefining the state's role in public education. For the first time, we are stating - explicitly - the content that students need to acquire at each grade level through grade eight and in grades nine through twelve. These standards are rigorous. With student mastery of this content, California schools will be on a par with those in the best educational systems in other states and nations. The content is attainable by all students, given sufficient time, except for those few who have severe disabilities. We regard the standards as firm but not unyielding; they will be modified in future years to reflect new research and scholarship.

Standards describe what to teach, not how to teach it. Standards-based education maintains California's tradition of respect for local control of schools. To help students achieve at high levels, local school officials and teachers - with the full support and cooperation of families, businesses, and community partners - are encouraged to take these standards and design the specific curricular and instructional strategies that best deliver the content to their students.

Standards are an enduring commitment, not a passing fancy. Every initiative in public education, especially one so bold as establishing high standards, has its skeptics. "Just wait a while," they say, "and standards, too, will pass." We intend to prove the skeptics wrong, and we intend to do that by completely aligning state efforts to these standards, including the statewide testing program, curriculum frameworks, instructional materials, professional development, preservice education, and compliance review. We will see a generation of educators who think of standards not as a *new layer* but as the *foundation* itself.

Standards are our commitment to excellence. Fifteen years from now, we are convinced, the adoption of standards will be viewed as the signal event that began a "rising tide of excellence" in our schools. No more will the critical question *What should my child be learning?* be met with uncertainty of knowledge, purpose, or resolve. These standards answer the question. They are comprehensive and specific. They represent our commitment to excellence.

Yvonne W. Larsen, President
California State Board of Education

Delaine Eastin
State Superintendent of Public Instruction

Introduction to the Science Content Standards

The *Science Content Standards for California Public Schools, Kindergarten Through Grade Twelve* represents the content of science education and includes the essential skills and knowledge students will need to be scientifically literate citizens in the twenty-first century. By adopting these standards, the State Board of Education affirms its commitment to provide a world-class science education for all California students. These standards reflect the diligent work and commitment of the Commission for the Establishment of Academic Content and Performance Standards (Academic Standards Commission) and the commission's Science Committee to define the common academic content of science education at every grade level.

Glenn T. Seaborg, one of the great scientific minds of this time and of all times, chaired the Academic Standards Commission's Science Committee. In "A Letter to a Young Scientist," Dr. Seaborg said, "Science is an organized body of knowledge and a method of proceeding to an extension of this knowledge by hypothesis and experiment."[1] *The National Science Education Standards* reflects this view of science and the balance between the "body of knowledge" and the "method" of scientific inquiry.[2] The standards provide the opportunity to make substantial and significant improvements in California's education system.

The standards include grade-level specific content for kindergarten through grade eight. A significant feature is the focus on earth science in the sixth grade, life science in the seventh grade, and physical science in the eighth grade. The standards for grades nine through twelve are divided into four content strands: physics, chemistry, biology/life sciences, and earth sciences. An Investigation and Experimentation strand describes a progressive set of expectations for each grade from kindergarten through grade eight, and one set of Investigation and Experimentation standards is given for grades nine through twelve.

The elementary and middle school standards provide the foundational skills and knowledge for students to learn core concepts, principles, and theories of science at the high school level. The standards are organized in sets under broad concepts. This organization is intended to help the reader move between topics and follow them as the content systematically increases in depth, breadth, and complexity through the grade levels.

The *Science Content Standards* serves as the basis of statewide student assessments, the science curriculum framework, and the evaluation of instructional materials. *The Science Framework for California Public Schools* is being revised to align with the standards. The framework will suggest ways in which to use the standards and make connections within and across grades; it will also provide guidance for instructional planning. However, the standards do not prescribe the methods of instruction. Students should have the opportunity to learn science by receiving direct instruction, by reading textbooks and supplemental materials, by solving standards-based problems, and by doing laboratory investigations and experiments. The Investigation and Experimentation standards should be integral to, and directly and specifically support, the teaching of the content strands and disciplines.

Development of the Standards

The California State Board of Education and the Academic Standards Commission reviewed the *National Science Education Standards,* the *Benchmarks for Science Literacy,*[3] and science standards and frameworks from numerous local school districts in California, from around the country, and from other nations with successful science education programs. In addition, hundreds of pages of written recommendations and hundreds of hours of testimony were considered. The Academic Standards Commission hosted nine community meetings, and the State Board of Education held five public hearings throughout California. Parents (guardians), teachers, school administrators, and business and community leaders participated and helped define key issues. Expert reviewers around the nation submitted formal comments on the drafts and also participated in invited public testimony. Their ideas contributed substantively to the final standards adopted by the State Board of Education.

Highlights of the Standards

These science standards will challenge not only California's students but also the entire K-12 education system. The elementary school standards call for early introduction of science facts and terms and will challenge the multiple-subject teacher to find time in the school day for science education. Quality textbooks and reading materials in science can support students in mastering these standards as they develop their reading skills and vocabulary. The Investigation and Experimentation standards should be implemented to allow students to make a concrete association between science and the study of nature as well as provide them with many opportunities to take measurements and use their basic mathematical skills.

The middle school science standards, with emphasis on the disciplines at each grade level, are intended to raise the bar substantially for students. Many teachers, schools, and districts will need to restructure their curriculum to meet these standards. The *Science Content Standards* provides educators with the opportunity to make the middle school curriculum more rigorous in response to a national call for excellence and better prepare these students for in-depth study of science at the high school level.

The high school science standards require more than two years of science courses for students to achieve the breadth and depth described. Schools and districts will be challenged to develop a science curriculum that meets the needs of their students and provides them the maximum opportunity to learn the standards while encouraging students to study further in science. In grades nine through twelve, standards that all students are *expected to achieve* in their science courses are unmarked; standards that all students should have *the opportunity to learn* in those courses are marked with an asterisk (*). Those opportunities should be offered at every high school.

The *Science Content Standards* reflects the desired content of science curriculum in California public schools. This content should be taught so that students have the opportunity to build connections that link science to technology and societal impacts. Science, technology, and societal issues are strongly connected to community health, population, natural resources, environmental quality, natural and human-induced hazards, and other global challenges. The standards should be viewed as the foundation for understanding these issues.

Time and considerable resources will be needed to implement the *Science Content Standards.* But the goal is clear, and the process of implementing the standards should start immediately.

[1]*Gifted Young in Science: Potential Through Performance.* Edited by Paul Brandwein and others. Arlington, Va.: National Science Teachers Association, 1989.
[2]National Academy of Sciences, *National Science Education Standards.* Washington, D. C.: National Academy of Sciences, 1995.
[3]American Association for the Advancement of Science staff, *Benchmarks for Science Literacy.* New York: Oxford University Press, 1994.

Kindergarten

3. Earth is composed of land, air, and water. As a basis for understanding this concept:
   a. *Students know* characteristics of mountains, rivers, oceans, valleys, deserts, and local landforms.
   b. *Students know* changes in weather occur from day to day and across seasons, affecting Earth and its inhabitants.
   c. *Students know* how to identify resources from Earth that are used in everyday life and understand that many resources can be conserved.

Investigation and Experimentation

4. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
   a. Observe common objects by using the five senses.
   b. Describe the properties of common objects.
   c. Describe the relative position of objects by using one reference (e.g., above or below).
   d. Compare and sort common objects by one physical attribute (e.g., color, shape, texture, size, weight).
   e. Communicate observations orally and through drawings.

Grade One

3. Weather can be observed, measured, and described. As a basis for understanding this concept:
   a. *Students know* how to use simple tools (e. g., thermometer, wind vane) to measure weather conditions and record changes from day to day and across the seasons.
   b. *Students know* that the weather changes from day to day but that trends in tem-perature or of rain (or snow) tend to be predictable during a season.
   c. *Students know* the sun warms the land, air, and water.

Investigation and Experimentation

4. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
   a. Draw pictures that portray some features of the thing being described.
   b. Record observations and data with pictures, numbers, or written statements.
   c. Record observations on a bar graph.
   d. Describe the relative position of objects by using two references (e. g., above and next to, below and left of).
   e. Make new observations when discrepancies exist between two descriptions of the same object or phenomenon.

Grade Two

3. Earth is made of materials that have distinct properties and provide resources for human activities. As a basis for understanding this concept:
   a. *Students know* how to compare the physical properties of different kinds of rocks and know that rock is composed of different combinations of minerals.
   b. *Students know* smaller rocks come from the breakage and weathering of larger rocks.

c. *Students know* that soil is made partly from weathered rock and partly from organic materials and that soils differ in their color, texture, capacity to retain water, and ability to support the growth of many kinds of plants.
d. *Students know* that fossils provide evidence about the plants and animals that lived long ago and that scientists learn about the past history of Earth by studying fossils.
e. *Students know* rock, water, plants, and soil provide many resources, including food, fuel, and building materials, that humans use.

Investigation and Experimentation

4. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
   a. Make predictions based on observed patterns and not random guessing.
   b. Measure length, weight, temperature, and liquid volume with appropriate tools and express those measurements in standard metric system units.
   c. Compare and sort common objects according to two or more physical attributes (e. g., color, shape, texture, size, weight).
   d. Write or draw descriptions of a sequence of steps, events, and observations.
   e. Construct bar graphs to record data, using appropriately labeled axes.
   f. Use magnifiers or microscopes to observe and draw descriptions of small objects or small features of objects.
   g. Follow oral instructions for a scientific investigation.

Grade Three

4. Objects in the sky move in regular and predictable patterns. As a basis for under-standing this concept:
   a. *Students know* the patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.
   b. *Students know* the way in which the Moon's appearance changes during the four-week lunar cycle.
   c. *Students know* telescopes magnify the appearance of some distant objects in the sky, including the Moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than the number that can be seen by the unaided eye.
   d. *Students know* that Earth is one of several planets that orbit the Sun and that the Moon orbits Earth.
   e. *Students know* the position of the Sun in the sky changes during the course of the day and from season to season.

Investigation and Experimentation

5. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
   a. Repeat observations to improve accuracy and know that the results of similar scientific investigations seldom turn out exactly the same because of differences in the things being investigated, methods being used, or uncertainty in the observation.
   b. Differentiate evidence from opinion and know that scientists do not rely on claims or conclusions unless they are backed by observations that can be confirmed.
   c. Use numerical data in describing and comparing objects, events, and measurements.
   d. Predict the outcome of a simple investigation and compare the result with the prediction.
   e. Collect data in an investigation and analyze those data to develop a logical conclusion.

Grade Four

4. The properties of rocks and minerals reflect the processes that formed them. As a basis for understanding this concept:
    a. *Students know* how to differentiate among igneous, sedimentary, and metamorphic rocks by referring to their properties and methods of formation (the rock cycle).
    b. *Students know* how to identify common rock-forming minerals (including quartz, calcite, feldspar, mica, and hornblende) and ore minerals by using a table of diagnostic properties.
    c. Waves, wind, water, and ice shape and reshape Earth's land surface. As a basis for understanding this concept:
    d. *Students know* some changes in the earth are due to slow processes, such as erosion, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.
    e. *Students know* natural processes, including freezing and thawing and the growth of roots, cause rocks to break down into smaller pieces.
    f. *Students know* moving water erodes landforms, reshaping the land by taking it away from some places and depositing it as pebbles, sand, silt, and mud in other places (weathering, transport, and deposition).

Investigation and Experimentation

6. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
    a. Differentiate observation from inference (interpretation) and know scientists' explanations come partly from what they observe and partly from how they interpret their observations.
    b. Measure and estimate the weight, length, or volume of objects.
    c. Formulate and justify predictions based on cause-and-effect relationships.
    d. Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.
    e. Construct and interpret graphs from measurements.
    f. Follow a set of written instructions for a scientific investigation.

Grade Five

3. Water on Earth moves between the oceans and land through the processes of evaporation and condensation. As a basis for understanding this concept:
    a. *Students know* most of Earth's water is present as salt water in the oceans, which cover most of Earth's surface.
    b. *Students know* when liquid water evaporates, it turns into water vapor in the air and can reappear as a liquid when cooled or as a solid if cooled below the freezing point of water.
    c. *Students know* water vapor in the air moves from one place to another and can form fog or clouds, which are tiny droplets of water or ice, and can fall to Earth as rain, hail, sleet, or snow.
    d. *Students know* that the amount of fresh water located in rivers, lakes, under-ground sources, and glaciers is limited and that its availability can be extended by recycling and decreasing the use of water.
    e. *Students know* the origin of the water used by their local communities.
4. Energy from the Sun heats Earth unevenly, causing air movements that result in changing weather patterns. As a basis for understanding this concept:
    a. *Students know* uneven heating of Earth causes air movements (convection cur-rents).
    b. *Students know* the influence that the ocean has on the weather and the role that the water cycle plays in weather patterns.

c. *Students know* the causes and effects of different types of severe weather. d. *Students know* how to use weather maps and data to predict local weather and know that weather forecasts depend on many variables.
d. *Students know* that the Earth's atmosphere exerts a pressure that decreases with distance above Earth's surface and that at any point it exerts this pressure equally in all directions.

5. The solar system consists of planets and other bodies that orbit the Sun in predict-able paths. As a basis for understanding this concept:
   a. *Students know* the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.
   b. *Students know* the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.
   c. *Students know* the path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.

Investigation and Experimentation

6. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
   a. Classify objects (e.g., rocks, plants, leaves) in accordance with appropriate criteria.
   b. Develop a testable question.
   c. Plan and conduct a simple investigation based on a student-developed question and write instructions others can follow to carry out the procedure.
   d. Identify the dependent and controlled variables in an investigation.
   e. Identify a single independent variable in a scientific investigation and explain how this variable can be used to collect information to answer a question about the results of the experiment.
   f. Select appropriate tools (e.g., thermometers, meter sticks, balances, and graduated cylinders) and make quantitative observations.
   g. Record data by using appropriate graphic representations (including charts, graphs, and labeled diagrams) and make inferences based on those data.
   h. Draw conclusions from scientific evidence and indicate whether further information is needed to support a specific conclusion.
   i. Write a report of an investigation that includes conducting tests, collecting data or examining evidence, and drawing conclusions.

Grade Six – Focus on Earth Science

Plate Tectonics and Earth's Structure

1. Plate tectonics accounts for important features of Earth's surface and major geologic events. As a basis for understanding this concept:
   a. *Students know* evidence of plate tectonics is derived from the fit of the continents; the location of earthquakes, volcanoes, and mid-ocean ridges; and the distribution of fossils, rock types, and ancient climatic zones.
   b. *Students know* Earth is composed of several layers: a cold, brittle lithosphere; a hot, convecting mantle; and a dense, metallic core.
   c. *Students know* lithospheric plates the size of continents and oceans move at rates of centimeters per year in response to movements in the mantle.
   d. *Students know* that earthquakes are sudden motions along breaks in the crust called faults and that volcanoes and fissures are locations where magma reaches the surface.
   e. *Students know* major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.

f. *Students know* how to explain major features of California geology (including mountains, faults, volcanoes) in terms of plate tectonics.
g. *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.

Shaping Earth's Surface

2. Topography is reshaped by the weathering of rock and soil and by the transportation and deposition of sediment. As a basis for understanding this concept:
   a. *Students know* water running downhill is the dominant process in shaping the landscape, including California's landscape.
   b. *Students know* rivers and streams are dynamic systems that erode, transport sediment, change course, and flood their banks in natural and recurring patterns.
   c. *Students know* beaches are dynamic systems in which the sand is supplied by rivers and moved along the coast by the action of waves.
   d. *Students know* earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.

Heat (Thermal Energy) (Physical Science)

3. Heat moves in a predictable flow from warmer objects to cooler objects until all the objects are at the same temperature. As a basis for understanding this concept:
   a. *Students know* energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.
   b. *Students know* that when fuel is consumed, most of the energy released becomes heat energy.
   c. *Students know* heat flows in solids by conduction (which involves no flow of matter) and in fluids by conduction and by convection (which involves flow of matter).
   d. *Students know* heat energy is also transferred between objects by radiation (radiation can travel through space).

Energy in the Earth System

4. Many phenomena on Earth's surface are affected by the transfer of energy through radiation and convection currents. As a basis for understanding this concept:
   a. *Students know* the sun is the major source of energy for phenomena on Earth's surface; it powers winds, ocean currents, and the water cycle.
   b. *Students know* solar energy reaches Earth through radiation, mostly in the form of visible light.
   c. *Students know* heat from Earth's interior reaches the surface primarily through convection.
   d. *Students know* convection currents distribute heat in the atmosphere and oceans.
   e. *Students know* differences in pressure, heat, air movement, and humidity result in changes of weather.

Ecology (Life Science)

5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment. As a basis for understanding this concept:
   a. *Students know* energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis and then from organism to organism through food webs.
   b. *Students know* matter is transferred over time from one organism to others in the food web and between organisms and the physical environment.
   c. *Students know* populations of organisms can be categorized by the functions they serve in an ecosystem.
   d. *Students know* different kinds of organisms may play similar ecological roles in similar biomes.

e. *Students know* the number and types of organisms an ecosystem can support depends on the resources available and on abiotic factors, such as quantities of light and water, a range of temperatures, and soil composition.

Resources

6. Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation. As a basis for understanding this concept:
   a. *Students know* the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.
   b. *Students know* different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable.
   c. *Students know* the natural origin of the materials used to make common objects.

Investigation and Experimentation

7. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
   a. Develop a hypothesis.
   b. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
   c. Construct appropriate graphs from data and develop qualitative statements about the relationships between variables.
   d. Communicate the steps and results from an investigation in written reports and oral presentations.
   e. Recognize whether evidence is consistent with a proposed explanation.
   f. Read a topographic map and a geologic map for evidence provided on the maps and construct and interpret a simple scale map.
   g. Interpret events by sequence and time from natural phenomena (e.g., the relative ages of rocks and intrusions).
   h. Identify changes in natural phenomena over time without manipulating the phenomena (e.g., a tree limb, a grove of trees, a stream, a hillslope).