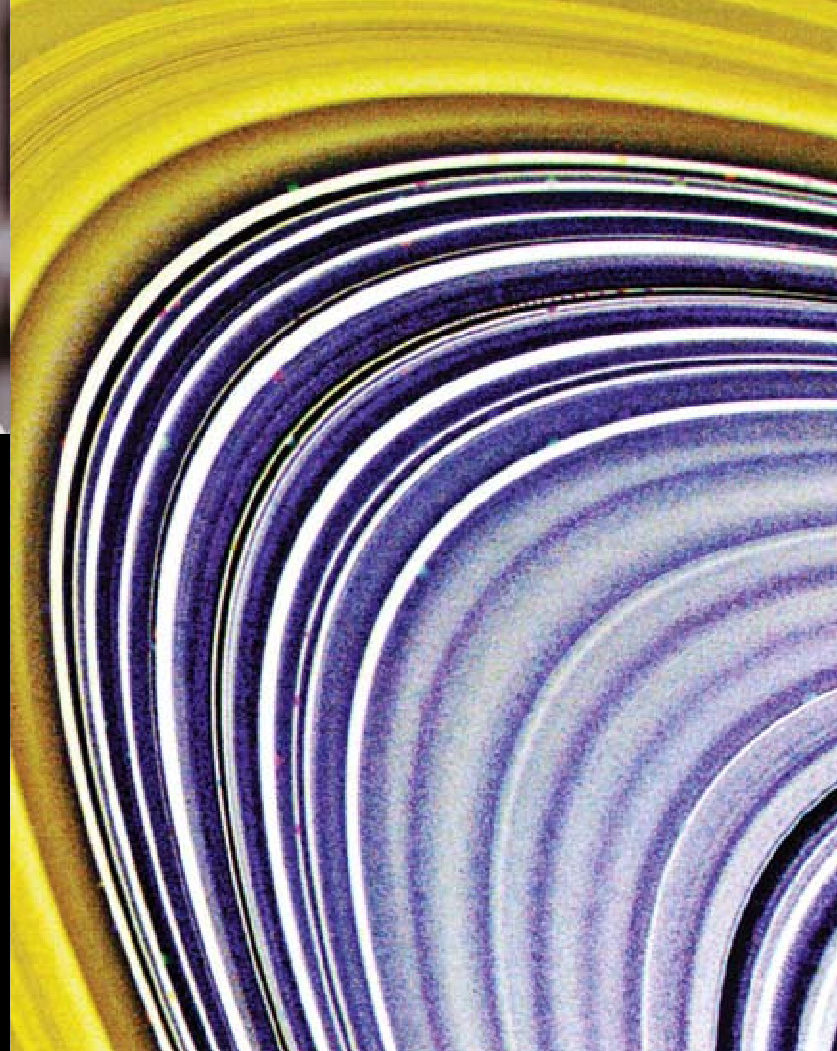
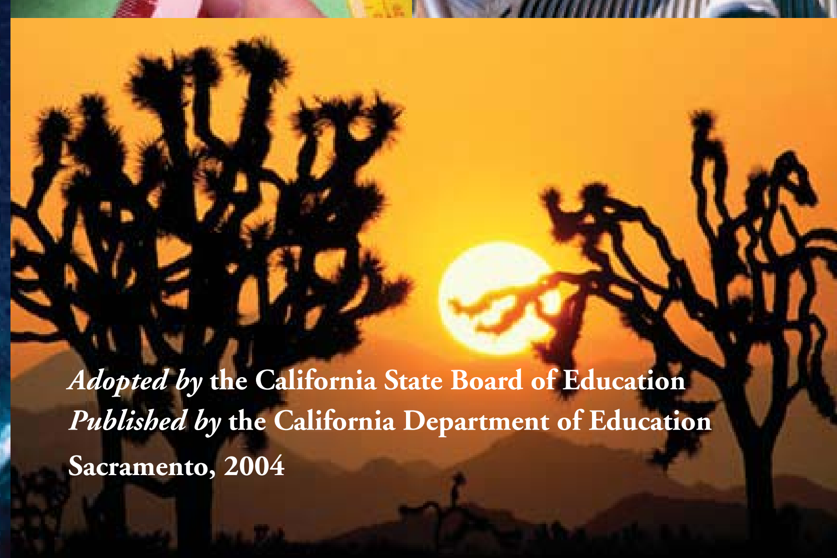


Science Framework for California Public Schools

Kindergarten Through Grade Twelve

With New Criteria for Instructional Materials



Adopted by the California State Board of Education
Published by the California Department of Education
Sacramento, 2004

Science Framework for California Public Schools

Kindergarten Through Grade Twelve

With New Criteria for Instructional Materials

Developed by the
Curriculum Development and Supplemental Materials Commission

Adopted by the
California State Board of Education

Published by the
California Department of Education

Publishing Information

On March 10, 2004, the California State Board of Education approved the modified *Criteria for Evaluating Instructional Materials in Science, Kindergarten Through Grade Eight,* The following persons were serving on the State Board at that time: Reed Hastings, President; Joe Nuñez, Vice President; Ruth Bloom; Don Fisher; Ruth E. Green; Glee Johnson; Jeannine Martineau; Bonnie Reiss; Suzanne Tacheny; Johnathan Williams. The new criteria are included in this edition of the framework.

When the *Science Framework for California Public Schools: Kindergarten Through Grade Twelve* was adopted by the California State Board of Education on February 6, 2002, the members of the State Board were the following: Reed Hastings, President; Joe Nuñez, Vice-President; Robert Abernethy; Donald G. Fisher; Susan Hammer; Nancy Ichinaga; Carlton Jenkins; Marion Joseph; Vicki Reynolds; Suzanne Tacheny; and Erika Goncalves.

The framework was developed by the Curriculum Development and Supplemental Materials Commission. (See pages vi–viii for the names of the members of the commission and the names of the principal writers and others who made significant contributions to the framework.)

This publication was edited by Faye Ong and Janet Lundin, working in cooperation with Greg Geeting, Assistant Executive Director, State Board of Education; Tom Adams, Administrator, and Christopher Dowell, Education Programs Consultant, Curriculum Frameworks and Instructional Resources Division, California Department of Education. It was designed and prepared for printing by the staff of CDE Press, with the cover and interior design created and prepared by Paul Lee. Typesetting was done by Jeannette Huff and Carey Johnson. The framework was published by the Department of Education, 1430 N Street, Sacramento, California 95814-5901. It was distributed under the provisions of the Library Distribution Act and *Government Code* Section 11096.

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Contents

Foreword

"The education of young people in science is at least as important, maybe more so, than the research itself."

—Glenn T. Seaborg

In 1998, with the adoption of the *Science Content Standards for California Public Schools*, California made a commitment that we will provide all students a world-class science education. Now, more than ever before, our students need a high degree of science literacy. This updated edition of the *Science Framework for California Public Schools* builds on the content standards, provides guidance for the education community to achieve that objective, and includes the 2004 evaluation criteria for the kindergarten-through-grade-eight instructional materials adopted by the State Board of Education. This framework is California's blueprint for our science curriculum, instruction, professional preparation and development, and instructional materials.

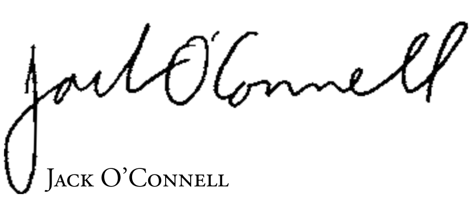
The framework offers guidance for science instruction in elementary, middle, and high schools. In kindergarten through grade five, students receive a solid foundation and acquire basic knowledge regarding physical, life, and earth sciences as well as learn investigation and experimentation skills.

Science instruction increases in depth and complexity in the middle grades, where the emphasis is on one science strand each year. In grade six, students focus on earth sciences; in grade seven, on life sciences; and in grade eight, on physical sciences. The investigation and experimentation standards increase in sophistication in the middle grades and require students to formulate a hypothesis for the first time, communicate the logical connections among hypotheses, and apply their knowledge of mathematics to analyze and report on data from their experiments.

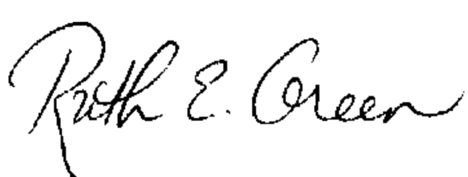
At the high school level, science content is presented as four separate strands—physics, chemistry, biology/life sciences, and earth sciences—each providing students the rigor they need to prepare for collegiate-level study and career pathways. Both the content standards and the framework are designed so that the standards can be organized either as strand-specific courses or as courses that draw content from several strands. The high school investigation and experimentation standards ensure that students have experience in a laboratory setting.

The framework addresses a number of audiences—teachers, administrators, instructional materials developers, professional development providers, parents, guardians, and students. It makes the important point that science education must take place in conjunction with other core subjects, not in isolation from them.

This document establishes guiding principles that define the attributes of a quality science curriculum at all grade levels. The framework reflects the fundamental belief that all students can acquire the science knowledge and skills needed to succeed in the world that awaits them.



Jack O'Connell
State Superintendent of Public Instruction



Ruth E. Green
President, California State Board of Education

Acknowledgments

When the *Criteria for Evaluating Instructional Materials in Science, Kindergarten Through Grade Eight* was adopted by the California State Board of Education on March 10, 2004, the following persons were serving on the State Board:

Reed Hastings, President
Joe Nuñez, Vice President
Ruth Bloom, Member
Don Fisher, Member
Ruth E. Green, Member
Glee Johnson, Member
Jeannine Martineau, Member
Bonnie Reiss, Member
Suzanne Tacheny, Member
Johnathan Williams, Member

The new criteria are included in this version of the framework.

Members of the Curriculum Development and Supplemental Materials Commission (Curriculum Commission) serving at the time the criteria were recommended for approval to the State Board were:

Edith Crawford, San Juan Unified School District, *Chair*

Norma Baker, Los Angeles Unified School District, *Vice Chair*

William D. Brakemeyer, Fontana Unified School District

Milissa Glen-Lambert, Los Angeles Unified School District

Kerry Hamill, Oakland Unified School District,

Deborah Keys, Oakland Unified School District

Wendy Levine, Inglewood Unified School District

Sandra Mann, San Diego City Unified School District

Julie Maravilla, Los Angeles Unified School District

Michael Matsuda, Anaheim Union High School District

Mary-Alicia McRae, Salinas City Elementary School District

Stan Metzenberg, California State University, Northridge

Charles Munger, Stanford Linear Accelerator Center

Rosa Perez, Canada College

Joseph (Jose) Velasquez, Los Angeles Unified School District

Richard Wagoner, Los Angeles Unified School District

Members of the Science Subject Matter Committee of the Curriculum Commission responsible for overseeing the development of the *Criteria for Evaluating Instructional Materials in Science, Kindergarten Through Grade Twelve* were:

Sandra Mann, San Diego City Unified School District, *Chair*

Charles Munger, Stanford Linear Accelerator Center, *Vice Chair*

Michael Matsuda, Anaheim Union High School District

Stan Metzenberg, California State University, Northridge

Richard Wagoner, Los Angeles Unified School District

Special appreciation is extended to:

Rae Belisle, Executive Director, State Board of Education, for her leadership and collaboration with representatives from the state science community in revising the criteria

Sue Stickel, Deputy Superintendent, Curriculum and Instruction Branch, California Department of Education, for her assistance in revising the criteria

Note: The titles and affiliations of persons named in this list were current at the time the document was developed.

The development of the *Science Framework* involved the effort, dedication, and expertise of many individuals. The original draft of the framework was prepared between October 1998 and December 2000 by the Science Curriculum Framework and Criteria Committee (CFCC), a diverse group that included teachers and school administrators, university faculty, representatives of the business community, and parents (guardians) of students in public schools. The State Board of Education and the Curriculum Commission commend the following members of the Science CFCC and extend great appreciation to them:

Michael Rios, Montebello Unified School District, *Chair*

Richard Berry, San Diego State University, *Vice Chair*

Wallace Boggess, Simi Valley Unified School District

Robert Bornick, California State University, Northridge

Liselle Clark, Stockton Unified School District

Richard Feay, Los Angeles Unified School District

Jonathan Frank, San Francisco Unified School District

Hanna Hoffman, San Jose, California

Rita Hoots, Yuba College

G. Bradley Huff, Fresno County Office of Education

Linda Kenyon, Ceres Unified School District

Mary Kiely, Stanford University

Janet Kruse, Discovery Museum, Sacramento, California

Charles Munger, Stanford University

Eric Norman, Lawrence Berkeley National Laboratory

Keith Nuthall, Poway Unified School District

Lynda Rogers, San Lorenzo Unified School District

Ursula Sexton, San Ramon Unified School District

Steve Shapiro, Los Angeles, California

Jody Skidmore, North Cow Creek Elementary School District

William Tarr, Los Angeles Unified School District

Lane Therrell, Placerville, California

Commendation and appreciation are also extended to the principal writers of the *Science Framework:*

Roland (Rollie) Otto, Center for Science and Engineering Education, Lawrence Berkeley National Laboratory

Kathleen Scalise, Lawrence Hall of Science, University of California, Berkeley

Lynn Yarris, Lawrence Berkeley National Laboratory

The members of the Curriculum Commission's Science Subject Matter Committee (SMC), along with 2001 Curriculum Commission Chair **Patrice Abarca,** provided outstanding leadership in overseeing the development and editing of the *Science Framework:*

Richard Schwartz, Torrance Unified School District, *Science SMC Chair*

Veronica Norris, Tustin, California, *Science SMC Vice Chair*

Catherine Banker, Upland, California

Edith Crawford, San Juan Unified School District

Viken "Vik" Hovsepian, Glendale Unified School District

Other members of the Curriculum Commission who were serving at the time the *Science Framework* was recommended for approval to the State Board were:

Patrice Abarca, Los Angeles Unified School District, *2001 Chair*

Roy Anthony, Grossmont Union High School District

Marilyn Astore, Sacramento County Office of Education, *2000 Chair*

Rakesh Bhandari, Los Altos, California

Mary Coronado Calvario, Sacramento City Unified School District

Milissa Glen-Lambert, Los Angeles Unified School District

Lora L. Griffin, Retired Educator, Sacramento City Unified School District

Janet Philibosian, Los Angeles Unified School District

Leslie Schwarze, Trustee, Novato Unified School District

Susan Stickel, Elk Grove Unified School District, *2001 Vice Chair*

Karen S. Yamamoto, Washington Unified

School District

Other individuals who served on the Curriculum Commission during the period of the *Science Framework's* development (1999-2000) were:

Eleanor Brown, San Juan Unified School District, *1999 Chair*

Ken Dotson, Turlock Joint Elementary School District

Lisa Jeffery, Los Angeles Unified School District

Joseph Nation, San Rafael, California

Barbara Smith, San Rafael City Elementary and High School District

Sheri Willebrand, Ventura Unified School District

The Curriculum Commission and its Science SMC received outstanding support and assistance from the State Board's curriculum liaison, **Marion Joseph.**

Final revision and editing of the *Science Framework* were conducted under the oversight of the State Board's science liaison, **Robert J. Abernethy,** who was assisted by **Greg Geeting,** Assistant Executive Director of the State Board, and **Charles Munger,** Stanford University.

During the review process, the Science SMC was aided by the following individuals who provided technical advice on science content issues:

Douglas E. Hammond, University of Southern California

William Hamner, University of California, Los Angeles

Eric Kelson, California State University, Northridge

George I. Matsumoto, Monterey Bay Aquarium Research Institute

Stan Metzenberg, California State University, Northridge

Martha Schwartz, University of Southern California

Steve Strand, University of California, Los Angeles

California Department of Education staff members who contributed to the *Science Framework's* development included:

Joanne Mendoza, Deputy Superintendent, Curriculum and Instructional Leadership Branch

Sherry Skelly Griffith, Director, Curriculum Frameworks and Instructional Resources Division

Thomas Adams, Administrator, Curriculum Frameworks Unit, Curriculum Frameworks and Instructional Resources Division

Christopher Dowell, Education Programs Consultant, Curriculum Frameworks Unit

Rona Gordon, Education Programs Consultant, Child, Youth, and Family Services Branch

Diane Hernandez, Education Programs Consultant, Standards and Assessment Division

Barbara Jeffus, School Library Consultant, Curriculum Frameworks Unit

Phil Lafontaine, Education Programs Consultant, Professional Development and Curriculum Support Division

Martha Rowland, Education Programs Consultant, Curriculum Frameworks Unit

Stacy Sinclair, Education Programs Consultant, Curriculum Frameworks Unit

Mary Sprague, Education Programs Consultant, Education Technology Office

William Tarr, Education Programs Consultant, Standards and Assessment Division

Deborah Tucker, Education Programs Consultant, Professional Development and Curriculum Support Division

Christine Bridges, Analyst, Curriculum Frameworks Unit

Belen Mercado, Analyst, Curriculum Frameworks Unit

Teri Ollis, Analyst, Curriculum Frameworks Unit

Lino Vicente, Analyst, Curriculum Frameworks Unit

Tracie Yee, Analyst, Curriculum Frameworks Unit

Tonya Odums, Office Technician, Curriculum Frameworks Unit

Beverly Wilson, Office Technician, Curriculum Frameworks Unit

State Board of Education Policy on the Teaching of Natural Sciences

Note: This policy statement on the teaching of natural sciences, which was adopted by the State Board of Education in 1989, supersedes the State Board's 1972 Antidogmatism Policy.

The domain of the natural sciences is the natural world. Science is limited by its tools—observable facts and testable hypotheses.

Discussions of any scientific fact, hypothesis, or theory related to the origins of the universe, the earth, and life (the *how*) are appropriate to the science curriculum. Discussions of divine creation, ultimate purposes, or ultimate causes (the *why*) are appropriate to the history–social science and English–language arts curricula.

Nothing in science or in any other field of knowledge shall be taught dogmatically. Dogma is a system of beliefs that is not subject to scientific test and refutation. Compelling belief is inconsistent with the goal of education; the goal is to encourage understanding.

To be fully informed citizens, students do not have to accept everything that is taught in the natural science curriculum, but they do have to understand the major strands of scientific thought, including its methods, facts, hypotheses, theories, and laws.

A scientific fact is an understanding based on confirmable observations and is subject to test and rejection. A scientific hypothesis is an attempt to frame a question as a testable proposition. A scientific theory is a logical construct based on facts and hypotheses that organizes and explains a range of natural phenomena. Scientific theories are constantly subject to testing, modification, and refutation as new evidence and new ideas emerge. Because scientific theories have predictive capabilities, they essentially guide further investigations.

From time to time natural science teachers are asked to teach content that does not meet the criteria of scientific fact, hypothesis, and theory as these terms are used in natural science and as defined in this policy. As a matter of principle, science teachers are professionally bound to limit their teaching to science and should resist pressure to do otherwise. Administrators should support teachers in this regard.

Philosophical and religious beliefs are based, at least in part, on faith and are not subject to scientific test and refutation. Such beliefs should be discussed in the social science and language arts curricula. The Board's position has been stated in the *History–Social Science Framework* (adopted by the Board).[1] If a student should raise a question in a natural science class that the teacher determines is outside the domain of science, the teacher should treat the question with respect. The teacher should explain why the question is outside the domain of natural science and encourage the student to discuss the question further with his or her family and clergy.

Neither the California nor the United States Constitution requires that time be given in the curriculum to religious views in order to accommodate those who object to certain material presented or activities conducted in science classes. It may be unconstitutional to grant time for that reason.

Nothing in the California *Education Code* allows students (or their parents or guardians) to excuse their class attendance on the basis of disagreements with the curriculum, except as specified for (1) any class in which human reproductive organs and their functions and process are described, illustrated, or discussed; and (2) an education project involving the harmful or destructive use of animals. (See California *Education Code* Section 51550 and Chapter 2.3 of Part 19 commencing with Section 32255.) However, the United States Constitution guarantees the free exercise of religion, and local governing boards and school districts are encouraged to develop statements, such as this one on policy, that recognize and respect that freedom in the teaching of science. Ultimately, students should be made aware of the difference between *understanding,* which is the goal of education, and *subscribing to* ideas.

Notes

1. *History–Social Science Framework for California Public Schools* (Updated edition with content standards). Sacramento: California Department of Education, 2001.

1

Introduction to the Framework

Introduction to the Framework

California is a world leader in science and technology and, as a result, enjoys both prosperity and a wealth of intellectual talent. The nation and the state of California have a history that is rich in innovation and invention. Educators have the opportunity to foster and inspire in students an interest in science; the goal is to have students gain the knowledge and skills necessary for California's workforce to be competitive in the global, information-based economy of the twenty-first century.

The *Science Framework for California Public Schools* is the blueprint for reform of the science curriculum, instruction, professional preparation and development, and instructional materials in California. The framework outlines the implementation of the *Science Content Standards for California Public Schools* (adopted by the State Board of Education in 1998)[1] and connects the learning of science with the fundamental skills of reading, writing, and mathematics. The science standards contain a concise description of what to teach at specific grade levels; this framework extends those guidelines by providing the scientific background and the classroom context.

Glenn T. Seaborg, one of the great scientific minds of this era, defined science as follows: "Science is an organized body of knowledge and a method of proceeding to an extension of this knowledge by hypothesis and experiment."[2] This framework is intended to (1) organize the body of knowledge that students need to learn during their elementary and secondary school years; and (2) illuminate the methods of science that will be used to extend that knowledge during the students' lifetimes.

Although the world will certainly change in ways that can hardly be predicted in the new century, California students will be prepared to meet new challenges if they have received a sound, basic education. This framework outlines the foundation of science knowledge needed by students and the analytical skills that will enable them to advance that knowledge and absorb new discoveries.

Audiences for the Framework

One of the primary audiences for this framework is the teachers who are responsible for implementing the science standards. These teachers are elementary and middle school teachers with multiple-subject credentials, middle and high school teachers with single-subject credentials in science, and those who may be teaching outside their primary area of expertise. The *Science Framework* is designed to provide valuable insights to both novice and expert science teachers.

For designers of science instructional materials, the framework may serve as a guide to the teaching of the science standards and as an example of the scholarly treatment of science that is expected in their materials. Publishers submitting science instructional materials for adoption in the state of California must adhere to a set of rigorous criteria described in this framework. The criteria include careful alignment with and comprehensive coverage of the science standards, good program organization and provisions for assessment, universal access for students with special needs, and instructional planning and support for the teacher.

The organizers of both programs of preservice professional preparation and in-service professional development will find this framework helpful. Skill is needed to teach science well, and training programs for teachers need to be especially mindful of the expectations placed on students.

Scientists and other professionals in the community often seek ways to help improve their local schools, and this framework will be helpful in focusing their efforts on a common set of curricular goals. By providing ideas and resources aligned with grade-level standards, professionals can make sure their outreach efforts and donations to classrooms will be put to best use.

For many high school seniors, commencement is followed shortly thereafter by baccalaureate courses. The *Science Framework* communicates to the science faculty at all California institutions of higher education what they may expect of entering students.

Finally, the parents, guardians, and other caregivers of students will find the *Science Framework* useful as they seek to help children with homework or gain an understanding of what their children are learning in school.

Instructional Materials

One of the best measures that local educational agencies (LEAs) can take is to ensure that all teachers of students in kindergarten through grade eight are provided with materials currently adopted by the State Board of Education (especially in science, mathematics, and reading/language arts) and are trained in their use. Those materials undergo a rigorous review and provide teachers and other instructional staff with guidance and strategies for helping students who are having difficulty.

In choosing instructional materials at the high school level, LEAs need to be guided by the science standards and the evaluation criteria set forth in Chapter 9. An analogy used in the *Reading/Language Arts Framework for California Public Schools* is equally applicable to the teaching of science: "Teachers should not be expected to be the composers of the music as well as the conductors of the orchestra."[3] In addition to basic instructional materials, teachers need to be able to gain access to up-to-date resources in the school library-media center that support the teaching of standards-based science. The resources must be carefully selected to support and enhance the basic instructional materials.

The Challenges in Science Education

Elementary school students often learn much from observing and recording the growth of plants from seeds in the classroom. But are the same students well served if seed planting is a focus of the science curriculum in the next year and the following one as well? The same question may well be asked of any instructional activity. To overcome the challenges in science education, several strategies are recommended:

Prepare Long-Term Plans

Long-term planning of a science curriculum over a span of grades helps students learn new things and develop new skills each year. A standards-based curriculum helps students who move from district to district; they will be more likely to receive a systematic and complete education.

The *Science Content Standards* and the *Science Framework* are designed to ensure that all students have a rich experience in science at every grade level and that curriculum decisions are not made haphazardly. Instructional programs need the content standards to be incorporated at each grade level and should be comprehensive and coherent over a span of grade levels.

Reforming science curriculum, instruction, and instructional materials will be a time-consuming process. To achieve the reform objectives, all educational stakeholders need to adhere to the guidance provided in this framework. The hope is that in the near future teachers will have a much greater degree of certainty about the knowledge and skills the students already possess as they file into the classroom at the beginning of a school year. Less time will be spent on review, and teachers will also have a clear idea of the content their students are expected to master at each grade level and in each branch of science.

Meet the Curricular Demands of Other Core Content Areas

The *Reading/Language Arts Framework* and *Mathematics Framework*[4] explicitly require uninterrupted instructional time in those subjects. In the early elementary grades, students need to receive at least 150 minutes of reading/language arts instruction daily and 50 to 60 minutes of mathematics instruction. At the elementary school level, the pressure to raise the academic performance of students in reading/language arts and mathematics has led some administrators to eliminate or curtail science instruction. This action is not necessary and reflects, in fact, a failure to serve the students. The *Science Framework* helps to organize and focus elementary science instruction, bringing it to a level of efficiency so that it need not be eliminated.

All teachers, particularly those who teach multiple subjects, need to use their instructional time judiciously. One of the key objectives set forth in the *Mathematics Framework* applies equally well to the study of science: "During the great majority of allocated time, students are active participants in the instruction."[5] In this case *active* means that students are engaged in thinking about science. If the pace of an activity is too fast or too slow, students will not be "on task" for much of the allotted time.

When large blocks of time for science instruction are not feasible, teachers must make use of smaller blocks. For example, an elementary teacher and the class may have a brief but spirited discussion on why plant seeds have different shapes or why the moon looks different each week. For kindergarten through grade three, standards-based science content is now integrated into nonfiction material in the basic reading/language arts reading programs adopted by the State Board of Education. Publishers were given the following mandate in the *2002 K–8 Reading/Language Arts/English Language Development Adoption Criteria:*

> In order to protect language arts instructional time, those K–3 content standards in history–social science and science that lend themselves to instruction during the language arts time period are addressed within the language arts materials, particularly in the selection of expository texts that are read to students, or that students read.[6]

There is no begrudging of the extended time needed for students to master reading, writing, and mathematics, for those are fundamental skills necessary for science. The *Reading/Language Arts Framework* states this principle clearly: "Literacy is the key to becoming an independent learner in all the other disciplines."[7] The *Mathematics Framework* bears a similar message: "The [mathematics] standards focus on essential content for all students and prepare students for the study of advanced mathematics, science and technical careers, and postsecondary study in all content areas."[8]

Despite the aforementioned curricular demands, the science standards should be taught comprehensively during the elementary grades. This challenge can be met with careful planning and implementation.

Set Clear Instructional Objectives

In teaching the science standards, LEAs must have a clear idea of their instructional objectives. Science education is meant to teach, in part, the specific knowledge and skills that will allow students to become literate adults. As John Stuart Mill wrote in 1867:

> It is surely no small part of education to put us in intelligent possession of the most important and most universally interesting facts of the universe, so that the world which surrounds us may not be a sealed book to us, uninteresting because unintelligible.[9]

Science education, however, is more than the learning of interesting facts; it is the building of intellectual strength in a more general sense:

> The scholarly and scientific disciplines won their primacy in traditional programs of education because they represent the most effective methods which . . . have been [devised] through millennia of sustained effort, for liberating and organizing the powers of the human mind.[10]

Science education in kindergarten through grade twelve trains the mind and builds intellectual strength and must not be limited to the lasting facts and skills that can be remembered into adulthood. Science must be taught at a level of rigor and depth that goes well beyond what a typical adult knows. It must be taught "for the sake of science" and not with any particular vocational goal in mind. The study of science disciplines the minds of students; and the benefits of this intellectual training are realized long after schooling, when the details of the science may be forgotten.

Model Scientific Attitudes

Science must be taught in a way that is scholarly yet engaging. That is, an appropriate balance must be maintained between the fun and serious sides of science. A physics teacher might have students build paper airplanes to illustrate the relationship between lift and drag in airflow; but if the activity is not deeply rooted in the content of physics, then the fun of launching paper airplanes displaces the intended lesson. The fun of science may be a way to help students remember important ideas, but it cannot substitute for effective instruction and sustained student effort.

There are certain attitudes about science and scientists that a teacher must foster in students. Scientists are deeply knowledgeable about their fields of study but typically are willing to admit that there is a great deal they do not know. In particular, they welcome new ideas that are supported by evidence. In doing their research good scientists do not attempt to prove that their own hypotheses are correct but that they are incorrect.[11] Though somewhat counterintuitive, this path is the surest one to finding the truth.

Classroom teachers must always provide rational explanations for phenomena, not occultic or magical ones. They need to be honest about what they do not know and be enthusiastic about learning new things along with their students. They must convey to students the idea that there is much to learn and that phenomena not currently understood may be understood in the future. Knowledge in science is cumulative, passed from generation to generation, and refined at every step.

Provide Balanced Instruction

Some of the knowledge of science is best learned by having students read about the subject or hear about it from the teacher; other knowledge is best learned in laboratory or field studies. Direct instruction and investigative activities need to be mutually supportive and synergistic. Instructional materials need to provide teachers with a variety of options for implementation that are based on the science standards.

For example, students might learn about Ohm's law, one of the guiding principles of physics, which states that electrical current decreases proportionately as resistance increases in an electrical circuit operating under a condition of constant voltage. In practice, the principle accounts for why a flashlight with corroded electrical contacts does not give a bright beam, even with fresh batteries. It is a simple relationship, expressed as $V=IR$, and embodied in high school Physics Standard 5.b. In a laboratory exercise, however, students may obtain results that seem to disprove the linear relationship because the resistance of a circuit element varies with temperature. The temperature of the components gradually increases as repeated tests are performed, and the data become skewed.

In the foregoing example, it was not Ohm's law that was wrong but an assumption about the stability of the experimental apparatus. This assumption can be proven by additional experimentation and provides an extraordinary opportunity for students to learn about the scientific method.

Had the students been left to uncover on their own the relationship between current and resistance, their skewed data would not have easily led them to discover Ohm's law. A sensible balance of direct instruction and investigation and a focus on demonstration of scientific principles provide the best science lesson.

Ensure the Safety of Instructional Activities

Safety is always the foremost consideration in the design of demonstrations, hands-on activities, laboratories, and science projects on site or away from school. Teachers need to be familiar with the *Science Safety Handbook for California Public Schools*.[12] It contains specific and useful information relevant to classroom teachers of science. Following safe practices is a legal and moral obligation for administrators, teachers, parents or guardians, and students. Safety needs to be taught. Scientists and engineers in universities and industries are required to follow strict environmental health and safety regulations. Knowing and following safe practices in science are a part of understanding the nature of science and scientific procedures.

Match Instructional Activities with Standards

Teachers need to use instructional materials that are aligned with the *Science Content Standards,* but how do they know when a curriculum or supplemental material is a good match? The State Board of Education establishes content review panels to analyze the science instructional materials submitted for adoption in kindergarten through grade eight. The panels consist of professional scientists and expert teachers of science. Local educational agencies would be well advised to use materials that have passed this stringent test for quality and alignment. The criteria are included in the *Science Framework* (Chapter 9) and may help guide the decisions of school districts and schools when they adopt instructional materials for grades nine through twelve.

In brief, teachers need to use instructional activities or readings that are grounded in science and that provide clear and nonsuperficial lessons. The content must be scientifically accurate, and the breadth and depth of the science standards need to be addressed. Initial teaching sequences must communicate with students in the most straightforward way possible, and expanded teaching used to amplify the students' understanding.[13] The concrete examples, investigative activities, and vocabulary used in instruction need to be unambiguous and chosen to demonstrate the wide range of variation on which scientific concepts can be generalized.

For example, in grade four Standard 2.a is: "Students know plants are the primary source of matter and energy entering most food chains."[14] This standard may be taught by using numerous concrete examples. Mastery of the concept, however, requires that students understand how the concept is generalized. Having learned by explicit instruction that plants are primary producers in deserts, forests, and grasslands, the students must be able to generalize the principle accurately to include other habitats (e.g., salt marshes, lakes, tundra). Although the standard is easily amenable to laboratory and field activities, it cannot be entirely grasped by observation of or contact with nature.

In high school this standard is explored in considerable depth as students come to learn about energy, matter, photosynthesis, and the cycling of organic matter in an ecosystem. Standard 2.a in grade four prepares students to learn more.

Another example of "preteaching" embedded in the science standards is Standard 1.h in grade three: "Students know all matter is made of small particles called atoms, too small to see with the naked eye."[15] The intent of this standard is not to make third-grade students into atomic scientists, but simply to introduce them to a way of thinking that is reinforced in grades five and eight and then taught in greater depth in high school.

This framework is designed to ensure that instructional materials are developed to the intended depth of each standard and that the relationships are made clear among standards across grade levels and within branches of science.

Science and the Environment

Environmental concerns that once received relatively little attention (e.g., invasive species of plants and animals, habitat fragmentation, loss of biodiversity) have suddenly become statewide priorities. Entire fields of scientific inquiry (e.g., conservation biology, landscape ecology, ethnoecology) have arisen to address those concerns. In general, there is an increased sense of the complexity and interconnectedness of environmental issues. The public response to California's environmental challenges has been profound as evidenced by the enactment of Senate Bill 373 (Chapter 926, Statutes of 2001). Senate Bill 373 requires the following topics to be included in this framework:

- Integrated waste management
- Energy conservation
- Water conservation and pollution prevention
- Air resources
- Integrated pest management
- Toxic materials
- Wildlife conservation and forestry

Several science standards address those topics directly; provide students with the foundational skills and knowledge to understand them; or incorporate concepts, principles, and theories of science that are integral to them. The suggestions in this framework include ways of highlighting the topics as follows:

- Students in kindergarten through grade five learn about the characteristics of their environment through their studies of earth, life, and physical sciences. For example, in grade three students learn how environmental changes affect living organisms.
- Students in grades six through eight focus on earth, life, and physical sciences, respectively; and standards at each grade level include the study of ecology and the environment.

- Students in grades nine through twelve expand their knowledge of habitats, biodiversity, and ecosystems associated with the biology/life science content standards. High school earth science standards include the study of energy and its usage as well as topics related to water resources and the geology of California.

The Legislature has declared "that [we have] a moral obligation to understand the world in which [we live] and to protect, enhance, and make the highest use of the land and resources [we hold] in trust for future generations, and that the dignity and worth of the individual requires a quality environment in which [we] can develop the full potentials of [our] spirit and intellect" (*Education Code* Section 8704). Toward that end LEAs and individual schools throughout California are contributing to the betterment of the environment in many ways, including replacing asphalt school grounds with gardens, recycling school waste, exchanging scientific data with the international community through Web sites, and restoring local habitats.

Specific programs of environmental education enhance the learning of science at all grade levels. These programs enhance scientific and critical thinking skills, enabling students to perceive patterns and processes of nature, research environmental issues, and propose reasoned solutions. Environmental education is not advocacy for particular opinions or interests, but it is a means of fostering a comprehensive and critical approach to issues. Students get a personal sense of responsibility for the environment; consequently, schools are tied more closely to the life of the communities they serve.

Guiding Principles

The following principles form the basis of an effective science education program. They address the complexity of the science content and the methods by which science content is best taught. They clearly define the attributes of a quality science curriculum at the elementary, middle, and high school levels.

Effective science programs are based on standards and use standards-based instructional materials.

Comprehensive, standards-based programs are those in which curriculum, instruction, and assessment are aligned with the grade level-specific content standards (kindergarten through grade eight) and the content strands (grades nine through twelve). Students have opportunities to learn foundational skills and knowledge in the elementary and middle grades and to understand concepts, principles, and theories at the high school level. Students use instructional materials that have been adopted by the State Board of Education in kindergarten through grade eight. For grades nine through twelve, students use instructional materials that are determined by local boards of education to be consistent with the science standards and this framework.

A *California Standards Test* in science is now administered at grade five, reflecting the cumulative science standards for grades four and five. Therefore, science instruction must be based on complete programs that cover all the standards at every grade level. The criteria for evaluating K–8 science instructional materials (see Chapter 9) state: "All content Standards as specified at each grade level are supported by topics or concepts, lessons, activities, investigations, examples, and/or illustrations, etc., as appropriate."

At the high school level, the *Science Content Standards* document does not prescribe a single high school curriculum. To allow LEAs and teachers flexibility, the standards for grades nine through twelve are organized as content strands. There is no mandate that a particular content strand be completed in a particular grade. Students enrolled in science courses are expected to master the standards that apply to the curriculum they are studying regardless of the sequence of the content. Students in grades nine through twelve use instructional materials that reflect the *Science Content Standards* and this framework. The grade nine through twelve standards maps posted on the California Department of Education Web site are tools that LEAs can use to determine if instructional materials are aligned with the standards.

The *California Standards Tests* for grades nine through eleven pertain specifically to the content of the particular science courses in which students are enrolled. The California Department of Education makes blueprints for those tests and sample questions available to the public. Local educational agencies are encouraged to review and improve (as necessary) their high school science programs to achieve the following results:

1. All high school science courses that meet state or local graduation requirements or the entrance requirements of the University of California or The California State University are based on the *Science Content Standards.*
2. Every laboratory science course is based on the content standards and ensures that students master both the content-specific standards and Investigation and Experimentation standards.
3. Every science program ensures that students are prepared to be successful on the *California Standards Tests.*
4. All students take, at a minimum, two years of laboratory science providing fundamental knowledge in at least two of the following content strands: biology/life sciences, chemistry, and physics. Laboratory courses in earth sciences are acceptable if prerequisite courses are required (or provide basic knowledge) in biology, chemistry, or physics.[16]

Effective science programs develop students' command of the academic language of science used in the content standards.

The lessons explicitly teach scientific terms as they are presented in the content standards. New words (e.g., *photosynthesis*) are introduced to reflect students' expanding knowledge, and the definitions of common words (e.g., *table*) are expanded to incorporate specific meanings in science. Developing students' command of the academic language of science must be a part of instruction at all grade levels (kindergarten through grade eight) and in the four content strands (grades nine through twelve). Scientific vocabulary is important in building conceptual understanding. Teachers need to provide explanations of new terms and idioms by using words and examples that are clear and precise.

Effective science programs reflect a balanced, comprehensive approach that includes the teaching of investigation and experimentation skills along with direct instruction and reading.

A balanced, comprehensive approach to science includes the teaching of investigation and experimentation skills along with direct instruction and reading. Investigation and experimentation standards are progressive and need to be taught in a manner integral to the physical, life, and earth sciences as students learn quantitative skills and qualitative observational skills. For example, the metric system is first introduced in grade two, but students use and refine their skill in metric measurement through high school. The methods and skills of scientific inquiry are learned in the context of the key concepts, principles, and theories set forth in the standards. Effective use of limited instructional time is always a major consideration in the design of lessons and courses. Laboratory space and equipment, library access, and resources are essential to support students' academic growth in science.

Effective science programs use multiple instructional strategies and provide students with multiple opportunities to master the content standards.

Multiple instructional strategies, such as direct instruction, teacher modeling and demonstration, and investigation and experimentation, are useful in teaching science and need to be included in instructional materials. Those strategies help teachers capture student interest, provide bridges across content areas, and contribute to an understanding of the nature of science and the methods of scientific inquiry.

Standards for investigation and experimentation are included at each grade level and differ from the other standards in that they do not represent a specific content area. Investigation and experimentation cuts across all content areas, and those standards are intended to be taught in the context of the grade-level content. Hands-on activities compose at least 20 to 25 percent of the science instructional time in kindergarten through grade eight. Instruction is designed and sequenced to provide students with opportunities to reinforce foundational skills and knowledge and to revisit concepts, principles, and theories previously taught. In this way student progress is appropriately monitored.

Effective science programs include continual assessment of students' knowledge and understanding, with appropriate adjustments being made during the academic year.

Effective assessment (on a continuing basis through the academic year) is a key ingredient of standards-based instruction. Teachers assess students' prerequisite knowledge, monitor student progress, and evaluate the degree of mastery of the content called for in the standards. Lessons include embedded unit assessments that provide formative and summative assessments of student progress. Teachers and administrators regularly collaborate to improve science progress by examining the results of *California Standards Tests* in science (both the general test at grade five and the specific tests in grades nine through eleven).

Effective science programs continually engage all students in learning and prepare and motivate students for further instruction in science.

Students who are unable to keep up with the expectations for learning science often lack basic skills in reading comprehension and mathematics. Therefore, students who need extra assistance to achieve grade-level expectations are identified early and receive support. Schools need to use transitional materials that accelerate the students' reading and mathematics achievement to grade level. Advanced learners must not be held back but be encouraged to study science content in greater depth.

Effective science programs use technology to teach students, assess their knowledge, develop information resources, and enhance computer literacy.

Across the nation science in the laboratory setting involves specialized probes, instruments, materials, and computers. Scientists extend their ability to make observations, analyze data, study the scientific literature, and communicate findings through the use of technology. High-performance computing capabilities are used in science to make predictions based on fundamental principles and laws. Technology-based models are used to design and guide experiments, making it possible to eliminate some experiments and to suggest other experiments that previously might not have been considered. Students have the opportunity to use technology and imitate the ways of modern science. Teaching science by using technology is important for preparing students to be scientifically and technologically literate. Assembly Bill 1023 (Chapter 404, Statutes of 1997) requires that newly credentialed teachers demonstrate basic competence in the use of computers in the classroom.

Effective science programs have adequate instructional resources as well as library-media and administrative support.

Standards-based teaching and learning in science demand adequate instructional resources. Local educational agencies and individual school sites need to include science resources as an integral part of the budget. Library-media staff must have science as a priority for resource acquisition and development. Administrators must ensure that funds set aside for the science resources are spent efficiently (e.g., through clear processes and procedures for purchasing and maintenance) and support students' mastery of the content standards. This priority requires planning, coordination, and dedication of space for science resources.

Effective science programs use standards-based connections with other core subjects to reinforce science teaching and learning.

Science instruction provides multiple opportunities to make connections with other content areas. Reading, writing, mathematics, and speaking skills are needed to learn and do science. In self-contained classrooms, teachers incorporate science content in reading, writing, and mathematics as directed in the *Reading–Language Arts Framework* and *Mathematics Framework*. In departmentalized settings (middle and high school levels) science teachers need to include essay assignments and require that students' writing reflect the correct application of English-language conventions, including spelling and grammar.

Organization of the Framework

The *Science Framework* is primarily organized around the *Science Content Standards.* The framework:

- Discusses the nature of science and technology and the methods by which they are advanced (Chapter 2)
- Describes the curriculum content and instructional practices needed for mastery of the standards (Chapters 3, 4, and 5)
- Guides the development of appropriate assessment tools (Chapter 6)
- Suggests specific strategies to promote access to the curriculum for students with special needs (Chapter 7)
- Describes the system of teacher professional development that needs to be in place for effective implementation of the standards (Chapter 8)
- Specifies the requirements for evaluating science instructional resources, including investigative activities, for kindergarten through grade eight (Chapter 9)
- Provides information on pertinent requirements of the California *Education Code* regarding science education in this state (Appendix)

The science standards are embedded in Chapters 3, 4, and 5 and are grade-level specific from kindergarten through grade eight. The standards for grades nine through twelve are organized by strands: physics, chemistry, biology/life sciences, and earth sciences.

Notes

1. *Science Content Standards for California Public Schools, Kindergarten Through Grade Twelve.* Sacramento: California Department of Education, 2000.
2. Glenn T. Seaborg, "A Letter to a Young Scientist," in *Gifted Young in Science: Potential Through Performance.* Edited by Paul Brandwein and others. Arlington, Va.: National Science Teachers Association, 1989. The late Dr. Seaborg was chair of the California Academic Standards Commission's Science Committee that created the *Science Content Standards for California Public Schools*.
3. *Reading/Language Arts Framework for California Public Schools, Kindergarten Through Grade Twelve*. Sacramento: California Department of Education, 1999, p. 2.
4. *Mathematics Framework for California Public Schools, Kindergarten Through Grade Twelve*. Sacramento: California Department of Education, 2000.
5. *Mathematics Framework*, p. 13.
6. These criteria are available on the Web site<*http://www.cde.ca.gov/cfir/rla/2002criteria.pdf*>. Click on Criteria Category 2, third bullet.
7. *Reading/Language Arts Framework,* p. 3.

8. *Mathematics Framework,* p. 18.
9. John Stuart Mill, inaugural address to the University of St. Andrew, quoted in George E. DeBoer, *A History of Ideas in Science Education.* New York: Teachers College Press, 1991, p. 8.
10. Arthur E. Bestor, *Educational Wastelands: The Retreat from Learning in Our Public Schools.* Champaign: University of Illinois Press, 1953. p. 18.
11. J. R. Platt, "Strong Inference," *Science,* Vol. 146 (1964), 347–53.
12. *Science Safety Handbook for California Public Schools.* Sacramento: California Department of Education, 1999.
13. Siegfried Engelmann and Douglas Carnine, *Theory of Instruction: Principles and Applications.* Eugene, Ore.: ADI Press, 1991.
14. *Science Content Standards,* p. 11.
15. Ibid., p. 8.
16. The laboratory science subject requirement for admission to the University of California and (beginning in fall 2003) to The California State University reads as follows: "d. Laboratory Science. Two years required, three recommended. Two years of laboratory science providing fundamental knowledge in at least two of these three disciplines: biology (which includes anatomy, physiology, marine biology, aquatic biology, etc.), chemistry, and physics. Laboratory courses in earth/space sciences are acceptable if they have as prerequisites or provide basic knowledge in biology, chemistry, or physics. The appropriate two years of an approved integrated science program may be used to fulfill this requirement. Not more than one year of ninth-grade laboratory science can be used to meet this requirement."

    Source: University of California Office of the President <*http://www.ucop.edu*> and The California State University <*http://www.calstate.edu*>.

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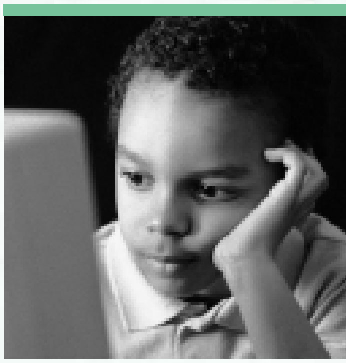

The Nature of Science and Technology

The Nature of Science and Technology

Science is the study of nature at all levels, from the infinite to the infinitesimal. It is the asking and answering of questions about natural processes or phenomena that are directly observed or indirectly inferred. From these questions and answers come tentative explanations called *hypotheses,* which lead to testable predictions about the natural processes and phenomena. Hypotheses that withstand rigorous testing of predictions will gradually lead to an accretion of facts and principles, which serve as the foundation of scientific theories. Scientific knowledge gives rise to many technologies that drive the economy and improve the quality of life for people. The term *technology* embraces not only tools (e.g., computers) but also methods, materials, and applications of scientific knowledge.

Scientific knowledge and technology built on that knowledge have expanded—one might even say exploded—in the last 50 years. The very nature of science as a human endeavor has made this expansion possible. Scientific research and development are both collaborative and international; literally millions of men and women around the world participate in the science and engineering enterprise.

To stay current with scientific developments, school science programs need to develop partnerships with library-media centers, museums, science and technology centers, colleges and universities, industry, and subject matter projects to build support for such programs.

The Scientific Method

The scientific method is a process for predicting, on the basis of a handful of scientific principles, what will happen next in a natural sequence of events. Because of its success, this invention of the human mind is used in many fields of study. The scientific method is a flexible, highly creative process built on three broad assumptions:

- Change occurs in observable patterns that can be extended by logic to predict what will happen next.
- Anyone can observe something and apply logic.
- Scientific discoveries are replicable.

The first assumption may be contrasted with the idea that the complexity of the natural world is so great as to be outside human understanding. Science asserts that change occurs in patterns within the human capability to perceive, that these patterns may be discerned by observation, and that the changes are subject to logic. The simple logic of *if-A-then-B* suffices to understand simple patterns; complex patterns require the more complex logic expressed in mathematics. The concentration of thought that mathematics lends to the study of the natural world is stunning. For example, the position of the planets over millions of years in the past can be closely approximated by using only two strings of symbols taken from Newton's laws of motion and gravity:

$F = ma$ and $F = Gm_1m_2/d^2$

The second assumption is that anyone can measure the strength of a scientific theory by fairly testing its predictions. Scientific research papers thus contain not only the results of an investigation, but all the information needed to replicate the research. The lifetime work of many scientists is replicating other scientists' experiments in order to test their conclusions.

The third assumption is that individuals and groups can make progress toward understanding natural phenomena, and their discoveries can be replicated at any time and suitable place by an objective observer. Truth in science knows no cultural or national boundaries. Science is not a system of beliefs or faith but a replicable body of knowledge. In fact, science is incapable of answering questions that are based on faith. Within the scientific community, individuals or groups may sometimes see only what they desire to see or have been conditioned to see. Scientific progress is sometimes stalled by incorrect theories or results; but once it is shown that those theories or results cannot be confirmed by others, progress resumes in the correct direction.

The scientific method ultimately allows for the formulation of scientific theories. Part of science education is to learn what these theories are and trace their operation in the world. A *theory* in popular language is a collection of related ideas that one supposes to be true; in science, a theory is defined by the principles of the scientific method. Those principles, in order of precedence, are as follows:

1. A scientific theory must be logically consistent and lead to testable predictions about the natural world.
2. The strength of a scientific theory lies solely in the accuracy of those predictions.
3. Of two scientific theories that make accurate predictions, the theory that makes a greater number of predictions with fewer underlying assumptions is likely to prove stronger.

The making and testing of predictions is what distinguishes science from other intellectual disciplines, and emphasizing the accuracy of predictions rather than the cogency of explanations is the key to scientific progress. A large assortment of recorded observations can often be accounted for with explanations that sound good but are nonetheless wrong. Predictions that can be tested and verified, however, provide a sound standard by which a scientific theory can be judged.

The requirement that a scientific theory makes predictions might seem to reject as unscientific any theory that describes the past. However, scientific theories that describe the past (such as those set forth by geologists, paleontologists, and so forth) do make predictions about what will be observed in the future. For example, if there was a mass extinction at the boundary between the Cretaceous and Tertiary periods more than 65 million years ago, then a sample of sedimentary rock at or below that boundary would be expected (at many sites) to show a much greater number (and diversity) of fossils than would a sample of rock immediately above it. Furthermore, if the extinction were to have been caused by the impact of an asteroid, the layer of "dust" falling after the impact would be expected to show signs of the explosive nature of the impact and the composition of the asteroid.

The three principles of the scientific method cannot be used to determine how the predictions of scientific theory should be tested. Nor can they be used to create new and even stronger theories. Inventing ways to test existing theories or devising new theories requires creativity as well as knowledge. The opportunity to make discoveries through creative experiments is what attracts many young people to science careers. As with all endeavors, practice, experience, and the opportunity to watch others engaged in similar efforts are highly beneficial to students.

Scientific Practice and Ethics

Scientists have the responsibility to report fully and openly the results of their experiments even if those results disagree with their favored hypothesis. They also have the responsibility to report fully and openly the methods of an experiment. For a scientist to hide data, arbitrarily eliminate anomalies in a data set, or conceal how an experiment was conducted is to invite errors and make those errors difficult to discover. All scientists must seek explanations for anomalous observations and results in order to improve their procedures or to discover something new. They also carefully consider questions raised by fellow scientists about the accuracy of their experiments. These accepted ethical practices of scientists need to be taught in the classroom at all grade levels.

Students sometimes feel pressure to come up with the right or expected answer when performing an investigation. Some may even alter the results of an experiment because they assume an error has been made in observing, measuring, or recording data. Teachers must encourage students to report the results they actually get. Variations in results allow students the opportunities to find problems with a procedure or an apparatus. Learning that such problems come with doing science and learning how to detect and correct these problems are as important as reaching the nominal goal of an investigation. To discard the unusual in order to reach the expected is to guarantee that nothing but the expected will ever be seen. That step would be a distortion of science.

Science and Technology

Technology is the repeatable and controlled manipulation of the natural world to serve human ends. A deep understanding of a phenomenon is not necessary for successful technology. For example, the Romans did not understand why mixtures of limestone powder, clay, sand, and water hardened, but they had no trouble using the result to mortar bricks. Still, the most spectacular technological advances often have followed from an understanding of fundamental scientific principles. Ancient peoples, for example, used the principles of genetic heredity to improve a few characteristics of some crops and animals, but not until Gregor Mendel's experiments on garden peas in the mid-1800s were the patterns of heredity discovered. Mendel's experiments marked the birth of genetic science, which has led to today's high-yield agricultural technologies and a new era in medicine. The Roman civilization and other earlier civilizations had the ability to combine and utilize raw materials. Only after scientists had sufficient knowledge of physics and chemistry to take those raw materials apart and rebuild them on a molecule-by-molecule (or even an atom-by-atom) basis did the stuff of today's technologies—from semiconductors and superconductors to a bewilderingly diverse array of synthetics—come into being.

As new scientific principles are discovered, new technologies can be devised, and the use of existing technologies can be expanded. The new technologies available even in the next decade cannot be predicted, but new technologies will certainly be needed to cope with foreseeable problems, such as human population growth, environmental pollution, and finite energy resources. It is also certain that technological advancements will be needed for the problems that no one has foreseen.

Teachers have the opportunity to incorporate technology, help students master the science standards, enhance students' abilities to use technology effectively, and help students understand the relationship between science and technology. Technology may serve the following functions in education:

- Enable teachers and students to have access to the latest information in science. In grade seven of the science standards, Standard 7.b calls for students to "use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project."[1] Any Internet usage, of course, must comply with the provisions of applicable law and policies adopted by the local educational agency (LEA).
- Provide students with experience in effective communication. The investigation and experimentation standards provide a range of skills beginning in kindergarten ("Communicate observations orally and through drawings")[2] and culminating in grades nine through twelve ("Select and use appropriate tools and technology [such as computer-linked probes, spreadsheets, and graphing calculators] to perform tests, collect data, analyze relationships, and display data").[3]
- Further scientific study in business, industry, and postsecondary education. The technologies used to address energy needs are discussed in Chapter 4 under "Grade Six," and chips and semiconductors are discussed under "Grade Eight." In the high school grades, the science standards call for students to "know how genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products."[4]
- Become integrated in instruction where it is likely to improve student learning. The focus must be on learning science and using technology as a tool rather than as an end in itself.

The *Mathematics Framework* contains an important precaution that equally applies to science: “The use of technology in and of itself does not ensure improvements in student achievement, nor is its use necessarily better for student achievement than are more traditional methods.”[5]

- Simulate or model investigations and experiments that would be too expensive, time-consuming, dangerous, or otherwise impractical. Investigation and Experimentation Standard 1.g requires students in grades nine through twelve to “recognize the usefulness and limitations of models and theories as scientific representations of reality.”[6]
- Support universal access to science content through assistive technologies, consistent with a student’s 504 accommodation plan[7] or individualized education program.[8]

Resources for Teaching Science and Technology

As students learn the skills and knowledge called for in the *Science Content Standards for California Public Schools* they will come to know implicitly the nature of science. They will understand the key concepts, principles, and theories of science and will have practiced scientific inquiry. The guidance and information provided in this framework may be used to implement effective science education programs in public schools from kindergarten through grade twelve that will provide students with the opportunity to become scientifically literate and understand the nature of science and technology.

The number of electronic resources for science education is increasing rapidly. The California Learning Resource Network <*http://www.clrn.org/science*> provides a way for educators to identify supplemental electronic learning resources, including Web sites, that simultaneously meet local instructional needs and align with the *Science Content Standards* and this framework. Educators should comply with applicable policies of their school districts regarding Internet resources.

When science and technology are discussed in the context of history and historical figures, instruction is often enriched. The *History–Social Science Content Standards* follows this principle.[9] The standards:

- Include references to scientists such as Ben Franklin, Louis Pasteur, George Washington Carver, Marie Curie, Albert Einstein, Nicolaus Copernicus, Galileo Galilei, Johannes Kepler, and Isaac Newton.
- Cover inventors such as Thomas Edison, Alexander Graham Bell, the Wright brothers, James Watt, Eli Whitney, and Henry Bessemer.
- Encompass the effects of the information and computer revolutions, changes in communication, advances in medicine, and improvements in agricultural technology.

Science and Society

Science does not take place in a secret place isolated from the rest of society. Nor are the technologies that it creates shielded from public scrutiny. The continued expansion of scientific knowledge and the new technologies that spin off that knowledge will inevitably challenge citizens to rethink their ideas and beliefs. For example, as new genetically modified crops and livestock are developed by scientists, some people have expressed concern about food safety and the ethics of such practices. On the other hand, people in developing countries have a compelling interest to use the new technologies to rid themselves of famine and diseases. Those types of tradeoffs are likely to become the focus of intense public discussion and political debate.

The presentation of some scientific findings or practices may be troubling to students who genuinely believe that those findings or practices conflict with their religious or philosophical beliefs. Dealing constructively and respectfully with those beliefs while holding firm to the nature of science is one of the greatest challenges to public school teachers.

Scientifically literate students need to understand clearly the major scientific theories and the principles behind the scientific method. They must also understand that though the scientific method is a powerful process for predicting natural phenomena, it cannot be used to answer moral and aesthetic questions. Nor can it be used to test hypotheses based on supernatural intervention. Science exclusively concerns itself with predicting the occurrence and consequences of natural events. This concern is explicitly expressed in Standard 7.10 of grade seven of the *History–Social Science Content Standards:* "Students analyze the historical developments of the Scientific Revolution and its lasting effect on religious, political, and cultural institutions"[10] The students go on to consider this analysis in terms of the roots of the scientific revolution, the significance of new scientific theories, the influence of new scientific rationalism on the growth of democratic ideas, and the coexistence of science with traditional religious beliefs.

Notes

1. *Science Content Standards for California Public Schools, Kindergarten Through Grade Twelve.* Sacramento: California Department of Education, 2000, p. 25.
2. Ibid., p. 2.
3. Ibid., p. 52.
4. Ibid., p. 44.
5. *Mathematics Framework for California Public Schools, Kindergarten Through Grade Twelve.* Sacramento: California Department of Education, 2000, p. 227.
6. *Science Content Standards,* p. 52.
7. A Section 504 accommodation plan is a document typically produced by school districts in compliance with the requirements of Section 504 of the federal Rehabilitation Act of 1973. The plan specifies agreed-on services and accommodations for a student who, as the result of an evaluation, is determined to have a "physical or mental impairment [that] substantially limits one or more major life activities." In contrast to the Individuals with Disabilities Education Act (IDEA), Section 504 allows a wide range of information to be contained in a plan: (1) the nature of the disability; (2) the basis for determining the disability; (3) the educational impact of the disability; (4) necessary accommodations; and (5) the least restrictive environment in which the student may be placed.

8. An individualized education program (IEP) is a written, comprehensive statement of the educational needs of a child with a disability and the specially designed instruction and related services to be employed to meet those needs. An IEP is developed (and periodically reviewed and revised) by a team of individuals, including the parent(s) or guardian(s), knowledgeable about the child's disability. The IEP complies with the requirements of the federal IDEA and covers such items as (1) the child's present level of performance in relation to the curriculum; (2) measurable annual goals related to involvement and progress in the curriculum; (3) specialized programs (or program modifications) and services to be provided; (4) participation with nondisabled children in regular classes and activities; and (5) accommodation and modification in assessments.
9. *History–Social Science Content Standards for California Public Schools, Kindergarten Through Grade Twelve.* Sacramento: California Department of Education, 2001.
10. Ibid., p. 31.