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ABSTRACT

In this framework, emphasis is placed on ways school personnel can change science instruction and motivate student interest more effectively. The document is organized into four chapters and six appendices. Chapter one discusses the acquisition and organization of knowledge in respect to developing broad generalizations and concepts. It defines what science is and how it can be applied to the learner, curriculum, and society. Chapter two provides information from research and suggests strategies for changing the science curriculum and designing new programs. Chapter three suggests four broad goals of science education for kindergarten through grade twelve. These goals fall into four areas: (1) attitude; (2) thinking processes; (3) skills; and (4) knowledge. Terminal objectives, examples of learner behavior, and the appropriate grade levels where the behavior is likely to be observed are categorized. Chapter four describes the components of a good learning environment and suggests instructional strategies that can be used to achieve these goals. (Author/BB)

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CALIFORNIA STATE DEPARTMENT
Wilson Riles Superintendent of

Science Framework

For California Public Schools

Kindergarten and Grades One Through Twelve

Approved by the
California State Board of Education

Prepared by the
California State Curriculum Framework and
Criteria Committee for Science

Under the direction of
California State Board of Education
Curriculum Development and Supplemental Materials Commission

California State Board of Education

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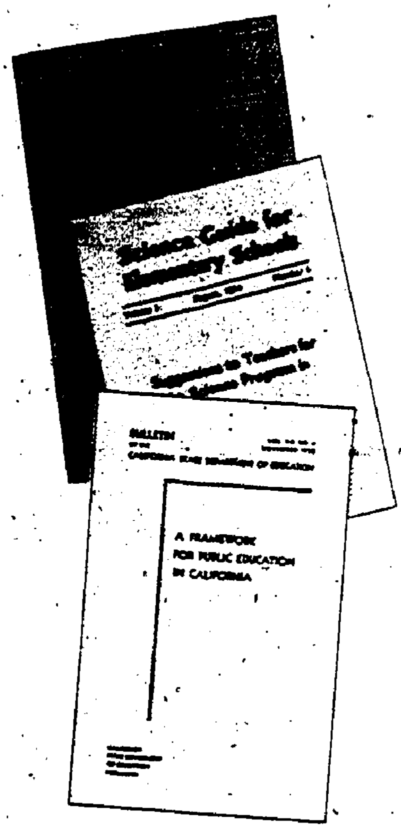
Cover

The cover photograph was selected to illustrate the need for "hands-on" activities in all science programs. The photograph shows students using a Secchi disc to study water turbidity. The study of the aquatic environment was chosen because understanding of the oceans, lakes, and rivers is particularly important to California students. Also, the activities associated with oceanography or limnology incorporate all of the sciences; i.e., biological, physical, earth, and space sciences.

Foreword

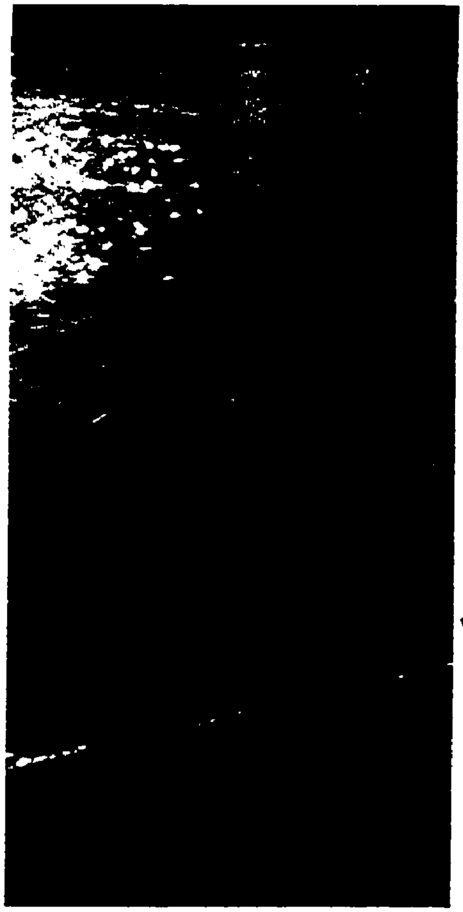


"To the child in whose education nature and science have occupied a significant place, life is a richer and a fuller adventure," wrote Helen Heffernan in the preface to the 1932 *Suggested Course of Study in Science for Elementary Schools*. Miss Heffernan, who is truly one of California's most outstanding educators, and the others who worked with her are to be congratulated for their pioneer efforts in developing the genesis of a state framework for science.

Two years later Miss Heffernan, who was then the Chief of the Division of Elementary Education and Rural Schools, and several other highly respected educators in the state prepared the first in a series of guides for teaching science. The guides, which were published over a period of almost ten years, carried such titles as *Tide-Pool Animals; Winter Birds; Earth Tremors; Frogs, Toads, and Salamanders;* and *Termites*. And the first guide in the series, *Suggestions to Teachers for the Science Program in Elementary Schools*, identified the major objectives that should be attained through science instruction:

1. An understanding of cause and effect relationships in connection with the natural phenomena which he [the student] is likely to encounter.
2. An understanding of the contributions of science to modern life.
3. An awareness of the challenging interests in the various fields of science.
4. An understanding of the local laws dealing with the conservation of wildlife.
5. The acquisition of skill in the scientific method of problem solving.
6. An appreciation of the beauty and resources of nature.

Even though the emphasis and degree of complexity may be different, those six objectives from 1934 are not too much unlike the objectives you will find in chapter 3 of this 1978 framework.



The comparison, it seems to me, reemphasizes the importance of our building on the past while making changes that reflect advances that have been made and meet the needs of our times.

The fact that Helen Heffernan was not content with the publishing of one course of study in science in 1932 is illustrative of the career of this forward-looking individual and others like her who have always worked so diligently to build on the past for a better future for our children. It was especially true when Miss Heffernan and 18 other leading educators accepted former Superintendent Roy E. Simpson's challenge in 1947 to develop the first *Framework for Public Education in California.* They worked three years on the task from the point of view that "the interests of all citizens will be best served as public education is unified through the consistent application of commonly accepted purposes and principles of action at all levels and in all fields of the curriculum."

Although documents produced in earlier times might have been considered frameworks, the 1950 publication was the first to carry the framework title. When the committee first began its work, the members agreed that the end product would be called a "framework," because the document, they said, "would be skeletal in structure, giving form and shape, strength and unity to all aspects of our rapidly expanding program of public education."

In the 28 years since that first framework was produced, the State Department of Education has published frameworks in 12 different curricular areas. And several of those documents, including this one in science, have undergone significant revisions, thus continuing the tradition of improving on that which has gone before.

I congratulate all of those whose names appear on pages xi and xii of this document for the fine work they have done in giving us a new framework in science—a document that reflects the needs and interests of our times and that continues the pioneer work my friend Helen Heffernan and others began so many years ago. As she reminded her readers in the 1932 course of study, I remind you today, "The teacher who builds a knowledge of and a scientific attitude toward the natural phenomenon which is everywhere about the child has immeasurably enriched his life." I am hopeful that this framework will help teachers in their most important work of enriching lives and showing each child his or her place as caretaker in the world of living things.

I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.

Sir Isaac Newton, 1642—1727

Wilson Riles

Superintendent of Public Instruction

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Introduction

Since the end of World War II, knowledge and technology have increased at a phenomenal rate. Societal values and attitudes toward science have fluctuated, and priorities and goals of science programs have changed. Immediately after World War II, science and science education were considered to be among the most important subjects to be taught in the schools. Support for science throughout the nation was profound in terms of funds, curriculum, and staff. In most cases, however, such support is no longer available. General public encouragement, interest, and emphasis in science education have leveled off to a great extent and in some cases have shown a downward trend as a result of other pressures and priorities. The lessening of emphasis in science has been most evident in kindergarten through grade six, but in general the trend has also been observed in secondary schools. Whether this trend continues, levels off, or turns around should be of serious concern to persons in industry, education, and the public at large.

While many believe in the capability of science and technology to solve a large number of humanity's pressing problems[1] and while opportunities for work in areas of technology and science continue to grow, studies generally show that voluntary science enrollments on a percentage basis (grades seven through twelve) are at a plateau or are declining slightly. Therefore, an apparent paradox exists: Many exemplary programs can be found throughout California, but as a whole science education is struggling in many of the schools, particularly in kindergarten through grade six. The attitudes and feelings children have toward formal school science programs develop at an early stage in their education, and schools need to attend to the development of the students' interests, skills, and knowledge in the sciences. In relation to some other school subjects, the current status of science instruction is low in many schools. At the same time the need is great for individuals and society to keep pace with the increase in scientific and technological knowledge, even though it can be a frustrating and

[1]Frank Press, "Science and Technology: The Road Ahead," *Science*, Vol. 200, No. 4343 (May 19, 1978), 737—41.

demanding experience. Thus, teachers and administrators have an important task of reevaluating the present status of science education in their schools to determine the future needs of students and the community that the school serves.

A concern for teaching methodology becomes a significant aspect of the reappraisal of the status of science instruction. There is no end to knowledge; therefore, generalizations and concepts in the subject matter of science to be taught in the schools become important considerations in restructuring science teaching. Interdisciplinary or integrated approaches to science education can be considered as one way of making science relevant for students and teachers.

The teaching of science in traditional ways needs to change in order to help students know or experience science in relation to their environment. Science learnings are important in themselves; however, the design and intent of science programs for kindergarten through grade twelve should take into account the practicality, probable use, timelessness, reasoning process, social application, and the value of science education for all students throughout their lives. Any science program design should include some experiences in the processes of science. Students can use such skills as observing, hypothesizing, calculating, locating information, measuring, explaining, summarizing, and other related process skills, both in science and in other areas of learning. For many students the end product might not be specific scientific knowledge but the development of attitudes of wonder and exploration and continued learning.

Two recent studies are cited here to provide educators with information concerning the status of science in California elementary schools and providing instruction for general scientific literacy.

A recent doctoral study titled *An Assessment of Science Programs in California Elementary Schools* sums up information that many persons thought was true but was not supported by research. Although no study presents a perfect compilation of all statistics and information, this research can be valuable to educators who are concerned with improving the quality of science education. The findings of the study include the following (with the page numbers on which the information appears in the doctoral thesis cited in parentheses):

1. Only 5 percent of California school districts employ full-time science specialists (pp. 1, 203).
2. Student participation in science activities averages 44 minutes per week in elementary schools (pp.103, 215).
3. Over 40 percent of the elementary teachers surveyed rated their own ability in science as below average when compared with other subjects and felt they did not have the skills to teach science processes and concepts (p. 203).

4. 45 percent of the elementary teachers and administrators predicted that less money for instructional materials will be spent on science, because state funds provided for instructional materials may be spent on any subject area as districts or schools see fit (within the established guidelines) (p. 167).
5. Although teachers expressed their support for the "hands on" concept, most continue to use textbooks (56 percent) or teacher-made written materials (57 percent) as the basis for their science instructional programs (pp. 2, 3).
6. Although science kits or systems have been purchased by many schools or districts, only 5 percent of the teachers use them extensively (p. 3).
7. Many respondents expressed the feeling that other subjects took a priority in time over science (p. 36).[2]

A recent article in the *Science Teacher* suggested that science instruction could be improved by (1) providing the student with a variety of learning approaches; or (2) matching the student with a teacher whose instructional style more closely matched the personality of the student.[3] Student personality styles were identified by the use of the *Myers-Briggs Type Indicator*. A strong plea was made to create a wider spectrum of instructional choices in order to increase general scientific literacy as well as to improve instruction for the science-oriented student.

In view of growing concerns among science educators about the current status of science in the schools, there is a need for a new focus on the importance of science education.

In this *Science Framework* emphasis is placed on ways school personnel can change the environment of science instruction and motivate student interest in science more effectively. Suggestions are given for developing human beings who not only realize the value of science to themselves and others but also understand the importance of science in providing a livable environment in a shrinking world. The emphasis on reasoning and the relevance of science can be obtained through a strong, interesting, and nonthreatening curriculum design. The challenge to give science education a higher priority in the curriculum structure must start with concerned educators. The *Science Framework* is one tool these educators can use in the process.

The *Science Framework* is organized into four chapters and six appendixes. Chapter 1 discusses the acquisition and organization of knowledge in respect to developing broad generalizations and concepts. The chapter defines what science is and how it can be applied to the learner, curriculum, and society.

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[2]Eugene H. Brown, *An Assessment of Science Programs in California Elementary Schools*. Berkeley: University of California, 1977 (doctoral thesis).

[3]Mary Budd Rowe, "Who Chooses Science? A Profile," *Science Teacher*, Vol. 45, No. 4 (April, 1978), 25—28.

Chapter 2 provides information from the latest research and suggests strategies for changing the science curriculum and designing new and vital programs. The steps in the development of a science curriculum are described.

Chapter 3 suggests the four broad goals of science education for kindergarten through grade twelve. These goals fall into four areas: attitude, thinking processes, skills (manipulative and communicative), and knowledge. Terminal objectives, examples of learner behavior, and the appropriate grade levels where the behavior is likely to be observed are categorized.

Chapter 4 describes the components of a good learning environment and suggests instructional strategies that can be used to achieve the four goals of science. It provides a model for evaluating progress toward student terminal objectives and gives examples of teacher behavior for each objective. Numerous evaluation techniques are suggested, and methods of evaluating learner performance are described.

The appendixes to the *Science Framework* provide specific information for those teachers and administrators who will be using the framework. In Appendix A the major conceptual organizations of scientific knowledge are described. Appendix B presents the currently approved criteria that are used in evaluating instructional materials. The design for decision making presented in Appendix C identifies responsibilities in curriculum development at the policy, curriculum, and instructional levels. Appendix D is a self-assessment checklist for teachers. Appendix E is an instrument districts can use to measure the professional growth of teachers of science. Appendix F presents information on developing and assessing science instruction skills.

Acknowledgments

During the course of development of the *Science Framework*, the California State Curriculum Framework and Criteria Committee for Science received invaluable assistance from many sources. It is virtually impossible to recognize individually all of the persons who contributed to the success of the project. Preliminary materials were read and discussed by representatives of school districts, offices of county superintendents of schools, and collegiate institutions. Their suggestions were most helpful. Special thanks are given to the many contributors, and especially to the committee members listed below, for their efforts.

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Gratitude also is expressed to the many individuals who contributed to the 1970 edition of the *Science Framework*. The work they began continues in this edition.

Chapter

1

Science: Definitions, Characteristics, and Relationships

Modern societies accepted the treasures and the power that science laid in their laps. But they have not accepted . . . its profounder message: the defining of a new and unique source of truth.

Jacques Monod
Chance and Necessity, page 170
Translated from the French by Austryn Wainhouse

Modern societies are built largely upon science and its offspring, technology. Human beings constantly are being reminded of this—in their use of communication, transportation, housing, clothing, food, water, and energy. It is important to learn about the scientific facts and discoveries that human beings have turned to their use.

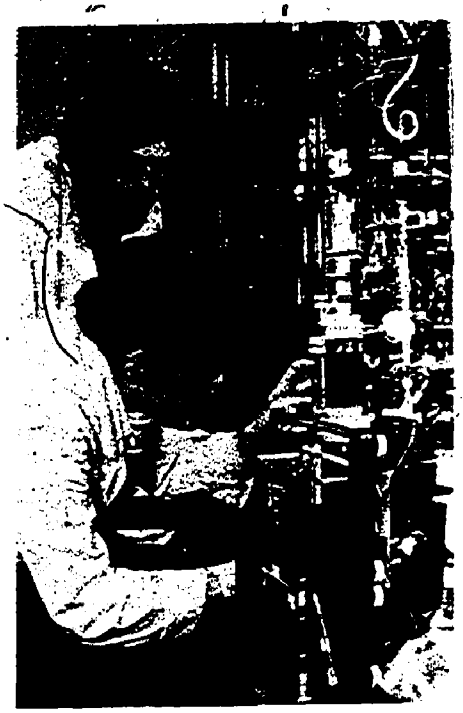
The countless benefits of science confer an obligation on teachers and learners alike. This obligation is to understand and practice the pursuit of objective knowledge as the source of truth. Only by vigorously adhering to objectivity, to an uncompromising search for facts, can science survive and flourish. Out of this pursuit comes liberation from superstition and a deepened understanding of people and of the universe.

Before people can begin to consider the impact of science on the world around them, they need to have a definition of science. Many such definitions exist; these generally can be divided into two categories.

In the first category of definitions, science is viewed as a body of collected knowledge comprised of interconnected sets of principles, laws, and theories that explain the universe. When people who take this view talk about science, they refer only to its content—the facts, principles, and laws used to describe the world around them.

In the second category of definitions, science is viewed as a set of processes that can be used to systematically acquire and refine information. People who take this view consider the scientific enterprise to be a set of processes for obtaining information.

For the purposes of this framework, the definition of science encompasses both points of view because one point of view cannot be learned or understood without the other. Through observation and experiment the scientist assembles facts about nature. He or she then seeks relationships that will link these facts into a coherent and useful network. In such a scientific enterprise, the facts, principles, and laws serve as knowledge-content building blocks, while processing and reprocessing procedures serve to organize and refine the building blocks. The dynamic relationship between systematic processes and pieces of knowledge is the essence of the enterprise. Thus, science is the acquiring and organizing of knowledge in such a way that natural phenomena are more adequately explained and their usefulness to human beings is enhanced.



Science as a Way to Acquire Knowledge

The main route to scientific knowledge is through *observing*, which can be characterized as a distinct process. When used in scientific research, observing is an attentive and intentionally objective activity that serves to answer specific questions. *Describing* is a more sophisticated process. It requires that the attributes of the observed object be distinguished from one another. One can observe an object as a whole, but describing requires attention to parts. *Comparing* is a process by which one systematically looks at objects in relation to other objects, identifying likenesses and differences. This process allows a scientist to begin the more complex process of *classifying*. Many other processes can be identified. Some processes, such as *hypothesizing, experimenting, inferring*, and *predicting*, consist of one or more of the previously mentioned activities.

All of these scientific processes can be learned; more individuals have learned to be scientists in the past 50 years than in all previous human history. Teachers cannot, of course, teach students to make great discoveries, but they should be able to describe some aspects of how discoveries are made. Scientists owe much of their success, for example in the conquest of disease, to the way they have been able to identify, use, and refine the scientific processes that lead to new knowledge. By using these processes, human beings have been able to organize knowledge and develop a clearer understanding of nature.

Science as a Way to Organize Knowledge

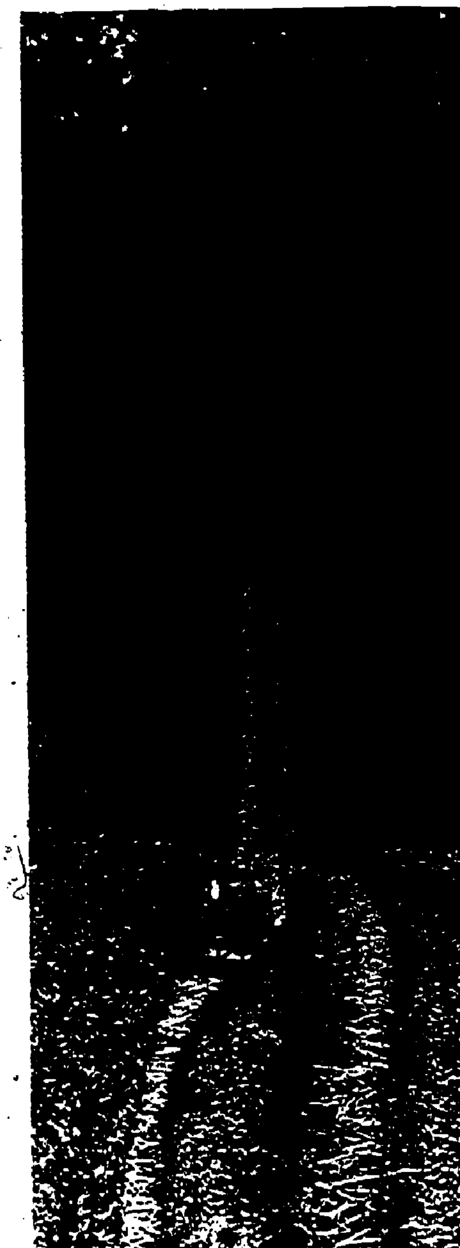
Facts alone do not constitute science; science exists only when relationships among facts are established. As facts are interrelated, organizations of knowledge result.

Even when the facts are observable, their relationships may be difficult to perceive. Human beings devise organizations that seem to fit the facts they observe. The scientist tries to build, step-by-step, a conceptual model of a possible organization, probing and testing each step. The procedure of testing whether a model of the relationship remains consistent with the facts when a new fact is added is crucial. The scientist must use a model to make a prediction. If a new fact contradicts the prediction, the scientist knows the model was, at least in part, in error.

When the fact conforms to the prediction, it supports the model. But *support is not proof* to the scientist. The new supporting fact is added to existing knowledge; it confirms the application of the model and widens its range, but it cannot be decisive or show that the model is universal. One purpose of experimentation is to uncover a situation in which the model fails. As a result of such experimentation, some organizations of knowledge of 100 years ago appear crude and primitive today. Such models must be continuously refined, updated, or replaced.

The very nature of the scientific enterprise is to (1) generate and test conceptual organizations or generalizations that provide models for the understanding of how certain facts are related; and (2) continually search for greater and greater generalizations. The result is the production of broader, more comprehensive concepts and, at the same time, the reduction of diverse ideas to fewer concepts. This is precisely the basis for scientific progress.

The major concepts with which factual data are explained and related in each major discipline (e.g., astronomy, biology, geology, chemistry, and the like) are readily available. One can make broad and comprehensive generalizations that are basic to many disciplines and that interrelate the many facts and principles of all the sciences. Examples of some of these basic conceptual generalizations of scientific knowledge are presented with explanations in Appendix A.



Science and Society

The ability of scientists to generate new knowledge is one of the world's major economic and social assets. Support for research to generate more knowledge and to apply that knowledge has been strong, but this support recently has become a political issue. Some results of research and development certainly have benefited humankind. People today have a greater abundance of food and a greater freedom from disease than did people in earlier generations and nonscience-oriented societies. Other results have had an unfavorable impact on the environment. Human health can be affected adversely by polluted air, water, and soil. The future survival of the world's population is being affected by the depletion of natural resources.

Science, technology, and societal concerns are intimately related, and individuals must become aware of the rapid changes that may directly affect their welfare. For example, the replacement of people by machines has had an enormous economic benefit. The trend toward automation that allows one individual to perform the tasks of many and the trend toward computerized data processing require that some consideration be given to the consequences. If society is to maintain full employment, the leisure time available to future citizens will be unequaled in history. The beneficial use of this time for the individual and for the nation must be an issue of high priority.

Other science-initiated trends should cause society to rethink its goals and beliefs. Progress in the medical sciences, for example, has increased the need for an understanding of the process of aging. This same progress has led to a reconsideration of the issue of euthanasia. How much value human beings place on life and, indeed, how they define the quality of that life are not strictly scientific questions, but are part of the presuppositions from which scientists begin. The economic considerations inherent in the use of artificial internal organs require that people understand the problems associated with their use. General concerns, such as the purity of foods, the quality of the environment, and the health and safety of people, are not matters for science alone—economical, ethical, and political factors may dominate these issues.

Informed people will be able to recognize that many major forces in society affect the learner, the schools, and science. Such individuals will know that science and technology are necessary but not sufficient in themselves to solve most of society's problems.

Science and the Curriculum

The production of new scientific knowledge and its importance to the progress of our culture make increasing demands upon schools and the science curriculum. Recognizing that it is not possible to predict what knowledge and processes are most likely to be valuable to individuals a dozen years from now, instructors, curriculum designers, and other educators must focus upon a few basic principles and processes. These can be used to guide the learner to think rationally and to continually test his or her opinions, beliefs, and concepts against observable phenomena. By instructing young people in these basic principles and processes, teachers of science can contribute to the attainment of a competent, orderly, and humane society, one in which the individual understands the functions of science. In such a society scientific research can help provide maximum opportunities and benefits for the individual.

Within the whole curriculum of the school, science can be a leavening ingredient. It can enhance language development by providing learners with opportunities to read, write, speak, and listen as well as by giving them experiences that are worth reading, writing, and speaking about. Science instruction can provide the experiential basis for young people to form concepts that, in turn, necessitate the development of vocabulary.

As with language instruction, science can reinforce the teaching of mathematics by demanding frequent application of mathematical skills and by providing occasions for practice. Science instruction, with its accompanying laboratory activities, can make such skills more interesting, more useful, and more applicable to "real life situations." Students can learn why there is a "best" part of a bat for hitting a ball. In metal shop students can learn why metals crack when they are bent too many times.

Practically every subject in the curriculum can be related in some way to science. The science curriculum should be designed in such a way that these relationships are emphasized at every opportunity.

Science and the Learner

Schools are composed of students who have a wide range of diverse characteristics. These differences are influenced by genetics, culture, society, environmental conditions, levels of aspiration, and other factors. Because of these diversities, the intellectual growth of students requires a science curriculum that is made up of different subjects that are taught through a rich array of instructional techniques. Such subjects should be paced at a rate that ensures steady progress, and they should be designed to bring each student to his or her maximum potential as a self-directed learner.

Science instruction can play a significant role in developing each student's potential. It should guide the student toward the rational resolution of problems, and it should emphasize both the worth of thinking for oneself and the difference between fact and opinion. The critical attitudes fostered by the study of science may indeed be essential for the successful functioning of a democracy. Our political system requires from its citizens maximum understanding of how to beneficially apply and control technology. This understanding cannot be realized without successful instruction in science.

Instruction in science should make the learner aware of the many career opportunities that can result from studies in science. Indeed, in the contemporary world one hardly can imagine any career that would not be made more effective by a knowledge of science.

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Chapter 2

Design and Change in Science Curricula

Science is not merely a collection of facts printed in an encyclopedia—it is a living adventure of human spirit.

Howard J. Hausman
Choosing a Science Program for the Elementary School, page 45

Many of the federally sponsored science curricula of the 1950s and the 1960s were conceived in terms of the science concepts and processes that were believed to be the most important to be taught. Although these are still valid, a contemporary science curriculum is broader in concept, moving toward science that is interrelated with human problems and with life in a complex society. Science is viewed as basic for all students, regardless of vocational or career plans. Knowledge, when it is used in real life issues, builds cross-disciplinary curricula. The term *curriculum* itself is derived from a Latin word related to action. Therefore, in this framework, the curriculum is conceived as the combination of learning experiences provided by a school district for its students.

Although one can identify many possible combinations of experiences that can be used to develop curricula, certain common components exist. These include an underlying philosophy that involves learning theories; a view of the society and learners served with an assessment of needs; overall goals and objectives that are consistent with the goals of science education; a scope and sequence; a collection of learning activities, which at a district level must be useful to a variety of teachers and learners; resources; and an evaluation plan that includes the examination of both long-term and short-term results.

The total curriculum should include a description of the methods by which the goals and objectives are to be achieved. These goals and objectives for science instruction are described in Chapter 3 under the categories of (1) scientific attitudes; (2) rational and creative thinking processes; (3) manipulative and communicative skills; and (4) scientific knowledge. These broad goals are common to the biological, physical, earth, and space sciences. These goals, the means used to achieve them, and the procedures used to assess achievement are derived from one or more educational philosophies.

This document was conceived from an eclectic philosophy. Local school philosophies vary, but if the science curriculum is to be effective, the underlying philosophy, the instructional sequences, and the chosen materials must be consistent with each other. This idea of consistency encompasses the attitudes, needs, and concerns of students, teachers, and members of the local community. The science curriculum has some flexibility, and it varies with the changing events in science and with the current needs of the students, the school, and the community; however, it must include content from each of the major scientific disciplines.

The designing, changing, developing, and implementing of a curriculum are parts of a cyclic process that involves not only school personnel but also students, their parents, and other members of the community. A systematic design for curriculum planning is imperative if personnel, materials, space, time, and funds are to be used effectively. A curriculum design deals with conflicting conceptions of the school's philosophy, its goals and objectives, and the ways to organize to meet these goals and objectives as well as fulfill the aspirations of the students' and parents.

The organization of the science curriculum may be based on science content knowledge by topic, by concept, or by process. It may even be based on the instructional methods or materials to be used. Some curricula provide a tightly sequenced hierarchy of concepts and/or processes. Others provide independent units or topics that can be used flexibly to meet local needs; still others incorporate an entire system of instruction. No one pattern of organization is superior. But regardless of the organizational focus that is adopted, the concepts, processes, units, equipment, materials, and systematic instruction must be considered fully by the writers of the curriculum.

Most science curricula reflect one or more of the following current trends in teaching-learning theories: the use of the interdisciplinary approach that involves mathematics, the arts, social sciences, industrial arts, and language arts; flexibility to meet individual needs and personal value systems; more electives at the high school level and/or minicourses based upon interests of students; activity-oriented experiences for individual students or groups; recognition of the contributions made to science by men and women of all races and religions; experiences outside the classroom; independent career explorations for both science and nonscience career students; and greater emphasis on the use of science.

To incorporate any of these trends, designers of a science curriculum should do the following:

1. Determine the status of the current science curriculum by performing an assessment and establishing priorities.
2. Determine what is desired in a new or modified science curriculum by (1) formulating goals and objectives; (2) identifying and previewing new programs and materials; and (3) determin-

ing the organization. scope, and sequence of the desired curriculum.
3. Establish plans for achieving what is desired by (1) selecting and organizing materials and other resources; (2) modifying and developing the teaching-learning experiences; and (3) identifying the implementation and staff development needs.
4. Evaluate the science curriculum by determining what is to be evaluated and how and when the evaluation will be made.

Status of the Current Science Curriculum

To develop a new science curriculum, one first must learn the status of current programs. The existing programs must be assessed thoroughly by the instructional staff through contacts with other teachers, administrators, support personnel, students, parents, and school board members. Cooperation from all participants and effective communication are especially important to this assessment. Also, the entire process of assessment is made easier if timelines are established to indicate when program and student evaluations will occur.

Performing an Assessment

Numerous components for a science curriculum must be considered in an assessment. The checklist shown in Figure 1 can serve as a guide to obtaining information on the major components; it can be modified or expanded by the user.

Establishing Priorities

When the assessment data have been gathered and analyzed, critical priorities can be identified. These can become the base for planning goals that will direct further science programming and development. The individuals involved in science curriculum development and decision making must continually assess the processes by which curriculum priorities are established. The data from the assessment can be synthesized into several levels of priorities: critical, important, and desirable. A science curriculum cannot be developed without regard for the entire school curriculum, and a balanced school curriculum includes science instruction.

Priorities may continue to change because of changing circumstances, but the critical priorities serve as strands for the science planning process.

Many different strategies can be used to develop a new science program or to redesign an existing one. The determination of what is desired is based on analyzed data gathered in the assessment and on the philosophy, goals, and objectives established by the curriculum designers. The general organization, scope and sequence, and some learning activities are also included in what is desired; but for plans to become operational, priorities have to be determined. The priorities that are decided upon become the focal point for achieving what is desired. The decision of whether to create, adopt, or adapt science curricula requires knowledge of what choices are available. Curriculum decision makers have the responsibility to provide the psychological and technical support that is needed to implement the curriculum.

Areas to check	Current	Desired
Learner		
Achievement of science education goals:		
• Scientific attitudes, interests, and attitudes toward science		
• Thinking processes		
• Manipulative and communicative skills		
• Science knowledge (content)		
Cultural community background		
Language background		
Current Science Program		
Current written and operational science curriculum		
Teaching-learning environment (See Chapter 4.)		
Location of science program in school		
Organization for instruction (self-contained, team teaching, and the like)		
Time spent in preparing for and instructing in science		
Instructing techniques		
Student grouping patterns		
Processes for evaluating learners and the science program		
Legal restrictions (animals, safety regulations, and the like)		
Instructional Staff		
Staff attitudes and interests		
Staff skills and talents (administrative, classroom, and nonclassroom)		
Staff processes (group communication, decision making, and school climate)		
Resources for Science		
Availability of science personnel		
Science equipment and instructional materials		
Science facilities (classrooms, labs, library, and the like)		
Consultants		
Money		
Community		
Attitudes toward the school and science program		
Interest and support		
Attendance at school functions and activities		
Monetary-materials-service support		

Fig. 1. Science curriculum assessment checklist

Determination of What Is Desired in the Curriculum

When the current science curriculum has been assessed and the priorities have been identified, curriculum designers must formulate their goals and objectives and preview the available instructional materials in science. The preview process and visitations to schools with exemplary science programs should aid the school staff in determining what is desired and what changes need to be made.

Formulating Goals and Objectives

The priorities identified as a result of the analysis of the information gathered from the assessment become the planning goals. For example, the data gathered might indicate there is no formal assessment of the learners at certain grade levels regarding achievement of the science program goals and objectives. A critical planning goal then would be the development of an assessment program to measure the achievement of the goals established for the science program.

Other planning goals and objectives are related to identified priority areas. Examples of identified priorities might be staff development activities, facility improvement, support for the science program, or community involvement. The goals and objectives should be formalized on the basis of the actual priorities that have been identified in the needs assessment of each district or school. In this process the ultimate science program will reflect input from the local schools and community.

Identifying and Previewing Programs and Materials

Because of the plethora of science programs, textbooks, and instructional materials available today, the school staff must set up a preview process. Visitations to exemplary science programs in other schools or school districts would be rewarding. County, state, and science teacher organizations can provide valuable information. Care should be given to the selection of materials so that all the sciences are covered. The preview process should provide the planning group with data that can be used in the decision-making process. The type of science program desired—whether text, text-activity oriented, or process oriented—can be decided upon. The organization of the content, the instructional materials needed, and the supporting resources must then be planned. If a new curriculum is created, schools might be selected to pilot all or part of the program. This procedure can be used to evaluate the appropriateness of the program for the school population.

Determining Organization, Scope, and Sequence

In this document *curriculum* has been defined in its broadest terms. Therefore, the organization, scope, and sequence of science curricula incorporate more than the traditional listing of science content. The science curriculum that follows the goals and objectives set forth in Chapter 3 includes the development of scientific attitudes, thinking processes, manipulative and communicative skills, and scientific knowledge. The wide acceptance of the importance of these goals for science education has resulted in changes in three curriculum considerations: the development of differing curriculum organizational patterns; an increased scope of science content beyond the traditional biological, physical, earth, and space sciences; and a variety of learning sequences. These changes have been recommended in curricula such as those sponsored by the National Science Foundation and by several publishers. Curriculum designers should supplement the following discussion by further study of current science curricula and by the use of science curriculum specialists. The need for this is emphasized by new developments in both science and education.

Organization. Science curricula generally have reflected an emphasis on facts, with content topics serving as the usual organizational pattern. Such content organization still can be used, but other modes of organization (e.g., process, attitude, skill or delivery system; and conceptual scheme) are commonly advocated. How the curriculum is organized reflects the background and experience of the developers. For example, a powerful mode of organization for science curriculum content is one based on a conceptual organization of knowledge such as that presented in Appendix A. Other conceptual organizations have been developed by competent scientists such as those who developed Appendix A, which incorporates these generalizations.

In a conceptual organization of knowledge, scientific information is brought together in broad generalizations that interrelate the many specific facts and principles of all of the sciences. Conceptual organizations can be used to facilitate both interdisciplinary and intradisciplinary studies. Students can gain greater meaning and understanding from such studies. A conceptual organization of the knowledge of science is vital to all levels of science and education because it is more stable than one based on ever-increasing and constantly changing facts or on nonrelated topics.

Science curriculum developers should be aware that, if concept generalizations are used as curriculum organizers for content, appropriate learning activities that illustrate the concept need to be determined and specified for each grade level and/or science course. Conceptual learning in science is a factor in the implementation of any science curriculum and is not dependent only on organizing the curriculum by concept.

Science processes may form another organizational basis for a written curriculum. One National Science Foundation project gave preeminence to scientific processes as a science curriculum organizer. School districts may devise their own process curriculum or adopt one that is already developed and tested. To devise a new process curriculum, the designers must specify illustrative activities.

Scientific attitudes are conceived as major organizers in some science curricula. Current national and scientific concerns and social concerns related to science can form the basis for curricula. Science activities or short courses that are popular with students and that build positive scientific attitudes may form still another organizational basis for curricula.

Other organizational methods may involve contemporary educational delivery systems such as learning centers and individual or group laboratory modules and media. Developmental or hierarchical designs also may serve as patterns for curriculum organization.

An historical organization may be used to emphasize the growth of scientific knowledge curriculum and the relationship of science to other areas of the curriculum.

The goals for science education as stated in Chapter 3 also may be used as part of an organizational theme around which a curriculum may be written, but whichever organizer is used for the written science curriculum, all the other organizers will affect the written and taught science curriculum.

Care should be taken to see that the basic learning theories associated with a particular curriculum organizational pattern are compatible with those of the school, its staff, and the community. Changes in organizational patterns should be encouraged if the changes help improve student learning in science.

Scope. The broad natural curiosity of children delineates the scope of a science curriculum that encompasses the universe. In recent years curriculum designs have been expanded to include an array of emphases based on student and national interests or on the more realistic involvement of students in problem solving and in science-related issues in such areas as economics and law. Creative designs have been built upon many of the following topics: environmental studies that may range from endangered animal species to problems of increased human population and energy and water conservation; bioengineering; energy source studies that explore the power possibilities of the sun, wind, and tide; geology studies involving theories of plate tectonics and earthquake predictions; space science activities, including space probes, the probability of other life, and space technology; engineering; meteorological studies in which satellite data and other references are used in the examination of world climates; oceanographic studies of the California coastline and its development; behavioral studies designed to help individuals better understand themselves and others; and combined physiological, psychological, and social studies dealing with such topics as birth, aging, and death.

The science curriculum for kindergarten and grades one through twelve should provide opportunities for all students to pursue interests in a variety of sciences at each level. Provisions also should be made for advanced learning in each of the sciences.

Sequence. Many sequences may be followed in developing a science curriculum. Little more than tradition justifies most of today's science curriculum sequences. Various science topics, concepts, and courses have been proposed as the most simple or basic; but, for example, some controversy still exists as to whether to require chemistry before biology.

If students are to be presented with concrete and familiar ideas as a basis for learning abstract concepts, the teacher must sequence their experiences accordingly. But sequences are arbitrary and may not fit individual students. What is necessary for students is a consistency in sequencing, following any organizational basis but making adequate provision for recycling ideas for those students who enter the established sequence at different places. Students who need additional help in understanding or who wish more experience should then be given more opportunities. Students are valuable resources and should be consulted in determining the sequences as well as determining what can and should be included in the curriculum.

Plans for Achieving What Is Desired

When curriculum designs are to be developed or existing science programs are to be modified, planners should consider the various sources of curriculum design; e.g., the state framework and district and school curriculum guides. The *Science Framework for California Public Schools* provides a broad base from which all levels of curriculum design can be developed; courses of study prepared by offices of county superintendents of schools provide greater specificity; school district courses of study or curriculum guides and school-level curriculum programs further increase the specificity; and, finally, classroom-level instructional objectives are directed toward more specific learning experiences in science.

The science program planning process referred to earlier in this chapter can be used by curriculum designers to develop plans for achieving what is wanted in new science programs. The cyclical and ongoing process may be visualized as shown in Figure 2.

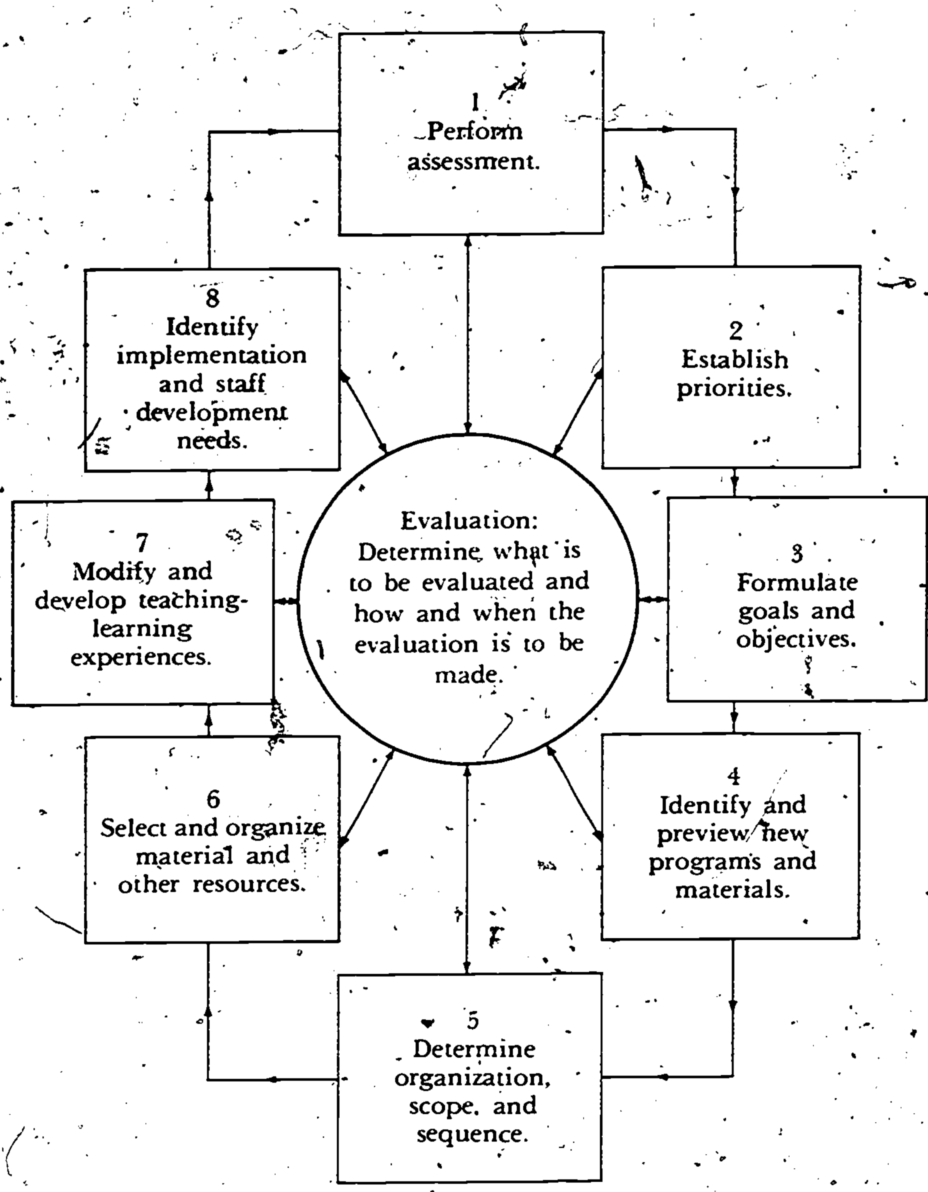

Fig. 2. Science program planning process

Selecting and Organizing Instructional Materials

Instructional materials in science, including equipment and supplies as well as print and media materials, should be selected to facilitate achievement of science curriculum goals and objectives and to provide variety and motivation for the learner. The use of good instructional materials increases sensory stimulation for the learners, giving them greater access to phenomena unavailable in the classroom.

A variety of science materials can be used to give learners practice in scientific inquiry. Teachers also can evaluate learning in different ways; for example, in laboratory seminars. More sophisticated equipment such as computers can make learning relevant and can give valuable experience for future careers.

Care must be taken, however, so that the materials do not become the curriculum. Science experiences outside the classroom should be provided. Extracurricular activities such as participation in science clubs and fairs should be included in the learning program.

In California, science materials are state-adopted only for kindergarten and grades one through eight. Materials for grades nine through twelve should, however, satisfy the criteria used by the evaluators of materials used in the lower grades. (See Appendix B.) The proliferation of science materials makes the selection process difficult and time consuming.

District boards and administrators should give priority to the development of policies and procedures for setting up local selection committees and provide members with sufficient released time (and a timeline) in which to make careful selections. Science material selection committees should include individuals who have an interest and a background in science. Students, school board representatives, administrators, support staff, and members of the community should be asked to provide input to the committees.

Before selecting any instructional materials, members of the curriculum and science selection committees should do the following:

1. Become familiar with the *Science Framework* and the criteria derived from it. These criteria should help members of district committees develop their own criteria for selecting materials. (See Appendix B.)
2. Review county and district courses of study and guides for science instruction.
3. Study district statements of philosophy and goals, data from local needs surveys, organizational patterns, and teacher statements concerning the science objectives for which individual teachers agree to assume responsibility.

4. Review recent literature on science education to become aware of current trends and practices.
5. Develop a criterion checklist for systematic local selection, replacement, and storage of instructional materials in science.
6. Obtain evaluation data relevant to checklist items from the California State Department of Education's *Instructional Materials Selection Guide—Science* (kindergarten and grades one through eight); reviews and articles from science education journals and other professional sources (kindergarten and grades one through twelve); science conference proceedings and publishers' displays; Educational Products Information Exchange (EPIE) reports; producers' brochures and catalogs; and users' evaluations.
7. Conduct an inventory of science materials and facilities that currently are available in the district to determine their condition and to ascertain whether they meet new criteria and can still be used.
8. Use collected data to eliminate those science materials that do not meet locally developed criteria.
9. Examine and evaluate state-adopted and other science materials that seem to meet local criteria and rate these materials in terms of each criterion.

Before making any determination in regard to the programs or materials to be adopted or modified, members of the selection committee should consider the following:

- Grade level match
- Compatibility with district and/or school goals and objectives
- Adaptability to existing program
- Type of class organizations and schedules indicated
- Instructional approaches to be used by the staff
- Student interest and motivation
- Parent/community involvement and needed support
- Personnel requirements, including support from classified staffs for secretarial, recordkeeping, and clean-up assistance
- Printed materials and science supplies
- Space requirements for students and materials
- Laboratory hardware and other equipment
- Reordering procedures and time lag
- Formal and informal evaluations of the program and materials
- Start-up and continuing costs
- Benefits to students, teachers, and the community

Modifying and Developing Learning Experiences

Science learning experiences in the classroom have always stressed student participation in laboratory work and other activities. Outside the classroom, learning experiences have gone beyond the confines of the school to situations where students at all levels are involved in science data gathering, problem solving, conducting research, and working on science-related jobs in the community.

The learning activities as well as the topics in current science curricula aim toward attitudes which reflect science in a more humane manner. People who are concerned about the world's energy resources should realize the need for developing positive attitudes toward science as well as exercising rational thinking.

Those who are developing today's science curricula should stress the integration of science into all aspects of life. Many students are preparing for careers and learning the importance of science courses in many occupations not related to science. Opportunities to experience different science-related careers need to be included in the science curricula.

Identifying Implementation and Staff Development Needs

Once the organization, scope, sequence, and materials are selected, implementation becomes the most critical part of the science curriculum design process. Unless the learners actually become consistently involved with sequential and meaningful science experiences, both in and out of the classroom, the science curriculum will be nothing more than a series of meaningless statements in the teacher's handbook.

Implementation needs. The staff must become involved before a new curriculum can be implemented. The lines of communication must be open among teachers at each grade level, between grade levels, and between schools. In the secondary school special efforts must be made to open the lines of communication between teachers and counselors. Counselors sometimes can defeat excellent science planning by predetermining assignments to new science programs. School districts must also provide for continuous communication between the various organizational levels that exist. No science curriculum program can be adequately implemented until consistent processes for communicating, planning, and decision making are established. (See Appendix C for a decision-making diagram.)

Science is a natural motivator for the learner. At the elementary level science topics can be integrated easily with other curriculum areas. The processes of science (observing, classifying, making inferences, or measuring) are applicable to all subjects. Local districts often incorporate science into the reading and mathematics activities at the elementary and intermediate school levels. Efforts currently are being made in secondary programs to take a multidisciplinary approach across the boundaries of all disciplines to achieve the objectives for more than one discipline.

Strong interdisciplinary curriculum offerings can be developed between the science department and other content areas to assist each learner in the secondary school in selecting science-oriented classes that are exciting, personalized, meaningful, and relevant. Good science teaching strategies can be used to involve and guide the learner and stimulate the total secondary school curriculum.

The term *implementation* implies that the school shares responsibility with its constituents, including members of the community and commercial suppliers of science materials. Because the community so often is overlooked for its potential science resources, its responsibilities also are overlooked. Support can come from members of the school board and from scientifically engaged individuals, businesses, and industries in the community. The school administration can provide psychological as well as financial and professional support through school inservice opportunities in science for principals, teachers, parents, and student assistants. Incentives can be developed for self-improvement programs on the part of teachers and students.

A supportive administrative staff can provide opportunities for professional growth in science through meetings, workshops, demonstrations, and presentations. Students should be encouraged to participate in various youth science activities such as those offered at state and county science fairs. They should also be given opportunities to gain work experience with science-related firms and organizations in the community. In the classroom students and volunteer aides can provide needed assistance.

Teachers and learners, who are partners in the educative process, also have responsibilities for implementing the school curriculum. They carry out these responsibilities by trying innovative procedures, withholding judgments, and suggesting workable changes.

Staff development needs. Persons responsible for staff development should first concentrate on the overall science curriculum and then on the individual science programs. When materials and supplies in science become available, more specific inservice instruction is needed. Consultants should be chosen for their knowledge of both the philosophy and the techniques needed to make a particular program work. If they are to succeed, these consultants must be able to relate well with teachers.

Optimum success will be achieved in implementing a meaningful program in science by using a team of teachers, district-level science specialists, university science educators, and publishers' representatives. The team works best when it has been provided with adequate support. The school demonstrates its support by providing released time, necessary science materials, and access to classes where different programs can be observed. To determine accountability, one must consider the extent to which such support services have been made available to the teacher.

A competent teacher can make up for a lack of good instructional material, but no instructional program can survive an

incompetent teacher. Being a successful teacher of science requires a knowledge of science and the learner, a command of scientific techniques, an appropriate sense of the purpose and role of science, and a desire for continuing self-improvement.

Teachers themselves must acquire particular competencies if they are to develop them in their students. Teachers first must acquire scientific attitudes, thinking processes, skills, and knowledge. They also must be competent in the social sciences, in the arts and humanities, and in the use of the English language. These and other competencies can be achieved only if teachers are given opportunities for self-evaluation and self-improvement. (See Appendix D.) Competencies can be achieved through various types of inservice experiences. A checklist of specific competencies, designed to give individual teachers an insight into areas that might need upgrading, is presented in Appendix D. The following experiences can help members of the staff improve their competencies.

Staff Development Experiences That Lead to Improved Competencies

Teachers can improve their competencies by participating in the following activities:

- Special events scheduled for teachers to hear outstanding speakers, to observe demonstrations, to become acquainted with new materials and equipment, and to discuss special problems or needs. One should realize, however, that isolated events have little long-term effect without some follow-up.
- Inservice programs of specified duration with qualified leaders to accomplish certain specific objectives. Such programs are effective only if the activities require real involvement of the participants and if a close relationship exists among the activities undertaken to meet the stated objectives.
- On-the-job experience in the classroom where the teacher tests and evaluates the new materials and techniques. Many of the instructional materials and techniques have first been observed by the teacher at workshops and conferences.
- Formal courses conducted by colleges and universities for updating and enriching the competencies of science teachers. These courses can help prepare the teacher to lead the students into special areas.
- Advanced research at the college or university level; in industrial laboratories; or in public, private, and governmental agencies. This can involve field work in various scientific disciplines. It also can provide excellent opportunities for developing the skills, attitudes, and approaches needed in science instruction.

Evaluation of the Evolving Science Curriculum

The science curriculum should be undergoing evaluation throughout the design, development and implementation phases. The curriculum is evaluated against the goals and objectives, for degree of reasonableness. The ultimate test of the curriculum is in the achievement of the students within the community. Parents or teachers may feel comfortable and satisfied with a curriculum that is inadequate for the progress of today's student; therefore, like the planning phase, the evaluation phase of a science curriculum design should be a joint effort of many individuals. Formative evaluation, that which is accomplished during the planning and implementation phases, is essential.

Student achievement instruments such as standardized tests, attitude assessment scales, and task performance devices can be used to gather basic data. All available data must be analyzed and evaluated in terms of a priori criteria that follow logically from the framework goals and objectives of the new science curriculum.

Other less quantitative and more subjective analyses may be used to examine the human interactions that occurred during the development and implementation phases of the design. Comments and views of various individuals can serve as indicators of the extent to which the design has contributed to the overall benefit of the students, teachers, parents, and administrators. Less standardized evaluation devices are available through the U.S. Office of Education and the National Science Teachers Association.

The writing of a summative evaluation of the curriculum should be scheduled at regular intervals to determine needed major shifts in goals or objectives, in materials, or in the science curriculum itself. This written evaluation should include not only perceptions and progress of the students but also those of the teachers and the support staff (including administrators). Factors such as facilities usage, equipment availability, materials effectiveness, and parent and public acceptance also should be included in the evaluation. Evidence of a positive evaluation can be obtained in many ways. By their participation in the various activities, the students will be expressing their attitudes toward the science program. The success of the science curriculum will depend upon the contribution made by each district employee and by each student.

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Chapter 3

Goals and Objectives

Human beings need not be driven to explore, to think, to learn, to dream, to seek out problems for solution; they are intrinsically constituted to do just this. The learner is not only a problem-solving and stimulus-reducing organism but also a problem-finding and stimulus-seeking organism.

J. W. Getzels
"Images of the Classroom and Visions of the Learners," in *Learning Environments*, edited by Thomas G. David and Benjamin D. Wright, page 10

Instructional goals are general statements that define the desired ends of education; objectives are more specific statements of the steps involved in reaching these goals. In this chapter goals and objectives convey the intent of the science curriculum for kindergarten and grades one through twelve.

The relative importance given to particular goals and objectives may vary in accordance with different philosophical positions. Care must be taken, however, not to stress any one goal to the neglect of others. All of the goals are interrelated, and each reflects a necessary aspect of scientific literacy. Continual reassessment is necessary to ensure that each goal is consistent with changes in cultural values, societal problems, the needs of learners, and the current status of science.

The goals for science instruction are described under the following categories: (1) achieving scientific attitudes; (2) achieving rational and creative thinking processes; (3) achieving manipulative and communicative skills; and (4) achieving scientific knowledge.

The learner's terminal objectives for each of the four categories are shown on charts 1 through 4. Terminal objectives are broad statements of instructional intent for the total science program (kindergarten and grades one through twelve). Such objectives usually are stated by program developers and by other groups concerned with the outcomes of the total science curriculum. In addition, some examples of learner behaviors that are related to levels of learner development have been identified for each terminal objective. These examples are indicators of the expected level of competency for the majority of students at particular grade levels in California's public schools.

Chart 11

Attainment of Positive Attitudes Toward Science

Goal: ***To develop values, aspirations, and attitudes that promote the individual's personal involvement with the environment and society***

The learner's attitudes will determine what he or she will do autonomously, without extrinsic motivation, as a result of science instruction. Because positive attitudes toward science and learning are prerequisite to effective learning in other goal areas, this goal area should be considered first.

The terminal objectives presented in Chart 1 define how a learner might behave as he or she perceives the scientist's "rules of the game," establishes the personal and social relevance of what has been learned about science and scientists, and enjoys learning about science. The grade levels indicate where the behavior is most likely to be observed. The broken lines indicate that the specific behavior may be evident before this level is reached and should continue through grade twelve.

Terminal objective
The learner:
1. Shows curiosity about objects and events.
2. Shows an awareness of and responds in a positive manner to beauty and orderliness in the environment.
3. Appreciates and respects all living organisms (including self) and their place in the environment.
4. Takes an active role in solving social problems related to science and technology.
5. Weighs alternative scientific, economic, psychological, or social factors when considering possible resolutions to some problems.

Examples of learner behaviors	Approximate grade level where behavior is usually observed (K 1 2 3 4 5 6 7 8 9 10 11 12)
The learner:	
• Finds pleasure in unfamiliar objects and events.	K
• Shows a willingness to examine and organize objects and events in the environment.	4
• Speculates about properties of substances that are not testable with one's own resources.	9
• Expresses consciousness and/or pleasure in color, form, texture, arrangement, or design of objects in the environment.	K
• Responds in a positive manner to color, form, texture, arrangement, and the design of objects in the environment.	2
• Searches for and reports evidence of order and symmetry when observing and investigating one's environment.	7
• Shows respect for the proper care of all living organisms.	K
• Accepts responsibility for the care of living organisms in natural and artificial environments.	3
• Appreciates both the interdependence of living organisms in the natural environment and the implications of that interdependence for their continued survival.	K
• Practices conservation in use of food, energy, and materials; e.g., avoids wasting paper.	K
• Expresses an opinion on a social issue (e.g., land use, alternative energy sources), using knowledge of science and technology to support his or her opinion.	4
• Seeks to influence the views and behaviors of others with respect to conservation, environmental problems, energy use, population control, public health, and other social issues related to science or technology.	10
• Recognizes the alternative factors to be considered when examining possible resolutions.	4
• Values the alternative scientific, economic, psychological, or social factors when considering some problems.	7
• Deliberately examines alternative points of view on scientific issues before forming opinions about them.	9

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Chart 1 (Continued)

Terminal objective

The learner:

6. Organizes and reports the results of scientific investigations in an honest and objective manner.

7. Shows a willingness to subject data and ideas to the criticism of peers.

8. Has a critical, questioning attitude toward inferences, hypotheses, and theories.

9. Habitually applies rational and creative thinking processes when trying to find relationships among seemingly unrelated phenomena and when seeking solutions to problems.

10. Gives attention to and values science as an endeavor of human beings from all racial, ethnic, and cultural groups.

11. Considers science-related careers and makes realistic decisions about preparing for such careers, taking into account the abilities, interests, and preparation required.

Examples of learner behaviors	Approximate grade level where behavior is usually observed (K 1 2 3 4 5 6 7 8 9 10 11 12)
The learner:	
• Shows a willingness to log only those data he or she actually has gathered.	4
• Forms opinions only after seeking a variety of data and ideas.	7
• Assumes responsibility for reporting results in an honest and objective manner.	9
• Readily admits own mistakes upon becoming aware of them.	2
• Shows a willingness to listen critically to explanations of others.	6
• Points out the limitations of one's own data.	9
• Listens to the ideas of others.	K
• Shows a willingness to respond to contradictions between data and theory.	5
• Tests theories that do not support his or her own theories.	9
• Spontaneously attempts to describe an object or event that has attracted his or her attention.	K
• Shows a willingness to look for problems and to note discrepancies.	5
• Applies science problem-solving techniques in a nonschool situation; e.g., diagnosing what is causing a car's engine to malfunction.	9
• Chooses to gather information and report on the scientific contributions of other cultures.	2
• States that race, sex, or nationality should not constitute a barrier to scientific study.	4
• Values the scientific contributions of human beings from various cultural groups.	7
• Shows respect for the many science-related careers of people in our society.	K
• Values the abilities, interests, and preparation required for a science-related career.	7
• Assumes responsibility for making a realistic decision about the pursuit of a science-related career.	10

Chart

2

Attainment of Rational and Creative Thinking Processes

Goal: ***To develop and apply rational and creative thinking processes.***

The term *thinking processes*, as defined here, refers to the cognitive processes involved in scientific inquiry as well as those processes that are basic to all rational thinking. Such processes as *observing, measuring, comparing,* and *classifying* lead to more sophisticated processes such as *inferring, generalizing,* and *theorizing*.

A major goal of science education is to have learners use these processes in a cyclical manner—moving from the generation of data, through the building of hypotheses, to the application and evaluation of data and procedures.

When the data generated by an experiment prove to be consistent with an hypothesis, the hypothesis is supported.

Some of the thinking processes in which the learner engages during science experiences are presented in Chart 2. The chart takes into account the developmental levels of students and thus provides a rationale for structuring learning activities at appropriate grade levels.

The selected examples describe only a few of the countless ways in which learners may show that they are thinking rationally. Even from this sparse sampling, however, one can easily see that the ability to engage in these processes is cumulative in nature. Although the ability to evaluate a situation critically may not develop until early adolescence, all the processes requisite to judging (including observation and recall) stay with the learner as part of his or her total thinking processes.

Terminal objective

The learner:

1. Develops ability to generate data by observing, recalling, recognizing, identifying, and measuring.

2. Develops ability to organize data by comparing, ordering, classifying, and relating.

3. Develops ability to apply and evaluate data and generate theories by hypothesizing, predicting, inferring, generalizing, theorizing, explaining, justifying, and judging.

4. Uses data-generating and theory-building processes in a cyclic manner to solve a problem; i.e., participates in scientific inquiry for the appropriate level.

Examples of learner behaviors	Approximate grade level where behavior is usually observed (K 1 2 3 4 5 6 7 8 9 10 11 12)
The learner:	
• Examines objects carefully, using a combination of senses to collect and process data, deriving meaning from the observation; and sees the need to use simple instruments such as hand lenses to aid the senses in making observations.	K
• Determines the need to repeat observations as a means of improving reliability; decides to use measurement as a means to improve observations; and identifies changes in properties and rates of change.	5
• Differentiates constants from variables and identifies correlational changes and variables.	10
• Perceives similarities and differences in a set of objects; and separates a set into groups according to a single characteristic such as size, shape, or color.	1
• Develops arbitrary classification systems wherein objects can be put into mutually exclusive categories and uses quantitative measurement as a criterion for grouping.	6
• Groups on the basis of a continuous variable; develops a classification system consisting of two or more stages or subsets with mutually exclusive categories; and uses an accepted classification system to key or identify objects or phenomena.	8
• Identifies statements or data that have no direct relationship to the solution of a specific problem and identifies contradictions within the data.	6
• Examines environmental issues, pointing out contradictions and discrepancies in the positions of various groups; and gathers data to form own point of view to resolve any earlier contradictions.	9
• Defines a problem related to a discrepant event.	5
• Identifies data needed to test an hypothesis; designs an experiment to generate the data; records and organizes data; and evaluates the hypothesis in light of the new data.	9

Chart 3

Attainment of Manipulative and Communicative Skills in Science

Goal: ***To develop fundamental skills in the manipulation of materials and equipment; in the care and handling of living organisms; and in the collection, organization, and communication of scientific information.***

Many different skills are needed when a learner employs his or her thinking processes to develop a conceptual understanding of the natural environment. The learner gathers information by observing, manipulating materials and equipment, reading, communicating, using measuring instruments, and handling living organisms. His or her linguistic, mathematical, graphical, and tabular skills are used to record and organize information. A major goal of science education is to provide opportunities for each learner to develop and use his or her manipulative and communicative skills.

Many areas of the curriculum are interrelated with the learning of skills that are critical to science education. Reading, writing, speaking, and listening skills are all basic to the communication needs of science students. Many of the skills included in Chart 3 are common across a broad spectrum of occupations. Accountants, salespersons, bankers, engineers, social scientists, physicians, nurses, and scientists must be able to obtain, record, process, interpret, and report information and to communicate ideas in a clear, convincing manner. Thus, this skills goal is not only critical to science education, but it is also important in the development of competencies that are required for effective citizenship.

Terminal objective

The learner:

1. Assembles and uses laboratory apparatus, tools, and materials in a skillful manner, giving due attention to accident prevention.
2. Demonstrates proper techniques for handling and caring for living organisms.
3. Gathers the descriptive and quantitative information needed for developing or testing inferences and hypotheses by making purposeful, objective observations of things and events.
4. Gathers needed information, which has been generated by others, from a variety of sources.
5. Records observations accurately and organizes data and ideas in ways that enhance their usefulness.
6. Communicates with others (orally and in writing) in a manner that is consistent with knowledge of scientific conventions, and facilitates the learning of the listeners or readers.
7. Uses the International System of Units (SI) metric system effectively.

Examples of learner behaviors	Approximate grade level where behavior is usually observed (K 1 2 3 4 5 6 7 8 9 10 11 12)
The learner:	
• Manipulates in a safe manner simple materials, apparatus, and equipment (e.g., balance, hand lens, and beaker).	3
• Demonstrates growth in the ability to manipulate more complex science materials and equipment (e.g., microscope and telescope).	6
• Acquires and assembles appropriate science apparatus, materials, and equipment in order to obtain designated data.	9
• Handles plants and animals carefully and follows suggested procedures.	K
• Provides a life-supporting environment for plants and animals.	6
• Makes purposeful, objective observations.	K
• Measures temperature changes.	3
• Records the time required for a series of events, e.g., chemicals reacting in a test tube or objects falling from a given point.	9
• Listens to the ideas of others.	K
• Reads and comprehends information in science textbooks and reference materials, and watches and comprehends science films or science presentations on television.	6
• Finds sources of information needed to learn about a topic to solve a problem.	9
• Orally describes a series of events.	K
• Tabulates information and uses tables.	4
• Interprets graphs and displays data graphically.	7
• Orally describes observations and answers questions.	K
• Explains, either orally or in writing, the methods and procedures involved in conducting an investigation.	6
• Writes an accurate and documented paper describing an investigation.	10
• Counts, uses numbers, and balances objects on an equal-arm balance scale.	1

Chart 3 (Continued)

Terminal objective
The learner:
7. Uses the International System of Units (SI) metric system effectively (continued).
8. Applies appropriate mathematical concepts and skills in interpreting data and solving problems.

Examples of learner behaviors	Approximate grade level where behavior is usually observed
The learner:	K 1 2 3 4 5 6 7 8 9 10 11 12
• Measures linear distances using a metric ruler, and uses a balance to determine the mass of objects.	5
• Measures volume of liquids in a graduated cylinder marked in millilitres.	8
• Calculates rates (speed, flow, and the like) from data.	6
• Finds mean (average), median, and modes of a series of measurements.	3
• Uses powers of ten (exponential notation) to express very large or very small numbers.	9
• Determines degree of precision of measurements and quantities derived from measurements.	11
• Uses calculators and computers to advantage in manipulating data and solving problems.	5

Chart

4

Attainment of Scientific Knowledge

Goal: *To develop knowledge of processes, facts, principles, generalizations, and applications—the products of science—and encourage their use in the interpretation of the natural environment*

The acquisition of organized knowledge is a long-range goal of science and science education. When the learner is able to understand different contributing facts, unifying principles, and relevant processes, then he or she begins to know what organized knowledge is.

Some knowledge will be acquired as a by-product of instruction intended to develop attitudes, skills, and thinking processes. Other knowledge, especially at the secondary school level where content information becomes increasingly prominent, is a deliberate objective of instruction. At all levels the knowledge goal must be in balance with and consistent with the other goals of science education.

Four types of knowledge can be highlighted as components of this goal:

1. Knowledge that enables the learner to verbalize the thinking processes and skills of science. Examples of learner behaviors related to the acquisition of knowledge are included in Chart 4 under Objective 1.
2. Knowledge that includes the content, basic concepts, and structure of the major disciplines in science (e.g., physics, biology, and astronomy). Statements of the content and major concepts and structure of a given discipline are readily available elsewhere. Examples of learner behaviors related to the major disciplines are included under Objective 2.

Terminal objective

The learner:

1. Demonstrates knowledge of the processes of scientific inquiry.
2. Demonstrates knowledge of the content of the major scientific disciplines.

Examples of learner behaviors	Approximate grade level where behavior is usually observed
The learner:	K 1 2 3 4 5 6 7 8 9 10 11 12
• Distinguishes between the process of trial and error and a more controlled investigation.	4
• Matches names of various processes and products of scientific inquiry with examples; e.g., data, theory, experiment, and inference.	6
• Criticizes a scientific investigation, pointing out the procedural steps that have been omitted or inadequately performed.	9
Astronomy	
• Identifies the planets in the solar system.	4
• Recognizes that the motion and path of celestial bodies are predictable.	8
• Identifies the regular movements of the earth and moon.	6
Biology	
• Identifies and describes living things that grow and develop in different environments.	2
• Recognizes that the capture of radiant energy by green plants is basic to the growth and maintenance of living things.	5
• Recognizes that a living thing is a product of its heredity and environment.	7
Chemistry	
• Recognizes that matter exists as solid, liquid, or gas.	2
• Demonstrates that in chemical or physical changes the total amount of matter remains unchanged.	5
• Recognizes that in nuclear reactions a loss of matter is a gain in energy and the sum of matter and energy remains constant.	8
Geology	
• Recognizes that the earth is constantly changing.	1
• Recognizes that rocks contain one or more kinds of minerals.	5
• Recognizes that volcanoes change the earth's surface by building mountains.	3

Chart 4 (Continued)

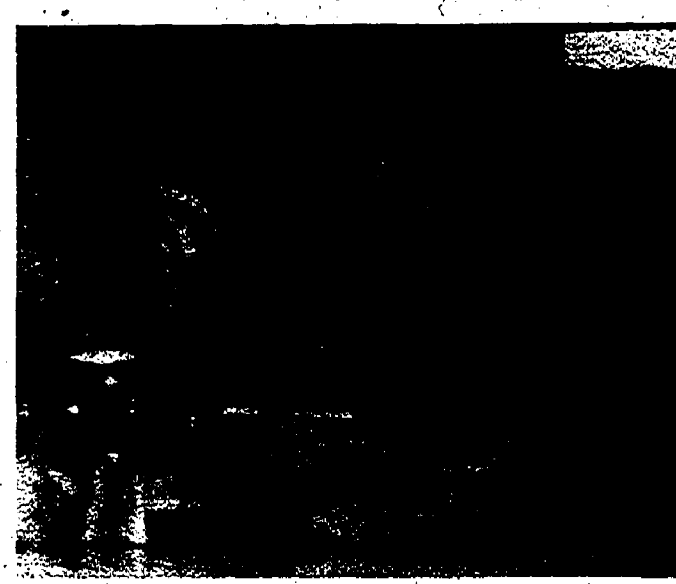
3. Knowledge that is composed of broad generalizations that interrelate the many facts, concepts, and principles of all the sciences. These concepts are basic to many disciplines. Examples of these broad generalizations are given in Appendix A, and examples of learner behaviors related to them are included under Objective 3.
4. Knowledge of how science and technology affect society. This concept of knowledge is relevant to the needs of the learner. Examples of learner behaviors are included under objectives 4 through 8.

Terminal objective

The learner:

2. Demonstrates knowledge of the content of the major scientific disciplines (continued).

3. Demonstrates understanding of some basic generalizations, relationships, and principles applicable to all the sciences.



Examples of learner behaviors	Approximate grade level where behavior is usually observed
The learner:	K 1 2 3 4 5 6 7 8 9 10 11 12
Physics	
• Recognizes that energy must be applied to produce an unbalanced force, resulting in motion or change in motion.	2
• Demonstrates that the amount of energy a machine produces does not exceed the energy consumed.	5
• Demonstrates the relationship between magnetism and electricity.	8
The following are examples of learner behaviors related to major conceptual organizations of scientific knowledge. A more complete discussion of these conceptual organizations is presented in Appendix A.	
A. Most events in nature occur in a predictable way, understandable in terms of a cause-and-effect relationship; natural laws are universal and are demonstrable throughout time and space.	
The learner:	
• Identifies simple cause-and-effect relationships; e.g., an object becomes hot when it is held over a flame.	1
• Uses a complex cause-and-effect relationship to make a prediction; e.g., by using data on relative positions of the sun and moon at various times of the month, the learner can predict when the highest and lowest tides will occur.	8
• Explains the nature of a statistical prediction involving many individual events of low predictability; e.g., radioactive decay or population growth.	10
B. Frames of reference for size, position, time, and motion in space are relative, not absolute.	
• Demonstrates knowledge of SI metric system units and how they are used.	5
• Explains why a beam balance will give identical results on the earth and moon and why a spring scale will not.	10

Chart 4 (Continued)

Terminal objective
The learner: 3. Demonstrates understanding of some basic generalizations, relationships, and principles applicable to all the sciences (continued):

Examples of learner behaviors	Approximate grade level where behavior is usually observed
C. Matter is composed of particles which are in constant motion.	K 1 2 3 4 5 6 7 8 9 10 11 12
The learner:	
• Describes changes that take place as heat is applied to an ice cube and then to water until it boils.	3
• Explains the changes that occur as heat is applied to an ice cube (using ideas of moving molecules, attractive forces, and relative distances between molecules).	9
• Describes, with the use of models, how properties of elements are related to the structure of their atoms.	11
D. Energy exists in a variety of convertible forms.	
• Recognizes that fuels are burned to generate electricity, heat homes, prepare meals, and the like.	K
• Identifies examples of the various forms of energy, including kinetic, potential, mechanical, heat, chemical, electrical, radiant, and nuclear energy.	6
• Designs and constructs a device involving at least four separate energy transformations.	10
E. Matter and energy are manifestations of a single entity; their sum in a closed system is constant.	
• Recognizes that, in a closed system, no appreciable mass is gained or lost in phase changes or chemical reactions.	8
• Describes, using appropriate equations, nuclear transformation that results in conversion of mass to energy.	10
F. Through classification systems, scientists bring order and unity to apparently dissimilar and diverse natural phenomena.	
• Identifies pairs of objects with similar characteristics.	K
• Describes the "rule" characteristic, or system of classification used to sort a group of miscellaneous objects.	4

Chart 4 (Continued)

ective

ng of some basic gen-
s, and principles ap-
ces (continued).

Examples of learner behaviors	Approximate grade levels where behavior is usually observed (K 1 2 3 4 5 6 7 8 9 10 11 12)
The learner:	
• Develops and applies a dichotomous key to classify an assortment of plants.	7
• Names the major groups within a plant and animal taxonomy (e.g., phyla).	9
• Recognizes that classification systems (e.g., plant and animal taxonomy and the periodic table of elements) are made by human beings for the use of human beings.	10
G. Living organisms have universal properties.	
• Matches pictures of animal parents and offspring.	K
• Observes and describes qualitative and quantitative ways in which individuals in a species vary.	3
• Writes a thoughtful essay on the topic, "Is an Organism a DNA Molecule's Way of Making Another DNA Molecule?"	10
• Cites major processes and assumptions related to Darwinian evolution.	10
H. Units of matter interact.	
H-1. The bases of all interactions are electromagnetic, gravitational, and nuclear forces whose fields extend beyond the vicinity of their origins.	
• Predicts the interaction of a magnet with various objects.	3
• Explains the functions of an electroscope, using the concept of repulsion of like charges.	7
• Using laws of gravitation, explains why a person "weighs" less on the moon than on the earth.	10
• Explains how chemical bonds between atoms result from electrical attraction between nuclei and electrons.	11
H-2. Interdependence and interaction with the environment are universal relationships.	
• Matches major organs and systems of the human body with their functions.	2

Chart 4 (Continued)

Terminal objective

The learner:

3. Demonstrates understanding of some basic generalizations, relationships, and principles applicable to all the sciences (continued).

4. Demonstrates knowledge of relationship between science and society.

5. Demonstrates knowledge of science-related careers and the preparation needed for such careers.

6. Demonstrates knowledge of the contributions to science and technology made by men and women of various races and nationalities.

Examples of learner behaviors	Approximate grade level where behavior is usually observed (K 1 2 3 4 5 6 7 8 9 10 11 12)
The learner:	
• Names and describes, in sequence, the processes of the water cycle.	4
• Identifies the major links in a food web.	8
• Describes the effects of human activity on a particular environment and vice versa.	6
H-3. Interaction and reorganization of units of matter are always associated with changes in energy.	
• Predicts what will happen when a piece of wood is placed on a fire.	K
• Gives examples of exothermic and endothermic chemical reactions.	8
• Traces the energy flow in an ecosystem.	10
• Describes ways in which an organism, to maintain its complex structure, must utilize energy and create disorder (increase entropy) in its surroundings.	10
• Gives examples of ways in which the use of scientific knowledge has affected society.	K
• Describes aspects of a society that tend to encourage or inhibit the advance of science.	9
• Identifies types of data that should be collected and used in deciding on the ideal location for a park, factory, or apartment building; and in predicting the consequences of locating same in various places.	10
• Compares the work done by people in different occupations, including one involving science.	1
• Identifies ways in which careers such as engineering, medicine, chemistry, or agriculture are related to science.	5
• Names science-related careers that he or she might consider and describes preparation needed for such careers.	9
• Matches significant discoveries to persons who made the discoveries.	5
• Relates time and place of important advances in science and technology to prevalent conditions and contemporary events.	7

Chart 4 (Continued)

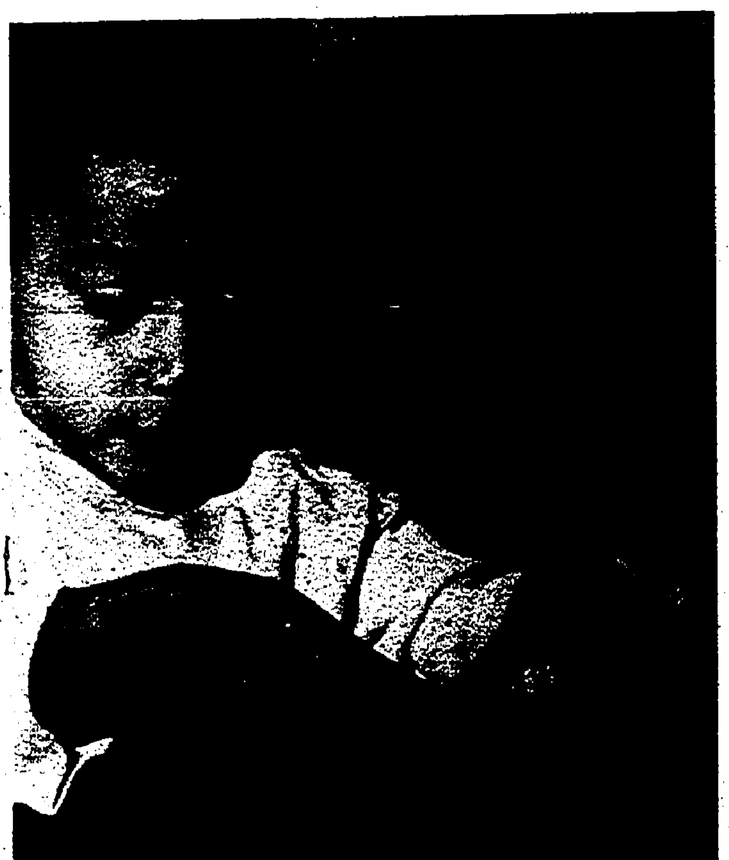
Terminal objectives

The learner:

6. Demonstrates knowledge of the contributions to science and technology made by men and women of various races and nationalities (continued).

7. Demonstrates knowledge of the relationship of science to other areas of human endeavor (e.g., art, history, and government).

8. Demonstrates knowledge of the ways in which attitudes, thinking processes, and skills can be coupled with content knowledge and used in personal decision making.



Examples of learner behaviors	Approximate grade level where behavior is usually observed
The learner:	K 1 2 3 4 5 6 7 8 9 10 11 12
• Describes instances in which a major scientific or technological advance has been based on the work of persons of several races and/or nationalities.	9 ....
• Compares a variety of artwork possible using only naturally occurring media with other artwork created using synthetic materials.	3 ....
• Creates materials to produce artwork.	6 ....
• Describes how modern dating techniques contribute to knowledge of earlier civilizations.	9 ....
• Given a list of foods, identifies items that would constitute a nutritious, balanced meal.	5 ....
• Given manufacturer's literature and consumer research data, selects an item for purchase (e.g., bicycle, dishwasher, or car).	8 ....
• Uses data from scientific investigations to present a position on a political issue.	10 ....

Use of Goals and Objectives in Planning and Evaluating

Each of the teaching behaviors and evaluative techniques presented in the following chapter needs to be considered in light of its effectiveness in assisting the learner to move toward the goals and objectives. The diversity of objectives clearly demands a diversity of skills and strategies on the part of the teacher.

A lesson that seeks to help the learner appreciate and respect all living organisms and their place in the environment and develop techniques for handling and caring for living organisms in a proper manner requires a different approach than a lesson that is aimed at getting learners to demonstrate their awareness of processes of scientific inquiry. Both are necessary. The evaluation of a teacher's effectiveness (including his or her self-evaluation of effectiveness) should deliberately be planned and conducted so as to assess effectiveness in the four major goal areas.

A course of study that was developed as part of a cooperative 50-county project is available from the office of any county superintendent of schools.

Planning and Evaluating the Curriculum

The goals and objectives are of major importance in the development of curriculum and the selection of instructional materials. (This is discussed in detail in Chapter 2.) Every lesson or segment of the science curriculum should be designed with *some* of the objectives in mind (and should not work counter to the achievement of any of the objectives), and the total science curriculum for each student should be directed toward *all* the objectives. The use of these objectives as a checklist in analyzing the present curriculum may reveal deficiencies that should be corrected when a new curriculum is being planned. Evaluation of learner progress must be made in *all* of the four goal areas; otherwise, teachers and learners will begin to concentrate heavily on the areas that are assessed, and the program will become unbalanced.

Evaluating Learner Achievement

The sample learner behaviors presented here may serve as a guide to teachers and students in defining the additional behaviors they hope will result from the learning process; however, no attempt should be made to predetermine all the outcomes of learning in specific behavioral terms. More importantly both teachers and learners should become sensitive to and value a wide variety of behaviors.

The goals and objectives also can be used in the development of graduation requirements based on broad interrelationships rather than on course outlines. For instance, a science program might be concerned with the relationships between matter and energy in biological and physical systems.

Science Education and the Community

Science education does not function in a societal vacuum. The perceptions and interests of members of the school community can have great impact on science programs at all grade levels. Public information programs should be used to stimulate awareness of, and interest in, science education. Active community involvement in science instructional programs should be encouraged because education is both a function and a responsibility of the total community.

The school community consists of all those who will benefit from the science program: students, parents, people in industry and labor, and concerned individuals. It also includes those persons who are charged with the responsibility for such instruction: teachers, administrators, counselors, paraprofessionals, volunteers, and members of the support staff. Each of these individuals should obtain specific information about the basic goals and directions of science education. School administrators can shape and give direction to these programs by providing a comprehensive two-way communication process.

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Chapter

4

The Learning Environment, Instruction, and Evaluation

Learning Environment for Science Instruction

The learning environment for science is the setting for the entire process that leads toward student achievement of the desired goals and objectives. It includes the teacher, the student, the physical setting, and the instructional strategies that are used to accomplish desired results that can be measured. (See Figure 3.)

The Teacher in the Educational Process

The prime ingredient in any learning environment is the teacher. A high degree of freedom normally exists for the teacher to use his or her own teaching style to bring about the desired student achievements in science.

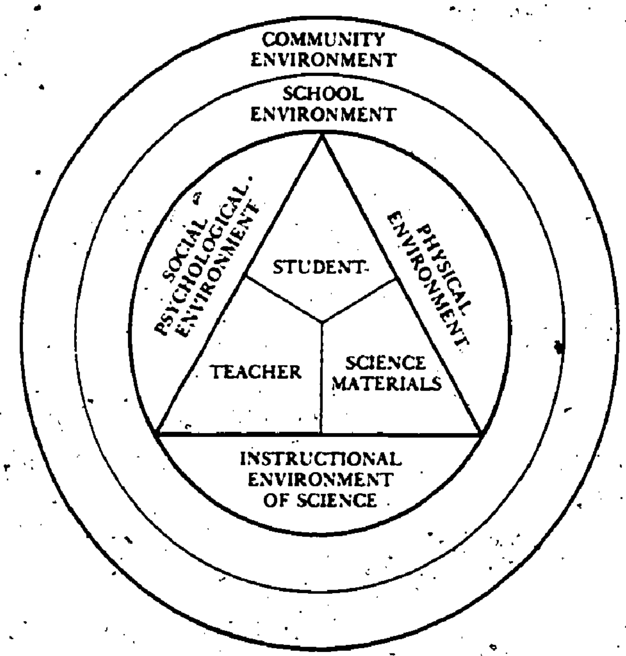


Fig. 3. Learning environment for science instruction

Teacher training, district staffing patterns, and school organization are important factors to be considered in determining what is the most effective teaching style for a particular system, school, or classroom. Teachers tend to teach as they have been taught. Elementary school teachers historically have acquired a general education while attaining their teaching credentials. Secondary school science teachers have received much of their formal education in the academic disciplines of science and mathematics. The emphasis of instruction at the elementary school level has been to attain a basic education to enhance the well-being of the individual, while at the secondary school level the emphasis has been to master the discipline. Academicians in the past have relied on the lecture technique as a preferred teaching style to impart the content of a discipline.

Teachers require extensive study in the field of education to vary their teaching styles. Group activities and individualized approaches require different teacher skills than does lecturing. Individualization of instruction is an instructional strategy that requires the teacher to maintain a teaching style of serving as a manager of students and materials to deal with the wide variety of problems that confront students when they must assume some responsibility for the education they seek.

Varied teaching styles can be used to give learners interesting experiences in science if the school has either self-contained classrooms or open-space learning areas and if teachers are allowed to use flexible staffing patterns

One myth of contemporary education is that most learning takes place in a classroom and depends upon the physical presence of a teacher, printed textbooks, and "proper motivation." But it is possible to distinguish between learning environments—which are characterized by a profusion of interesting, novel, and useful objects designed to be manipulated, smelled, measured, and arranged—and the typical American classroom, which is intended as a teaching environment.

Robert Sommer and Franklin Becker
"Learning Outside the Classroom," in *Learning Environments*. edited by Thomas G. David and Benjamin D. Wright, page 75

Preservice preparation. Creative preservice preparation of the potential teacher and the continuing process of updating and refining competence in science instruction throughout the teacher's career are important factors that contribute to the creation of an exciting environment for learning science.

Because teachers often are inclined to teach a subject in much the same manner as they were taught, some of their collegiate science experiences must be consistent with the types of science curricula considered most appropriate for learners. Course content coverage must also be tailored to the prospective needs of the teacher. In many instances breadth of coverage is of greater importance than depth of coverage. Science must be taught as a creative human endeavor, utilizing processes, skills, and content that can be appropriately applied to other areas of knowledge and, most importantly, to solving the problems encountered in daily living.

Staff development. School district administrators, county superintendents of schools, and university directors bear the major responsibility for giving teachers and other members of the school's staff opportunities to improve their competencies. Some suggestions for implementing staff development are the following:

- Through the cooperative efforts of all educational personnel (administrators, supervisors, and instructors) within a school district, determine staff science knowledge as well as instructional needs. Assessment of needs should include the determination of the instructional behaviors teachers are currently using. One should identify the disparity between current science teaching methods and the methods required to achieve the goals of science stated in this framework.

- Provide school staffs with various sources of science information (e.g., newsletters, bulletins, progress reports, periodicals, and journals) for their continuing education.
- Plan and conduct both long-term and short-term programs that include alternative activities designed to improve competencies in science curriculum and instruction.
- Capitalize on available resources in the community, and cooperate with other agencies that sponsor programs for improving the effectiveness of science instruction.
- Provide released time for professional growth activities.

School districts should be able to assess their staff development efforts. A data analysis sheet, an example of which is shown in Appendix E, may be used in such an assessment.

The Student as the Center of Attention

Students need to be provided a science education that is consistent with their needs and desires and also with society's wish that they function as scientifically literate citizens.

Group instruction traditionally has met the goals of both the teacher and student with varying degrees of success. Individualized instruction provides a structure and allows autonomy for the student to determine activities to be pursued in achieving the goals and objectives of the teacher and student. The most fully developed individualized program would provide a rich learning environment from which the student could select activities to achieve his or her goals and objectives.

To individualize science teaching, the teacher must provide students with experiences and activities that have personal meaning and are at the same time scientifically accurate. The ultimate goal of individualized learning, then, is a self-motivated learner who is interested in science and is capable of making rational decisions concerning science.

While educators have attempted to meet the individual needs of students, they also have realized that the range of individual differences is extremely broad.

Many individuals in the school population are being labeled exceptional students. The term *exceptional* refers to a significant number of learners who, for a variety of reasons, require other than routine curricular treatment. The term includes individuals currently classified as (1) mentally gifted minors (MGM); (2) bilingual-bicultural learners; and (3) students with a variety of physical, emotional, or learning impairments.

Supplemental funding has been available to local school districts through the California State Department of Education from federal funds, and most school districts have taken advantage of this source of funding to augment their regular curricular offerings in all subject matter disciplines, including science. The programs tend to stress activities leading to a high level of individualization and are often interdisciplinary.

The highly motivated and talented high school science student can study college-level biology, chemistry, or physics by participating in the College Entrance Examination Board's Advanced Placement Program. College credit is given if the student successfully passes an examination offered by the Educational Testing Service.[1] In some school districts advanced high school students can enroll part-time in community college courses.

In California schools many students have a primary language that is other than English. Until recently little attention was directed to such students, but some science materials now are available in Spanish. Additional instructional materials are needed in languages other than English.

Science materials for visually handicapped students have been developed in recent years. These materials involve extensive "hands on" experiences that rely on senses other than sight to provide the experiential bases for concept development. In similar fashion adaptations of science experiences have been developed for students with hearing impairments and for those with a variety of other physical disabilities that make acquisition of motor skills difficult or impossible (e.g., individuals with cerebral palsy, paralysis, specific dyslexia, and the like). These students require modified apparatus and approaches that are designed to allow them to compensate for these disabilities. Various means of working with handicapped students are available.

Other individuals have learning dysfunctions attributable to a variety of inherent, cultural, or emotional causes that are qualitative, rather than merely quantitative, in nature. For such learners more is required than merely to slow down and thus take longer to "cover" the science concepts. Rather, special materials, proceeding from a learning philosophy that acknowledges this distinction, are required, and some preliminary efforts have been made in this direction.

Each learner has different abilities. Efforts should be made to meet each learner's needs to attain a science education commensurate with his or her mental and physical abilities.

The Physical Setting

The physical resources of the entire school plant and the community should be taken into consideration in planning the science

[1]Additional information may be requested from Educational Testing Service, P.O. Box 1025, Berkeley, CA 94701.

instructional program. The optimum physical setting for science instruction provides for the flexible use of facilities for large-group and small-group instruction, laboratory activities, outdoor experiences, demonstrations, audiovisual presentations, seminars, and individual project work.

Use of facilities. The change in emphasis in science instruction from the presentation of factual information to the learning of principles and concepts through involvement in laboratory and multimedia experiences has had a profound impact on the physical facilities required for science instruction. Implementation of the various elementary science programs may not require elaborate laboratory facilities; however, tables are necessary and a sink is highly desirable. Secondary school facilities must safely and efficiently accommodate complex laboratory procedures that involve the use of volatile and flammable liquids or corrosive chemicals. Facilities for the storage, preparation, and replacement of these materials also should be carefully planned and utilized, in accordance with local and state safety regulations and requirements.

Science learning centers or resource rooms can be used to provide for individual student needs. The nature of these facilities would differ somewhat between the elementary and secondary levels; however, a table, storage space, and a sink should be made available to provide for individual and small-group laboratory activities. The students also will need a variety of materials, equipment, and reference books.

A fenced outdoor environmental study area with a southern exposure can be an excellent resource for an elementary school plant or secondary science facility. A small, shallow pond can be used for observing plant and animal development and for providing live specimens for classroom use. A gardening or planting area should be included. A greenhouse can also be a valuable instructional resource.

Use of supplies and equipment. The changes in emphasis in science instruction require the careful selection and management of materials. Allowing for "hands on" experiences requires a wide variety of supplies and equipment that must be readily available in adequate supply and in good condition. These materials usually are purchased as complete kits. Frequently, at the secondary level, basic equipment and supply items are purchased for use by several departments, and specialized materials are acquired as necessary for the individual programs.

Many supplies for science experiences can be obtained at no cost by using items that are available in the school or in the home.

Because science learning requires students to work with equipment, safety precautions are essential. Teachers should examine and use the equipment and materials to check out possible hazards, organize the classroom to facilitate supervision, limit the group size in specific activities; and allow sufficient time for each activity. Special consideration should be given to requiring the use of safety glasses or goggles whenever caustic, abrasive, or otherwise dangerous materials are to be used. If the facilities or equipment are not appropriate for certain activities, the activities should not be allowed.

Before requiring activities with plants, the teacher should determine whether any student is allergic to certain flowers or molds.

The care and use of animals in the instructional program must conform with local school policy and with the California Education Code. Section 51540 (formerly Section 10401) of the code states that live animals must be housed and cared for in a humane and safe manner. They must not be experimentally medicated, drugged, or treated in a manner that would cause pain.

Instructional Strategies for Achieving Science Goals and Objectives

Science instruction must involve: (1) the nature of the subject area to be learned; (2) the goals and objectives for the subject; and (3) knowledge of instructional strategies that facilitate learning. Without a reasonable balance among these aspects, the instructional goals will not be realized.

The purpose of this framework is not to present an endless array of learning theories. Its purpose is to provide basic considerations for teaching science, considerations that are derived from several different theories, each of which is important in planning science instruction.

All learning theories imply that *learning moves from the familiar to the unfamiliar*. Human thought progresses from hazy, vague ideas about objects and events to notions that are more clear and distinct. Thus, what is spatially near is more effectively introduced before that which is spatially distant. A tangible idea should be presented before an intangible one. The present is best studied before the remote past. In science instruction the concrete, observable, and reproducible events serve as a data base for concept formation. At the same time, they offer possibilities for creativity and imagination.

Instructional strategies encompass the action plans that teachers generally use to elicit, observe, and evaluate student behavior (as related to long-range goals and objectives). Teachers use techniques and select learning activities that are consistent with each strategy and that are related to the attainment of specific learning objectives.

Instructional strategies and techniques are derived from what is known about teaching-learning theories and methodologies that have been determined to be appropriate for the learning styles of different students. Strategies and techniques vary within each goal and objective, with each teacher, and with each learner or group of learners.

The different kinds of learning must of necessity work together. The achievement of the objectives in the rational thinking goal, for example, depends to some degree upon manipulative and communicative skills and upon knowledge. The development of positive attitudes toward science depends upon the exercise of rational thinking processes and the acquisition of skills and knowledge.

Instruction of Positive Attitudes Toward Science

Goal: ***To develop values, aspirations, and attitudes that promote the personal involvement of the individual with the environment and society***

Positive attitudes toward learning and science are a prerequisite to the effective attainment of other goals in science. Such attitudes are more likely to be acquired when learners hold positive attitudes toward themselves, relate their own choices to those made by persons they seek to emulate, experience success in applying scientific thinking and skills, and understand the relevancy of science to their own lives and life-styles.

The following instructional ideas may be useful in developing positive scientific attitudes.

Instructional Ideas That Facilitate the Development of Positive Attitudes Toward Science

Teachers can help develop positive attitudes toward science by doing the following:

- Provide opportunities for students to interact with individuals who derive satisfaction from scientific activities and modes of thought.
- Determine the values and interests of each student so that instruction can be built upon the student's life base and upon his or her curiosity about the world.
- Be continually alert to opportunities that provide a motivational basis for science instruction.
- Design science instruction that provides successful experiences from the earliest grades onward.
- Help each student develop a positive attitude toward himself or herself—a prerequisite to developing positive attitudes toward science.
- Establish an environment that includes a variety of interesting experiences and opportunities to explore, gather data, examine alternatives, and stimulate curiosity.

Instruction of Rational and Creative Thinking Processes

Goal: *To develop and apply rational and creative thinking processes*

Educational theorists and practitioners are not in agreement on the most appropriate method of achieving the ability to think rationally and creatively. Each of the following instructional ideas, which were derived from current schools of thought, has had success with some students.

Instructional Ideas That Facilitate the Development of Rational Thinking Processes

Teachers can help develop rational thinking processes by doing the following:

- Create classroom situations in which each student can participate in a scientific investigation—a situation involving the use of scientific inquiry to solve a problem. For instance, a student confronted with a discrepant event could propose explanatory hypotheses, test those hypotheses experimentally, draw conclusions, and make predictions from the results.
- Gradually introduce increasingly complex and progressively less-structured problem situations.
- Build, as much as possible, on prior learning of simple inquiry processes. Some theorists hold that to perform the more complex thought processes, one must have gained competency in performing simpler processes (such as observing events, classifying collected information, and quantifying data). Others find that these simple processes are more effectively learned by some students when they must attain these competencies in order to find their own solutions and explanations for the problems and events they encounter.
- Provide experiences that parallel those of the scientists by making available investigations involving phenomena, concepts, and facts about which students have already acquired some relevant knowledge.
- Start with a complex problem that the learner cannot resolve unless he or she has additional knowledge and skills. Proceed to break it into smaller component problems that can be investigated and resolved. Thinking processes and knowledge thus can be developed systematically to the point where the student can handle the larger problem.
- Encourage students to define their own problems, obtain and process data, verify their hypotheses, and derive alternative explanations of objects and events that occur in the universe.

Instruction of Manipulative and Communicative Skills in Science

Goal: *To develop fundamental skills in the manipulation of materials and equipment; in the care and handling of living organisms; and in the collection, organization, and communication of scientific information*

Students generally can acquire a skill most effectively if it is taught at a time when it contributes to the attainment of other goals or more complex skills. Skills, whether communicative or manipulative, are best learned in the environment in which they are used.

Because the reading skills of some students are far below grade-level expectations, techniques for assessing the reading levels of students and printed materials are included in this framework. (See Appendix F.)

The following instructional ideas may be useful in developing skills in science.

Instructional Ideas That Facilitate the Development of Skills in Science

Teachers can help develop skills in science by doing the following:

- Arrange skill development so that it is gradual and sequential.
- Demonstrate the skills that the students are to practice. This facilitates the mastery of laboratory skills.
- Have a variety of resources available for student exploration and use.
- Encourage interactions between students to develop manipulative and communicative skills.
- Create situations where learners are motivated to acquire the skills needed to reach a goal; i.e., solve a relevant problem.
- Devise and provide opportunities for students to share science ideas and experiences outside the classroom.
- Help learners attain the highest level of skill competency by showing them how to develop the manipulative and communicative skills needed in independent investigations.

Instruction of Scientific Knowledge

Goal: *To develop knowledge of processes, facts, principles, generalizations, and applications—the products of science—and encourage their use in the interpretation of the natural environment*

The knowledge of science and related subjects incorporates personal experiences, facts, concepts, principles, and generalizations. Various methods and techniques can be used to impart factual knowledge. The following instructional ideas were derived from theories of concept formation and were selected for their relevance to science instruction. The ideas should be useful at all grade levels.

Instructional Ideas That Facilitate the Acquisition of Scientific Knowledge

Teachers can help learners acquire scientific knowledge by doing the following:

- Select a sequence of learning experiences that will help the student proceed from simple to more complex concepts. Generally speaking, simple concepts are those that (1) are the most familiar and concrete; (2) have the most easily defined properties; (3) are most closely related to known concepts; and (4) require the students to process the least possible information at each learning attempt.
- Introduce students to a variety of situations involving the same concept. Conceptual systems are built as the learners see connections and interrelationships developing from one situation to the next.
- Provide students with experiences or scientific data that conflict with their present conceptual comprehension of a familiar object or event. This will stimulate inquiry and lead to a broader or deeper conceptual understanding.
- Devise or have the learners devise a technique that highlights the relevant characteristics in examples of concept application. Simplified diagrams, models, and cuing devices are all helpful in alerting students to significant aspects of the stimuli used in categorization.
- Provide experiences that will help learners synthesize their knowledge of related concepts into a broader concept, generalization, or principle.
- Encourage students to use their conceptual knowledge to explain observations of objects and events in their daily lives.

Evaluation Techniques for Determining Student Progress in Science

Evaluation, which is a continual, ongoing process, must be clearly linked with the educational goals and objectives. The main implication of these goals and objectives for evaluation of learner achievement may be summed up in the terms *variety* and *balance*. No one or two techniques, however effective, can suffice to assess learner growth toward the attitudes, thinking processes, skills, and knowledge defined here. The techniques used in teaching toward (and evaluating attainment of) a given objective should be consistent with those used in fulfilling other educational objectives. The various techniques of evaluating student progress are as follows:

1. Observations, which can be made by teachers, students (observing other students or observing themselves), principals, parents, or other individuals, are important in evaluating progress toward objectives. Observations can be directed generally as when one is looking for evidence of learner attitudes that are revealed in spontaneous situations where the learners do not feel that they are being tested or graded. In other situations observations can be specifically directed as when one is looking for proficiency in laboratory skills, oral communication, and the like.
2. Discussions and interviews with students or parents can be valuable in evaluating progress in all four science goal areas. Tapes or notes can be helpful when the interviews and discussions are being analyzed.
3. Questionnaires, opinion surveys, and semantic differential rating scales can be used to evaluate changes in learner attitudes. Care should be taken to ensure that the learners feel free to express their true feelings; i.e., that they do not feel pressured to respond in ways they think will be more acceptable to teachers.
4. Student projects, written and oral reports, and responses to essay-type test questions can provide evidence of progress in all four goal areas. This may involve a project for a science class or the selection of a science-related topic for a paper or project in an English, art, or social studies class.
5. Performance tests can be used to evaluate manipulative skills. Evaluation may be made by the teacher, other learners, or the individual involved.
6. Objective tests are useful in diagnosing and evaluating the growth of knowledge and the use of rational thinking processes.
7. Attendance records, transfer requests, and enrollment data showing the actual number of students who avoid taking science courses, can provide useful insights for evaluating student attitudes and learning experiences.

Chart

5

Evaluating the Achievement of Positive Attitudes Toward Science

Goal: *To develop values, aspirations, and attitudes that promote the individual's personal involvement with the environment and society*

The development of positive attitudes toward science requires an integrated relationship among overall goals, specific objectives, learner behavior, teacher behaviors, and evaluations of student progress.

The assessment of attitudes, to be honest and effective, must be separated from the system of rewards (e.g., grades).

Terminal objectives for the attitude goal described in Chapter 3 are presented in Chart 5. Instructional ideas that can be used to achieve each objective are included on the chart, along with suggestions for evaluating learner performance.

Terminal objective

The learner:

1. Shows curiosity about objects and events.
2. Shows an awareness of and responds in a positive manner to beauty and orderliness in the environment.
3. Appreciates and respects all living organisms (including self) and their place in the environment.
4. Takes an active role in solving social problems related to science and technology.
5. Weighs alternative scientific, economic, psychological, or social factors when considering possible resolutions to problems.

Examples of teacher behaviors	Observations	Interviews	Surveys	Projects, reports	Performance tests	Objective tests	Miscellaneous
	Evaluation techniques (See page 61.)						
The teacher:							
• Demonstrates interest and pleasure when confronted with unfamiliar objects and phenomena.	X	X		X			X
• Confronts learners with objects and events in which to become interested.							
• Shares feelings of appreciation for the aesthetically pleasing (e.g., organisms, color changes, and crystal formations).	X	X	X	X			X
• Accepts and values feelings of aesthetic appreciation expressed by learners.							
• Handles living organisms carefully.	X	X	X	X	X		X
• Discusses with class the ways of minimizing environmental disruption on a field study.							
• Practices conservation of energy and materials in the classroom.	X	X	X	X			X
• Asks divergent questions aimed at increasing the learner's sensitivity to environmental problems.							
• Encourages each learner to collect data from many sources, to form opinions, and to try to influence opinions of others about community problems involving science and technology.							
• Accepts learners' opinions and values relating to socially significant problems (e.g., overpopulation and energy shortages).	X	X		X			
• Asks questions that encourage consideration of the economic impact of proposed solutions to the energy crisis.							

Chart 5 (Continued)

Terminal objective
The learner:
6. Organizes and reports the results of scientific investigations in an honest and objective manner.
7. Shows a willingness to subject data and ideas to the criticism of peers.
8. Has a critical, questioning attitude toward inferences, hypotheses, and theories.
9. Habitually applies rational and creative thinking processes when trying to find relationships among seemingly unrelated phenomena and when seeking solutions to problems.
10. Gives attention to and values science as an endeavor of human beings from all racial, ethnic, and cultural groups.
11. Considers science-related careers and makes realistic decisions about preparing for such careers, taking into account abilities, interests, and preparation required.

Examples of teacher behaviors	Evaluation techniques: Observations	Interviews	Surveys	Projects, reports	Performance tests	Objective tests	Miscellaneous
The teacher:							
• Does not place undue emphasis on learner's obtaining "correct" or expected results in laboratory investigations.	X	X		X	X		
• Provides opportunities for class laboratory data to be posted in a way that permits discussion of anomalous results without subjecting learners to embarrassment.							
• Accepts learner's criticisms of ideas, opinions, and interpretations advanced during a discussion.	X	X	X	X			
• Maintains an atmosphere in which learners can criticize ideas without attacking each other.							
• Accepts the learner's critical, questioning attitude toward theories, even those widely accepted by practicing scientists and even those the teacher may have come to regard as "truth."	X	X	X	X			
• Encourages students to question what they read and hear.							
• Accepts and encourages the learner's attempts to apply thinking processes to a problem, even when they lead the learner away from the "right" answer.	X	X		X			X
• Is willing to admit not understanding a discrepant event (e.g., "failure" of a demonstration); seeks explanations for what has been observed.							
• Encourages female students to consider entering fields (e.g., engineering) traditionally stereotyped as "male" activities.	X	X	X	X	X		X
• Cites advances in science and technology brought about by persons from various racial and ethnic groups.							
• Expresses admiration for persons engaged in exacting science-related work that required extensive preparation.	X	X	X	X			X
• Provides opportunities for learners to interact with persons engaged in science-related careers.							

Chart

6

Evaluating the Achievement of Rational and Creative Thinking Processes

Goal: *To develop and apply rational and creative thinking processes*

Educators frequently make distinctions among attitudes, skills, content, and processes when they describe educational goals and evaluate program results. Processes are an important part of science education. When making an investigation, the learner engages in observation, measurement, classification, and other processes.

The terminal objectives for the thinking process goal presented in Chapter 3 are listed in Chart 6. Instructional ideas that can be used to achieve each objective and suggestions for measuring that achievement are included in the chart.

Terminal objective
The learner:
1. Develops ability to generate data by observing, recalling, recognizing, identifying, and measuring.
2. Develops ability to organize data by comparing, ordering, classifying, and relating.
3. Develops ability to apply and evaluate data and generate theories by hypothesizing, predicting, inferring, generalizing, theorizing, explaining, justifying, and judging.
4. Uses data-generating and theory-building processes in a cyclic manner to solve a problem; i.e., participates in scientific inquiry for the appropriate level.

Examples of teacher behaviors	Evaluation techniques (See page 61.)						
	Observations	Interviews	Surveys	Projects, reports	Performance tests	Objective tests	Miscellaneous
The teacher:							
• Makes possible a variety of laboratory investigations and field experiences.	X	X		X	X	X	
• Asks learners to report their observations, e.g., the characteristics of a rock or organism or the flight of a paper airplane.							
• Provides opportunities for learners to match oral or written descriptions with models, pictures, or specimens of the objects described.							
• Asks convergent questions to reinforce learning of important facts.							
• Confronts learners with discrepant events (e.g., owl pellets or pulse glass); encourages them to ask questions and note relationships to other phenomena.	X	X		X	X		
• Asks learners to develop schemes for ordering or classifying various objects.							
• Suggests alternative explanations for a phenomenon; asks learners to evaluate those explanations in light of available data.							
• Calls upon learners to test their hypotheses verbally and experimentally.	X	X		X		X	
• Has learners, when making a series of measurements (such as temperature versus pressure of a gas), try to predict results after the first three or four measurements are made.							
• Provides opportunities for learners to participate in research projects.							
• Asks divergent questions.							
• Following an inquiry lesson, reviews with learners a tape of the discussion, pointing out sequences of inquiry processes used.	X	X		X	X		X
• Calls upon learners to describe and evaluate the inquiry processes they use.							

Chart

7

Evaluating the Achievement of Skills in Science

Goal: ***To develop fundamental skills in the manipulation of materials and equipment; in the care and handling of living organisms; and in the collection, organization, and communication of scientific information***

To become successful scientists and citizens of the community, learners must first develop their manipulative and communicative skills.

The terminal objectives for the skills goal presented in Chapter 3 are listed in Chart 7. Each objective is accompanied by instructional ideas and suggestions for evaluating student progress.

Terminal objective

The learner:

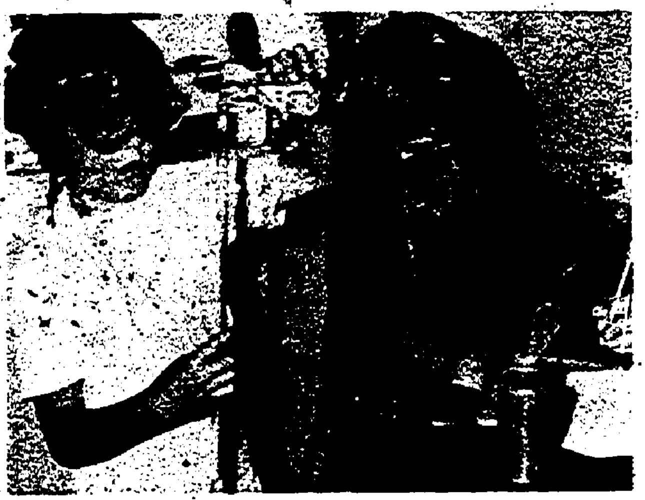
1. Assembles and uses laboratory apparatus, tools, and materials in a skillful manner, giving due attention to accident prevention.

2. Demonstrates proper techniques of handling and caring for living organisms.

3. Gathers the descriptive and quantitative information needed for developing or testing inferences and hypotheses by making purposeful, objective observations of things and events.

4. Gathers needed information, which has been generated by others, from a variety of sources.

Examples of teacher behaviors	Evaluation techniques (See page 61.) Observations	Interviews	Surveys	Projects, reports	Performance tests	Objective tests	Miscellaneous
The teacher:							
• Provides small groups of learners with appropriate materials and, without giving further direction, asks each to make an electromagnet that will pick up three paper clips.	X			X	X	X	
• Demonstrates the assembly of an electromagnet (using dry cell, wires, nails, and the like); challenges learners to make better ones.							
• Cautions learners about the hazards involved in a particular laboratory investigation; demonstrates ways to minimize them.							
• Demonstrates incorrect assembly or use of laboratory equipment, inviting the class to critique.							
• Keeps a variety of living things in the classroom.	X			X	X	X	
• Assigns, on a rotating basis, specific responsibilities for the care of living things.							
• Arranges for a resource person from a nature museum to demonstrate techniques of handling and caring for animals.							
• Provides opportunities for learners to make, record, and compare observations and measurements of organisms, chemical reactions, geologic formations, photographs, and the like.	X	X		X	X	X	
• Has learners measure the period of a pendulum, speculate about what could cause the period to change, and manipulate variables to test their hypotheses.							
• Makes a variety of reference materials of varying difficulty accessible to learners.	X	X		X	X	X	
• Arranges for learners to prepare for a tidepool field study by consulting maps, tide tables, checklists of plants and animals likely to be found, weather forecasts, and the like.							
• Helps learners develop techniques of effective reading of science textbooks and other materials. (See Appendix F.)							



Terminal objective

The learner:

5. Records observations accurately and organizes data and ideas in ways that enhance their usefulness.

6. Communicates with others (orally and in writing) in a manner that is consistent with a knowledge of scientific conventions and that facilitates the learning of the listeners or readers.

7. Uses the International System of Units (SI) metric system effectively.

8. Applies appropriate mathematical concepts and skills in interpreting data and solving problems.

Examples of teacher behaviors	Observations	Interviews	Surveys	Projects, reports	Performance tests	Objective tests	Miscellaneous
The teacher:							
• Displays samples of accurate, well-organized observation records.	X			X	X	X	
• Provides histogram or graph to display results of a class laboratory investigation and facilitate discussion of variation and central tendency.							
• Has learners graph plant growth, using strips of paper cut to length of plant.							
• Provides opportunities for learners to make oral reports on their investigations and to respond to questions and comments.	X	X		X	X	X	
• Encourages learners to prepare science reports for the school newspaper or a local radio station.							
• Has learners make and calibrate their own metric measuring instruments.	X			X	X		
• Uses metric system consistently in discussing experimental results and describing objects and events.							
• Provides multiple opportunities for learners to measure and make calculations using the metric system.							
• Provides opportunities for learners to gather quantitative data and make calculations of rates, averages, densities, and the like.	X			X	X	X	
• Teaches and reinforces mathematical skills as needed by learners.							
• Provides opportunities for learners to use calculators and computers.							

Chart

8

Evaluating the Achievement of Scientific Knowledge

Goal: *To develop knowledge of processes, facts, principles, generalizations, and applications—the products of science—and encourage their use in the interpretation of the natural environment*

Science is as much an organized body of knowledge as a system or method of discovery. It consists of both content (fact and generalizations) and method of discovery. In the classroom discoveries (content knowledge) cannot be separated from the processes of investigation. Thus, instruction must include content knowledge and the methods of obtaining that knowledge.

The terminal objectives for the knowledge goal presented in Chapter 3 are listed in Chart 8. Several instructional ideas and processes of evaluating progress are provided for each objective.

Terminal objective
The learner:
1. Demonstrates knowledge of the processes of scientific inquiry.
2. Demonstrates knowledge of the content of the major scientific subdisciplines.
3. Demonstrates understanding of some basic generalizations, relationships, and principles applicable to all the sciences.
4. Demonstrates understanding of the relationship between science and society.
5. Demonstrates knowledge of science-related career opportunities and the preparation needed to pursue science-related careers.
6. Demonstrates knowledge of the contributions to science and technology made by men and women of various races and nationalities.

Examples of teacher behaviors	Observations	Interviews	Surveys	Projects, reports	Performance tests	Objective tests	Miscellaneous
The teacher:							
• Accepts and models processes of scientific inquiry; encourages observing, classifying, quantifying, and hypothesizing.	X	X		X	X	X	
• Calls attention to and identifies various aspects of the inquiry process as they occur in the classroom and laboratory.							
• Asks convergent questions to reinforce learning of important facts.		X		X	X	X	
• Introduces major ideas (such as energy conversion) repeatedly in different contexts and demonstrates the broad applicability of such ideas.		X		X	X	X	
• Provides opportunities for learners to apply basic scientific principles to explain unfamiliar phenomena.							
• Encourages learners to speculate on how their lives would be different if certain scientific discoveries had not been made or had turned out differently.		X		X	X	X	
• Creates opportunities for learners to become involved in community problems involving science and technology.							
• Shows familiarity with various science-related careers.		X	X	X	X	X	
• Provides learners with information about the preparation needed for various science-related careers.							
• Gives examples of how knowledge of science can be useful in careers not normally considered "science-oriented" (e.g., law, journalism, business, sales, and building maintenance).							
• Brings to learners' attention scientific and technological contributions made by men and women of various races and nationalities.		X		X	X	X	
• Provides opportunities for the learner to interact with men and women who have made contributions to science and technology.							

Evaluation techniques (See page 61.)

Terminal objective
The learner: 7. Demonstrates awareness of the relationship of science to other areas of human endeavor (e.g., art, history, and government). 8. Demonstrates knowledge of the ways in which attitudes, thinking processes, and skills can be coupled with content knowledge and used in personal decision making.

Examples of teacher behaviors	Evaluation techniques: Observations	Interviews	Surveys	Projects, reports	Performance tests	Objective tests	Miscellaneous
The teacher:							
•Calls upon learners to identify examples of the relationship of science to other subject areas.		X		X	X	X	
•Shows learners the ways in which knowledge of attitudes, thinking processes, and skills can be used in personal decision making.		X	X	X	X	X	
•Encourages learners to use such knowledge in making their own decisions.							

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Conclusion

Science can be thought of as (1) a structured discipline or body of knowledge; (2) a powerful way of acquiring new knowledge; (3) a basis for technology; (4) a potent social, economic, and cultural influence; and (5) an interesting avenue of personal fulfillment for both the scientist and the learner. At various times (and for different reasons) the science taught has emphasized one or another of these facets. For instance, the curriculum reform of the 1960s highlighted the processes of science and the structure of its disciplines.

To meet the needs of learners during the coming years, science teachers must emphasize all these facets in a balanced program. Science constantly must be related to language, mathematics, social sciences, career opportunities, and the creative use of leisure time. If teachers are to meet the needs of learners, they must use effectively every strategy and technique at their command. No single solution will suffice.

The search for truth is in one way hard and in another easy. For it is evident that no one can master it fully nor miss it wholly. But each adds a little to our knowledge of nature, and from all the facts assembled there arises a certain grandeur.

Aristotle, 384—322 B.C.

The process for improving curriculum and instruction in science is much the same as it is for improving curriculum and instruction in any subject area. One should study the existing programs and determine how they are helping the learners. If certain goals and objectives are not being met for some of the learners, that is the signal that change is needed. If time and resources are available, a new curriculum can be developed by formulating goals and objectives, developing structure, selecting content, reviewing materials, and establishing evaluation criteria. More often, the process will be one of looking at existing curriculum materials, finding the best possible match with the needs to be served, and adapting and supplementing them as necessary for effective implementation. In either case nothing that is printed on paper will work miracles. Almost anything that is really an improvement in curriculum will require that teachers learn new ways of working with learners. The interaction that occurs among the teacher, learner, materials, and ideas is the "moment of truth" in curriculum improvement.

The objectives set forth in this framework have been classified under four major goals: attitudes, rational and creative thinking processes, manipulative and communicative skills, and knowledge. Regardless of how the curriculum is organized, the materials, teaching strategies, learning experiences, and evaluative techniques used must be consistent with these goals and reflect a balance among them.

The teaching of science must motivate young people to continue learning. This is an awesome challenge, but because the processes of science are at the heart of all learning and the subject matter of science is as broad and varied as the universe itself students should attempt no less.

Appendix A

Examples of Major Conceptual Organizations of Scientific Knowledge

The content of science can be summarized into broad generalizations that interrelate many specific facts and principles. Such generalizations, or concepts, can be the basis for the selection of the content to be used in science instruction. One should emphasize that (1) the very nature of a scientist is to be continually searching for greater and greater generalizations and to be making continual refinements to existing generalizations, and these are based on current data and theories and are always subject to change; (2) conceptual organizations provide a foundation for the understanding of how certain facts are related; and (3) conceptual organizations provide education for the future because they offer a perspective by means of which future discoveries may be correlated and understood.

A. *Most events in nature occur in a predictable way, understandable in terms of a cause-and-effect relationship; natural laws are universal and demonstrable throughout time and space.*

This first conceptual organization of knowledge, or generalization, is an overall summation of the other 12 generalizations described in this appendix. The others are extensions or elaborations of the above statement. The main ideas contained in this first concept may be restated in greater detail in the form of the following four points:

1. Events in nature are the result of multiple cause-and-effect relationships. The laws and theories of nature—as they apply to motion, energy, change, conservation, and atomic structure—are simplifying generalizations in which a cause and an effect are related. These laws and theories are based on experience and verified either by experiment or by controlled and objective observations.
2. Knowledge of cause and effect makes possible the prediction of events. Knowledge concerning the motion of the earth and moon allows one to predict the sunrise and sunset and the time and magnitude of the tides. Knowledge about chemical bonding allows one to predict the amount of heat that will be liberated when an acid is added to an alkali. The validity of a prediction based upon cause-and-effect relationships is determined by the reproducibility of experimental results.

3. Cause-and-effect relationships are universally applicable. A major goal of the scientist is to discover universal laws of nature as well as ordered patterns of diversity that have causal relationships.
4. Predictions based on cause-and-effect relationships may also be made if the events are random. Some events in nature, however, occur in such random fashion that predictions concerning individual events can be made only with great uncertainty. One can predict many occurrences with a high degree of certainty by applying statistical techniques in the study of such random events. For example, one can predict the fraction of atoms that will disintegrate in a given mass of radioactive atoms in a given period of time, but one cannot predict when a single atom will disintegrate.

B. *Frames of reference for size, position, time, and motion in space are relative, not absolute.*

This conceptual organization of knowledge, or generalization, deals with the measurable attributes of objects and events. It can be developed from the following two points of view.

1. The masses and dimensions of objects are measured to determine their magnitudes, but such measurements are never absolutely precise. With increasing accuracy of instruments and techniques, measurements come closer to, but can never reach, absolute values. The position of an object is determined by measuring its distance and direction from other objects or from fixed basepoints. Events in time are measured by means of clocks, marking off intervals from a reference point in time. The motion of an object can be characterized in terms of its changes in position with reference to time and basepoint. The most difficult quantitative concepts are those that are well beyond the level of intellectual comprehension: the numbers of atoms and stars or atomic and cosmic dimensions.
2. These measurements seem rigid and constant—a kilogram is a unit of mass, valuable because of its constant dependability regardless of its position in the universe. But it is also used as a standard unit of weight at the earth's surface where its particular value depends on the earth's gravitational field. When the kilogram is transferred to an environment away from the earth's surface, however, this standard unit of weight loses its earthbound value.

C. *Matter is composed of particles that are in constant motion.*

Different kinds of matter can be classified in accordance with their particulate natures and in accordance with the energetic movements of the particles within them. The model in which matter is composed of moving particles has been used to explain many natural phenomena, such as the solid, liquid, and gaseous states of matter.

According to the model, for example, water is made up of many moving molecules. In the solid state the molecules are less free to move about. When energy in the form of heat is applied to these molecules, they vibrate energetically. If enough heat energy is applied, the substance will change from the solid into a liquid, then to a gas.

Molecules, in turn, are made up of smaller units called atoms. Atoms are sometimes called "basic building blocks of matter" because they determine the properties of the basic elements. But atoms, too, are composed of smaller, subatomic particles such as electrons, protons, and neutrons. Further study has led to the discovery of many more subatomic particles. Their relationships are as yet only poorly understood. Our present ideas about the nature of matter probably will change as new experiments lead to new knowledge.

D. *Energy exists in a variety of convertible forms.*

Energy and its conversion is a common strand that runs through all the sciences, from physics to biology and from geology to cosmology. The rise of people from being their own beasts of burden to the development of modern technology has increased in direct proportion to their ability to find and convert energy to replace muscle power. One measure of a nation's progress and material well-being might be the average amount of energy consumed per citizen per year. However, this particular kind of progress cannot be extended indefinitely. It may lead to intolerable pollution of the biosphere. In addition, the increasing demand for greater amounts of energy threatens the very existence of people through catastrophic warfare.

The principle of energy conversion underlies almost every major scientific discipline. The physicist sees a swinging pendulum as an example of the transformation of energy from potential energy to kinetic energy and vice versa. The chemist observes that energy is transferred between molecules when they collide. The biologist understands that all changes in living organisms, from simple cells to human beings, involve a flow of energy to and from the environment.

E. *Matter and energy are manifestations of a single entity; their sum in a closed system is constant.*

In most observations taken at the beginning and at the end of natural phenomena, the amounts of matter and energy appear to remain constant. However, investigations of certain subatomic and cosmic phenomena show that the relationship between matter and energy is best expressed by Einstein's famous equation, $E = mc^2$. Two important characteristics of this relationship are: (1) the amount of energy (E) appearing or disappearing is proportional to the amount of matter (m) that is destroyed or created; and (2) the proportionality constant (c^2) is a large number (the square of the speed of light). Thus, a small amount of mass is equivalent to a huge amount of energy.

Throughout the universe matter constantly is being transformed into energy, and matter simultaneously is being created from energy. A currently popular belief is that the two processes are in balance; but scientists have not determined if such a state of equilibrium actually has been attained. To date, however, all evidence tends to confirm the conclusion that the sum of matter and energy in the universe remains constant.

F. *Scientists use classification systems to bring order and unity to apparently dissimilar and diverse natural phenomena.*

Through observation and analysis, scientists search among distinguishing characteristics or properties of natural phenomena for generalizations that might serve as unifying themes upon which classification systems or taxonomies could be developed. The taxonomy of plant and animal kingdoms, the periodic table of elements, and the electromagnetic spectrum are examples of classification systems based upon underlying principles or unifying themes.

In any classification system devised to bring order to our concepts of the universe, there must be an awareness that the classification is, after all, made by human beings for human beings. The human intellect has superimposed upon nature a system in order to better understand the universe. It is not surprising, therefore, that certain objects do not fit into the classification system. Human beings are, in a very real sense, limited in their understanding of natural phenomena by their mental processes and patterns. They are also limited, in part at least, by the modes by which they acquire knowledge.

F-1. *Matter is organized into units which can be classified into organizational levels.*

Structure within the natural order is observed in classifications from the smallest subatomic particles to the matter within huge galactic masses. Basic units of matter, small or large, are found in every organizational level in the physical and biological structures of the natural order. Scientists attempt to bring order to the world they investigate by grouping and classifying matter in accordance with its properties. Although the basic unit selected varies with the particular field of inquiry, a trend toward interrelationships among the natural sciences is becoming evident.

F-2. *Structure and function are often interdependent.*

On every organizational level of matter, scientists have used the interdependence of function and structure as a useful tool. In most cases, if the function of a unit of matter can be observed, the scientist can make informed guesses as to its structure. Sometimes, however, cause-and-effect relationships can be misinterpreted. For example, Lamarck was wrong when he predicted that changed functions or environments could give rise to changed hereditary structural adaptations.

Experimental research indicates that structures evolve in such a way that some organisms are more likely to survive their environment than others. Studies also show that changed environments favor the persistence and spread of certain spontaneous hereditary changes. When organisms evolve parts that do not function successfully within their environment, they do not survive for long.

G. *Living organisms have universal properties.*

Living organisms have universal properties, including derivation of energy from outside sources and reproduction. Evolutionary studies indicate that these organisms are naturally selected from generation to generation, producing descendants with different characteristics and producing variability among populations of living species. The process has been going on so long that it has produced all the groups and kinds of plants and animals now living as well as others that have become extinct.

Living organisms are highly organized systems of matter and energy, and any introduction to biology should include a definition of life. Perhaps this is best done by listing some of life's properties. Living organisms derive energy from outside sources, primarily the sun, and use it for their own purposes. Green plants use the energy to form chemical compounds that undergo metabolic reactions that enable the plants to grow, respire, and reproduce. Other organisms, such as animals, consume plants or animals as sources of chemical energy.

The most characteristic property of life is reproduction. This central function of organisms is carried out by means of information that is stored in molecules of deoxyribonucleic acid (DNA) with the exception of some viruses that use ribonucleic acid (RNA) for this purpose.

In addition to reproduction, another characteristic of life is change in its genetic material with passage of time. This process, termed evolution, takes place through changes in DNA. Changes in DNA molecules are produced by mutation, which includes replacement of some DNA bases by others, and recombination in which segments of DNA are added to or subtracted from genes. Duplication of genes sometimes also occurs. Most mutations are harmful and do not persist; they are eliminated by natural selection.

Beneficial mutations occasionally take place and are responsible for the appearance of new characteristics. A third class is "neutral" or "near neutral" mutations. Some of these mutations are adopted during evolution. The progress of evolution can be measured by comparing DNA molecules of closely related species and measuring the percentage differences in the sequences of their components (bases). The differences are roughly correlated with the passage of time as measured by the fossil record. On an average, about one or two DNA bases in each billion are changed each year in each species. This process also can be measured in proteins because the sequences of amino acids in protein molecules are controlled by base sequences in DNA through the genetic code. This indicates that all living organisms on earth have a common ancestor from which they have diverged by evolution during about three billion years. Throughout this immense time, the DNA molecules have maintained a continuous existence that has never been interrupted. If DNA were to disappear, all life on earth would become extinct.

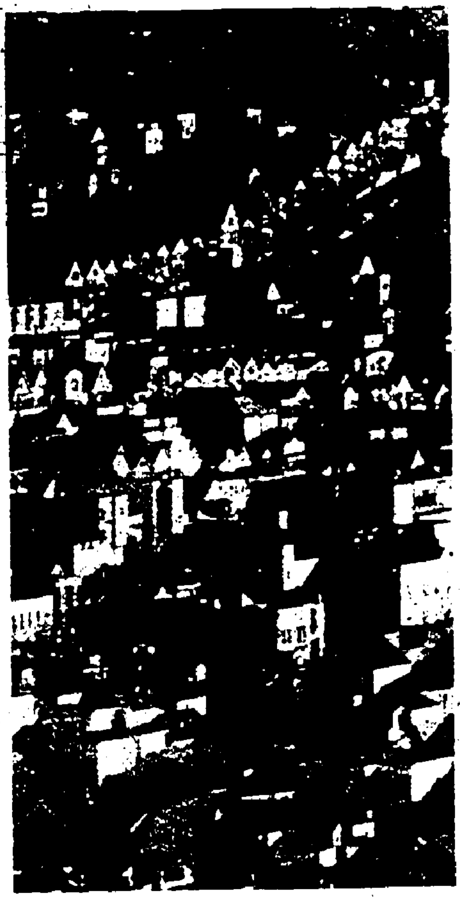
H. *Units of matter interact.*

The properties and behavior of every unit of matter in the universe are dependent upon its interactions with other units of matter. The study of interactions constitutes a large part of scientific investigation, and such studies have led to the formulation of a number of closely related ideas.

H-1. *The bases of all interactions are electromagnetic, gravitational, and nuclear forces whose fields extend beyond the vicinity of their origins.*

Certain forces are present in every interaction. The three basic forces—electromagnetic, gravitational, and nuclear—have the rather amazing property of acting at a distance; that is, they permit interactions to take place without any direct contact between the units of interacting matter.

Most everyday interactions do not seem to result from action-at-a-distance forces because they require at least a surface contact between objects. A closer look at such interactions on a microscopic level, however, leads to quite a different conclusion. All contact interactions are believed to result from the electromagnetic forces that bind electrons to nuclei to form atoms, and atoms to atoms to form molecules. What appears to be a direct contact between the surfaces of two interacting objects actually is only a relatively close proximity between molecules, calling into play the attractive and repulsive actions of charged particles.



H-2. *Interdependence and interaction with the environment are universal relationships.*

Interaction and interdependence are found in the smallest subatomic particles and in the most gigantic astronomical bodies. Nothing in the universe exists in isolation. Every object that exists is either dependent upon an interacting event for its origin or is in the process of change due to interactions. The components of a living cell, for example, are integrated by interactions, and these interactions lead to new properties that are not apparent in the isolated components. The cell as a whole interacts with its environment by exchanging matter and energy across the cell surface.

At the higher organizational levels of organism, population, community, and ecosystem, the components within any given unit interact with each other, and the unit as a whole exchanges matter and energy with its environment. More than ever before in history the effects of human activity on the ecosystems must be assessed. Much of the quality of human life certainly depends on the maintenance of the quality of other life forms.

Many interdependent events that occur in the natural order are cyclic in character. A pattern of sequential events gives rise to a repetitive chain of events in which one link of the chain is dependent upon its preceding link. The food and water cycles are examples of dependent cyclic interactions.

A food chain links together the members of an ecosystem. Green plants begin the chain (phytoplankton in the marine ecosystem). The green plants manufacture food by using light energy from the sun and water, carbon dioxide, and nutrients from the soil. A first-order consumer (e.g., a deer or cow) comes along and eats the plant. A second-order consumer (e.g., a cougar or human) eats the first-order consumer. We even can have a transfer of food and energy from the producer to a higher-order consumer. The decomposition of living things also provides food for the plants.

Another order of interactions is that of evolutionary events, which produce predictable changes in certain kinds of objects over long periods of time. One theory claims that atoms, interacting with one another and evolving over eons of time, gave rise to the present assemblage of various kinds of elements. Another evolutionary thesis describes the progress of stars all the way from young gaseous nebulae to pulsating dying stars. Still another interacting series of events has produced the evolution of rocks from igneous to sedimentary and metamorphic-type materials.

Interactions between organisms and their environments produce changes in both. Changes in the environment are readily demonstrable on a short-term basis; i.e., over the period of recorded history (circa 5,000 years). These changes have been inferred from geologic evidence over a greatly extended period of time (billions of years), although the further back we go, the less certain we can be. During the past century and a half, the earth's crust and the fossils preserved in it have been studied intensively by scientists.

From fossil evidence it can be inferred that organisms populating the earth have not always been structurally the same and that anatomical changes have taken place through time. The process of change through time is termed evolution. In modern biology, the Darwinian theory of evolution is the unifying theme that provides a genetic basis for the biological development of complex forms of life in the past and present and the changes noted through time.

The concepts that are the basic foundation for the theory of evolution are that (1) inheritable variations exist among members of a population of like organisms; and (2) differential successful reproduction (i.e., survival) is occasioned by the composite of environmental factors impinging upon the population generation after generation. Darwinian evolution is used to explain the many similarities and differences that exist between diverse kinds of organisms. It also provides a structural framework upon which many seemingly unrelated observations can be brought into more meaningful relationships.

Scientists also have developed, from experiments and observations, hypotheses concerning the development of life from the nonliving matter of the prebiological earth. This research and its hypotheses usually are referred to as "chemical evolution." Philosophic and religious considerations pertaining to the origin, meaning, and value of life are not within the realm of science because they cannot be analyzed or measured by present methods of science.

H-3. *Interaction and reorganization of units of matter always are associated with changes in energy.*

The relationship among all things and their environments can be compared to a spider's web consisting of many interwoven threads that form a complicated pattern. An interplay of matter and energy holds the "web" together; however, the total process has an orderly pattern.

Interactions of matter and energy are consistent and describable in terms of natural laws. The following two ideas are concerned with the energy changes that accompany changes in the organization or state of matter:

1. In a closed system (an approximate example of which is a sealed, light-tight, vacuum-jacketed laboratory flask), when units of matter interact, the system tends toward a condition of equilibrium in which free energy, or the ability to do net work, is at a minimum. A closed system is also one that tends toward a state of maximum disorder or randomness (also known as a state of maximum entropy).
2. In an open system units of matter may interact in such a way as to maintain a steady state or condition of homeostasis.

We do not know, of course, whether the universe is an open or closed system. Living systems, on the other hand, are obviously open ones—

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Appendix B

Criteria for Evaluating Instructional Materials in Science

Kindergarten and Grades One Through Eight

Approved by the Board of Education on March 12, 1976

Although no single definition of science would be acceptable to everyone, in a general sense the term science embraces much of our objective efforts to understand nature. Applied science (technology) uses this knowledge to make the world a better place in which to live. Thus, science includes the ideas and concepts which scientists have created in order to understand nature as well as the intellectual skills and particular modes of thinking used to develop this understanding.

Goals

The goals of the science program are as follows:

1. To develop those values, aspirations, and attitudes which underlie the personal involvement of the individual with the environment and society
2. To develop and apply rational thinking processes
3. To develop fundamental skills in manipulating materials and equipment; in caring for and handling living things; and in gathering, organizing, and communicating scientific information
4. To develop knowledge of processes, facts, concepts, generalizations, and unifying principles—the products of science—that assist in interpreting the natural environment

Interrelatedness of the Sciences

Although science has been organized into such disciplines as astronomy, biology, chemistry, geology, and physics, the science program should emphasize the essential commonality of the scientific enterprise in presenting a unifying picture of nature. To this end, organization along with a problem-solving or skills-developing approach is preferred over a sequence of discontinuous topics along disciplinary lines.

Interrelationships Between Science and Other Subjects

Science has not developed in isolation nor does it exist in isolation from other activities. For proper perspective science must be presented in the context of human endeavors. The interfaces between science and mathematics, fine arts, social science, language arts, health, and so forth, exist and must be recognized if realistic scientific literacy is to be achieved.

Responsiveness to Human Needs

Science instruction must meet the different needs and interests of individual students and use appropriate teaching-learning styles, strategies, and materials.

General Criteria: The Instructional Program at All Levels

Science materials must reflect a philosophy which is consistent with that expressed in the current *Science Framework for California Public Schools* as adopted by the State Board of Education.

Material in a language other than English and parallel to English curricular material shall be included when available and when in conformance with these criteria. Because these criteria are meant to be used with a complete science program, some educational materials may meet only selected parts of the criteria.

Attitudes and Values

Print and nonprint educational materials will be used by the teaching staff to:

1. Help learners develop and extend their personal interests and experiences through science.
2. Develop an understanding that major forces in society affect the learner, the schools, and science; and that advances in science technology in turn affect society, the learner, and the schools.
3. Develop those positive values, aspirations, and attitudes which underlie the personal involvement of the individual with the environment.
4. Help learners promote critical questioning of unsupported inferences, hypotheses, and theories.
5. Promote an awareness of energy/ecological relationships in the environment and of their social and economic implications.

Process and Content

Both print and nonprint educational materials will be used by the teaching staff to:

1. Give learners the opportunity to engage in the major activities that are employed in scientific inquiry: observing, experimenting, verifying, predicting, organizing, inferring, analyzing, synthesizing, and generalizing.
2. Help learners develop fundamental skills in manipulating materials and equipment; in caring for and handling living things; and in gathering, organizing, and communicating scientific information.
3. Provide concepts and ideas that are appropriate to the students' levels of development, their reading abilities, and their varying needs.
4. Provide opportunities to integrate the knowledge and skills learned in other disciplines (e.g., mathematics, language arts, health, and social sciences) with those abilities that lead to the achievement of scientific goals.

5. Provide students with a science program that will develop a knowledge of specifics: facts, conventions, sequences, and classifications.
6. Provide learners with an opportunity to develop a knowledge of concepts, generalizations, and unifying principles.
7. Demonstrate the interrelatedness of scientific information and the processes by which that information is obtained.
8. Provide a variety of experiences in the biological, physical, earth, and space sciences.
9. Show the relationship between people and their environment, and promote awareness of and responsibility toward that environment.
10. Develop an awareness of diminishing natural resources, and emphasize the need for wiser management.
11. Identify science-related careers, and stress the importance of science skills in careers.
12. Make consistent use of the SI metric system, and convey to the learners the important contributions they can make in explaining the system to persons who are not familiar with these units.
13. Emphasize standard health and safety practices.
14. Describe contributions to science and technology made by women and men of various races, ages, and nationalities.

Instructional Strategies

Both print and nonprint educational materials will meet the following criteria:

1. Be adaptable to a variety of teaching-learning strategies that treat all learners with respect, recognizing individual differences by adapting instruction to individual interests, needs, and learning styles.
2. Provide a structure for organizing and sequencing learning experiences with illustrative instructional models. Include group instruction planning and assessment, diagnostic/prescriptive teaching, and concept and process development.
3. Provide the learner with opportunities to select from a variety of activities that contribute to the attainment of an objective.
4. Include guidance for extending student experiences by introducing new topics and alternative paths of study, developing appropriate media, and the like.

Organization

The print and nonprint educational materials will meet the following criteria:

1. Provide an organizational perspective (print: table of contents, index, and so forth; nonprint: scope and sequence chart and so forth).
2. Provide for an organized sequence of development that is readily apparent to both learner and teacher.
3. Be so arranged that ideas and skills reappear in varying contexts and at increasing levels of sophistication.
4. Provide questions that elicit a variety of learner responses, such as discussion and investigation. At the appropriate level material

should encourage higher-order questions or knowledge, comprehension, application, analysis, synthesis, and evaluation.

Assessment and Evaluation

Both print and nonprint materials will meet the following criteria:

1. Provide for a variety of evaluative techniques, teacher-student evaluation, and student self-evaluation.
2. Include provisions for frequent interim and end-of-program assessment of student progress. Some focuses for evaluation are (1) rational thinking; (2) interpretation of nature; (3) understanding of the nature of science; (4) development of appropriate attitudes toward science and nature; and (5) manipulative and communicative skills.
3. Be consistent with the stated goals and objectives of the materials.

Teacher Materials

The materials used by the teacher will meet the following criteria:

1. Be easily distinguishable from student materials and convenient for use; for example, annotated student materials may be used as the teacher's edition.
2. Show a consistent correlation with student materials.
3. Contain practical hints and advice, such as the following:
   a. Itemized lists of materials and equipment
   b. Techniques
   c. Recipes for solutions
   d. Sources of materials
   e. Care and maintenance of equipment and living things
   f. Primary references and additional sourcebooks
   g. Suggested storage, space requirements, and ordering procedures
   h. Hints on how to avoid commonly encountered difficulties
4. Provide a related reference list and suggestions for extended and in-depth supplemental activities for learner and teacher.
5. Include an overview and/or summary of each unit with goals and objectives.
6. Provide background information, including relevant questions, discussion and reading, expected responses, and historical information.
7. Indicate the readability level of learner materials.
8. Identify common goals with other subject areas.
9. Indicate standard health and safety practices.
10. Show applications to other subject areas of attitudes, rational thinking processes, skills, and knowledge developed in science.
11. Provide suggestions for using community resources.

Instructional Media Standards

Printed materials such as books and laboratory manuals will meet the the following criteria:

1. Use paper and binding of a quality appropriate for the intended usage.
2. Be printed in type that is clear, readable, and appropriate to the content and maturity level of the learner.

3. Provide aesthetic visual arrangements using color, illustration, and photographs where appropriate.

Visual nonprint presentations (films, filmstrips, charts, and so forth) will meet the following criteria:

1. Be characterized by aesthetic appeal that contributes to the student's learning experiences.
2. Fulfill the function suitable to the medium.
3. Be current.

Materials designed for auditory presentation (records, tapes, and the like) will meet the following criteria:

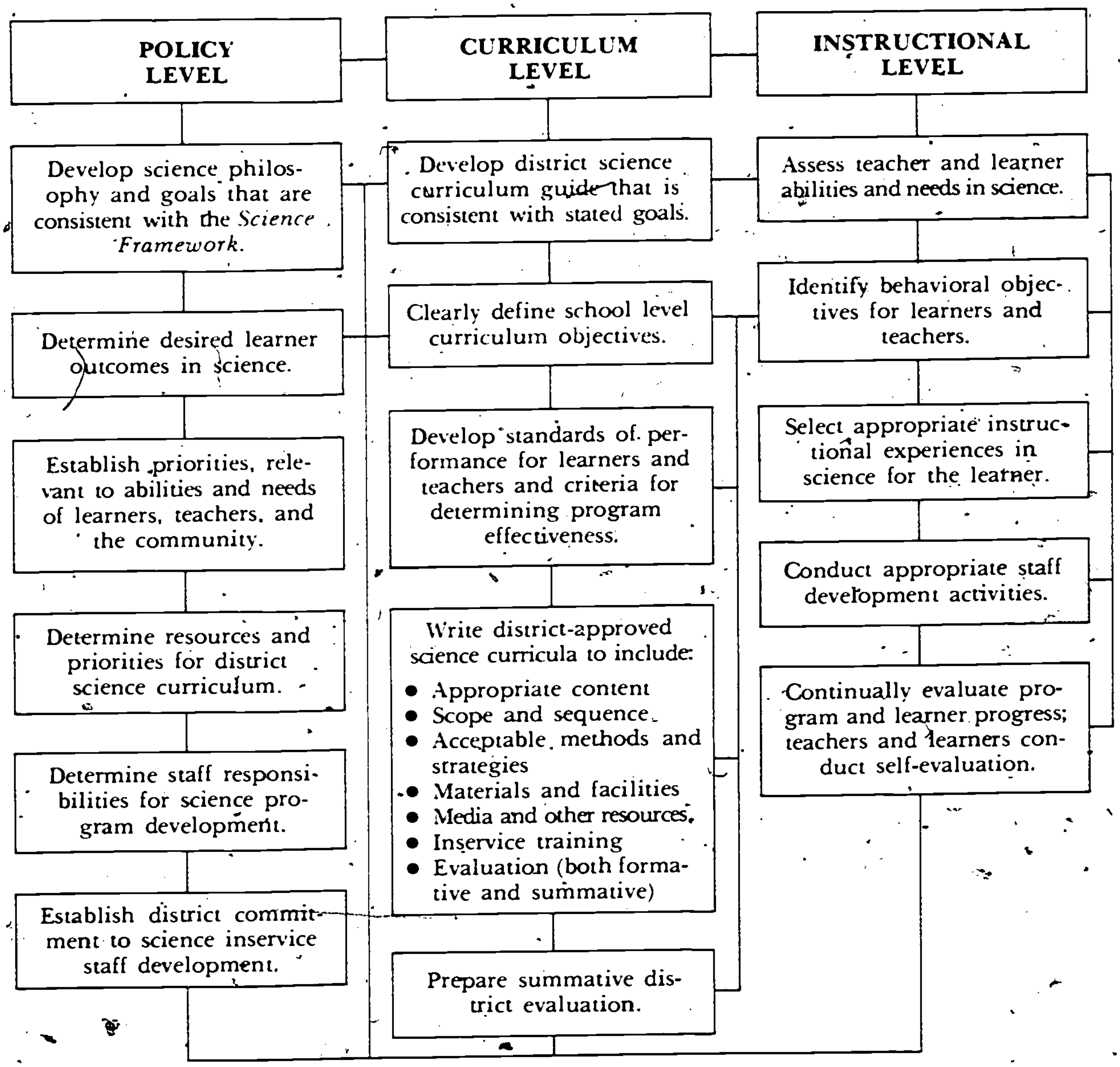
1. Present voices that are clear and well modulated or appropriate to the role portrayed.
2. Have technical quality sufficient to reproduce the sound frequencies that are necessary.
3. Be appropriate in content and length for the intended audience.
4. Use standard English. (When a language other than English is presented, authentic native or near-native speakers should be provided. They should represent the voices of male and female adults and c[illegible] speaking at an appropriate rate and with accurate inte[illegible]

Materials designed for manipulative use (e.g., laboratory equipment or games) will meet the following criteria:

1. Conform to current safety standards.
2. Be clearly identified and durable.
3. Be convenient to handle, use, and store.
4. Be replaceable and easily available from the supplier when needed; for example, consumable materials and components of kits, systems, laboratories, games, and so forth.
5. Lead to achievement of instructional goals and objectives.

Appendix C

A Design for Decision Making in the Educational Program



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Appendix D

Self-Assessment Checklist for Teachers of Science[1]

Scientific Attitudes, Thinking Processes, Skills, Knowledge, and Liberal Arts	Low — High
1. My students see in me an attitude of open-mindedness and suspended judgment.	1 2 3 4 5
2. I enjoy designing and conducting experimental studies to test hypotheses or account for discrepant events.	1 2 3 4 5
3. I willingly subject personally acquired data and ideas to peer criticism.	1 2 3 4 5
4. I am proficient in manipulating and utilizing the tools and equipment of science.	1 2 3 4 5
5. I am able to apply mathematics to gathering, processing, and communicating data in my teaching (measurement in metric units).	1 2 3 4 5
6. I can use oral and written communication skills effectively.	1 2 3 4 5
7. I am familiar with the basic recognition and recall content of my field and/or level of science.	1 2 3 4 5
8. I understand the factors affecting the physical, emotional, and intellectual growth and development of my students.	1 2 3 4 5
9. I can identify and construct conditions that motivate inquiry in the learner.	1 2 3 4 5
10. I use effective methods and materials to guide students in their consideration of science-related careers.	1 2 3 4 5
11. I seek to know, understand, and support the needs, aspirations, and positive attitudes of the community toward education.	1 2 3 4 5
12. I interact and cooperate with other teachers in providing a healthy, balanced total school atmosphere.	1 2 3 4 5
13. I am aware of community resources that will enhance my science instructional program.	1 2 3 4 5
14. I can describe the interrelationships among various fields of scientific endeavor.	1 2 3 4 5

[1]The statements in the checklist are characteristic of those made by teachers who provide quality programs of instruction in science. These statements have been organized into a checklist to help teachers determine the degree to which they can compare themselves with these attributes. This material was adapted from evaluation criteria developed by the National Science Teachers Association.

	Low High
15. I know of scientists in my community and can relate them to my instructional program.	1 2 3 4 5
16. I work with other teachers to interrelate the teaching of science with that of other subjects.	1 2 3 4 5
17. I can interpret the relationships between science and other aspects of human endeavor.	1 2 3 4 5
18. I have developed and follow a philosophy of education which deals with the place of science teaching in the school's total education effort.	1 2 3 4 5
19. I am aware of energy/ecological relationships in the environment and of their social and economic implications.	1 2 3 4 5
20. I have studied the social/economic/environmental impacts of science and the social and moral responsibilities of scientists.	1 2 3 4 5

Instructional Methods and Techniques

1. I use specific course and curriculum development techniques (construction of lesson plans, development of minicourses, modules of learning activity packages, writing performance objectives, and the like).	1 2 3 4 5
2. I know where to obtain and how to use data (about each learner's conceptual level, cognitive style, interests, and abilities) to provide unique individual experiences.	1 2 3 4 5
3. I can effectively utilize current technological devices and materials in my teaching (e.g., motion pictures, overhead projectors, audio- and videotape recorders, and computer time-share).	1 2 3 4 5
4. I can select, construct, use, and interpret various kinds of evaluation instruments for determining student progress.	1 2 3 4 5
5. I use a variety of teaching styles (i.e., student inquiry, lecture, demonstration, individual project work, convergent and divergent questioning, seminars, and simulations).	1 2 3 4 5
6. I make provisions for the safety of students while they are participating in classroom/laboratory activities and can handle emergencies that arise.	1 2 3 4 5
7. I implement a variety of forms of classroom organization: individual, small and large group, open classroom, laboratory, and team teaching.	1 2 3 4 5
8. I can provide a rich environment (of data sources, materials for experimentation, phenomena to observe, and ideas) for use by my students in achieving class objectives.	1 2 3 4 5
9. I am familiar with the legal requirements relative to the care and use of animals in the classroom in my instructional program.	1 2 3 4 5

Professional Education and Development	Low – High
1. My background equipped me with the understanding of the life, physical, and earth-space sciences needed for teaching in my current assignment.	1 2 3 4 5
2. I have a working knowledge of recent national curriculum projects; e.g., Science Curriculum Improvement Study (elementary) or Biological Sciences Curriculum Study, Chemical Education Material Study, and Intermediate Science Curriculum Study (secondary).	1 2 3 4 5
3. I participate in the activities of at least one (national, state, or local) organization primarily related to science teaching; e.g., the National Science Teachers Association and the California Science Teachers Association.	1 2 3 4 5
4. I attend the conferences and conventions held by national, state, or local organizations related to my field of science interest (American Association of Physics Teachers, American Chemical Society, National Association of Biology Teachers, and National Science Teachers Association).	1 2 3 4 5
5. I have attended one or more special inservice programs for science teaching (e.g., summer institute, inservice institute, or inservice course) in the past two years.	1 2 3 4 5
6. I contribute to the development or evaluation of new programs and ideas in science teaching; e.g., I participate in or conduct a research study, develop innovative curriculum materials, or pilot-test newly developed materials.	1 2 3 4 5
7. I participate in the science teacher preparation programs of nearby colleges and universities by working with student teachers and/or teaching extension courses.	1 2 3 4 5
8. I use professional days or released time to visit other schools and observe innovative science programs and/or outstanding teachers in action.	1 2 3 4 5
9. I use my training and experience to identify students with special needs or problems and refer them to persons or agencies qualified to provide help.	1 2 3 4 5
10. I am familiar with the special science-related opportunities (clubs, competitions, fairs, symposia, or congresses) available to my students and encourage and advise them in their participation.	1 2 3 4 5

Appendix E

An Example of a Data Analysis Sheet for Professional Growth in Science

Personnel		Professional growth resources											
		Through school-directed activities				Through other directed activities				Available materials and services			
Category	Number	Science program in-service	Science content workshops	Consultant assistance	Allotted district time	Community activities in science	Science conference	University classes	Visitations	Professional library	Resource center	Science equipment for special projects	Allocated funds (where applicable)
Science specialist													
Multisubject teacher													
Teacher aides													
Other school personnel (e.g., lab assistants)													
Nonschool personnel (e.g., volunteers)													
Total allocated funds													
Actual expenditures													

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Appendix

F

Reading in Science Instruction

Developing Reading Skills

The nature of science and the unique organization of scientific information and processes give rise to special difficulties in reading scientific materials. One of the primary difficulties is posed by science vocabulary. There are several reasons for this: (1) The vocabulary in science is more exact, specialized, and extensive than in other fields; (2) many commonly used words cause confusion because they have a different and/or more exact meaning in science (e.g., *mass, force, compound, cell, colony,* and *culture;* (3) many scientific words are derived from Greek or Latin words that are completely new to students so that previously learned word analysis skills are frequently of little or no help, and students have to make new applications of the skills and formulate new generalizations; and (4) one word is often applied to a complicated concept or process (e.g., *sterilize, magnetism, photosynthesis,* and *electrolysis).*

Although basic reading skills apply to all subjects, scientific materials require emphasis on special skills that are fundamental for effective reading in science. To successfully complete their science research project, students should learn to do the following:

1. Use the specific science vocabulary.
2. Change the rate of reading in accordance with the difficulty level.
3. Draw important generalizations from the reading of scientific books and articles.
4. Obtain information from graphs, charts, maps, scales, and diagrams and relate them with the printed word.
5. Use and understand scientific symbols and formulae.
6. Read and follow a sequence of steps in a technical process and in performing investigations.
7. Select, locate, and use outside references and compare information from various sources.
8. Read and identify the cause-and-effect pattern in science.
9. Recognize and follow problem-solving techniques.
10. Apply the information in helping to understand everyday problems.

The reading level assessment of printed materials is often complicated when the printed word is accompanied by illustration, diagrams, tables, and other format variations which are included to aid in comprehension. Also, the more modified structures a basic sentence has in it, the more complicated it is. For example, prepositional phrases, dependent clauses, inverted word order, and excessive subordination require higher reading skills. The following techniques are only two of several reading assessments that can be used. Others can be selected from a variety of testing procedures listed in the references at the end of this appendix.

Assessing Student Reading Skills

Teachers can develop a "cloze"[1] reading test to determine which students will be able to understand specific printed materials and the degree of assistance that will be required by others. The procedure provides a means for determining whether the material is at the independent, instructional, or frustrational level for each student.

Independent Reading Level

The learner is at the independent reading level when he or she is able to read and understand without help. The material should have high interest value and should cause no difficulty.

Instructional Reading Level

At the instructional reading level, the individual is able to read and understand with some help from the teacher. The material may be challenging but not too difficult.

Frustrational Reading Level

At the frustrational reading level, the individual is unable to read with minimum teacher assistance. Comprehension of the material is poor, and frustration results.

An informal cloze reading test can be constructed as follows:

1. Select a representative passage from the printed materials. The passage should include an initial sentence that is kept intact and followed by 250 words.
2. Delete every fifth word and replace it with a blank using the underline typewriter key. All the blanks should be uniform in length.
3. Have students complete each blank as nearly as possible to the word omitted (every fifth word will be "clozed" by the student).
4. Score the test results by considering only the exact word to determine a direct match score, or determine an adjusted score by accepting alternative words.
5. Interpret the scores as follows:

   65 to 100 percent—independent reading level
   55 to 64 percent—instructional reading level
   0 to 54 percent—frustrational reading level

Assessing the Reading Level of Printed Materials

A discrepancy often exists between the intended grade level use and the reading level of published materials. Teachers should be familiar with different techniques for determining the approximate reading level of printed materials. One technique involves the use of the Fry readability graph. It has a high correlation with other reading level assessment

[1]A test of reading comprehension that involves having the individual being tested supply words that have been systematically deleted from a text.

devices; however, all such assessment devices have built-in limitations, particularly with science vocabulary. The graph can be used only to *approximate* the reading level of materials. (See Figure 1.)

DIRECTIONS: Randomly select three 100-word passages from a book or an article. Plot the average number of syllables and the average number of words per sentence on a graph to determine the area of readability level. Choose more passages per book if great variability is observed.

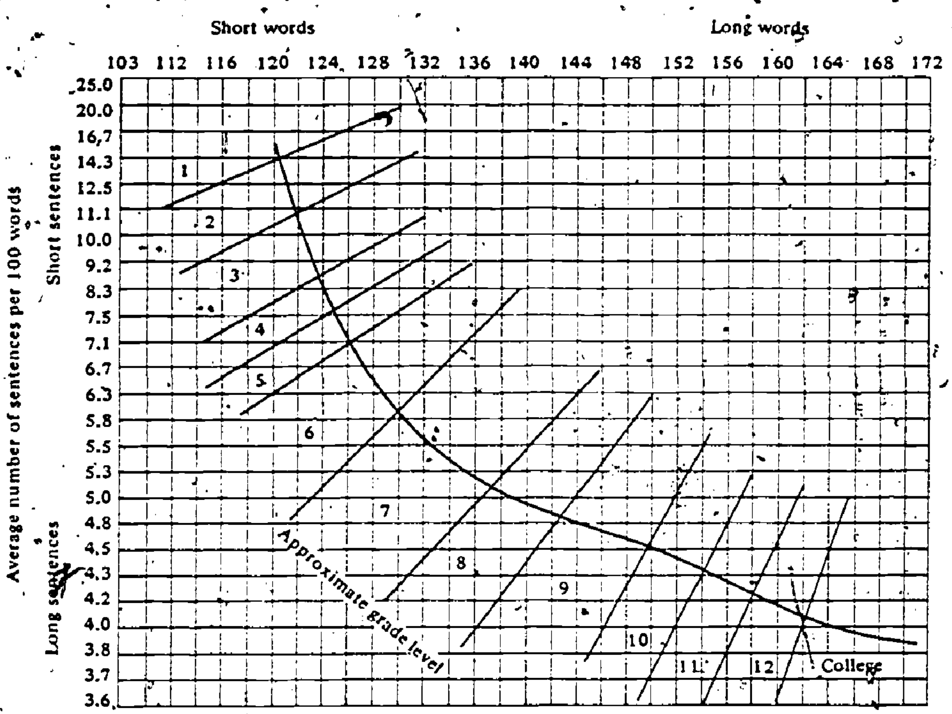

Fig. 1. Graph for estimating readability[2]

[2]Used by permission from Edward Fry, Rutgers University Reading Center, Rutgers University, New Brunswick, N.J. The readability graph is not copyrighted. Anyone may reproduce it in any quantity, but the author and the editors would be pleased if this source were cited.

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Frameworks Available from the Department of Education

The *Science Framework for California Public Schools,* which was adopted for use in California by the State Board of Education, is one of a series of curriculum frameworks that are available for purchase from the California State Department of Education.

The frameworks, with date of publication and selling price, are as follows:

Art Education Framework (1971) $.85
Bilingual-Bicultural Education and English-as-a-Second-Language Education: A Framework for Elementary and Secondary Schools (out of print; currently being revised)
California Curriculum Frameworks: A Handbook for Production, Implementation, and Evaluation Activities (1977) $.85
Drama/Theatre Framework for California Public Schools (1974) $1.05
English Language Framework for California Public Schools (1976) $1.50
Foreign Language Framework for California Public Schools (1972) $.85
Health Instruction Framework for California Public Schools (1978) $1.35
Mathematics Framework for California Public Schools (1975) $1.25
Music Framework for California Public Schools (1971) $.85
Physical Education Framework for California Public Schools (1973) $.85
Framework in Reading for the Elementary and Secondary Schools of California (1973) $1.25
Science Framework for California Public Schools (1978) $1.65
Social Sciences Education Framework for California Public Schools (1975) $1.10

Other publications that may be of interest to the reader are the following:

Curriculum Guide for Teaching Gifted Children Science in Grades One Through Three (1977) $.85
Curriculum Guide for Teaching Gifted Children Science in Grades Four
Ekistics: Guide for an Interdisciplinary Environmental Curriculum (1973) $.85
Handbook on California's Natural Resources, Vol. I (1972) $.85
Handbook on California's Natural Resources, Vol. II (1970) $.85

Orders should be directed to:

California State Department of Education
P.O. Box 271
Sacramento, CA 95802

Remittance or purchase order must accompany order. Purchase orders without checks are accepted only from government agencies in California. Six percent sales tax should be added to all orders from California purchasers.

A complete list of publications available from the Department may be obtained by writing to the address listed above.

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