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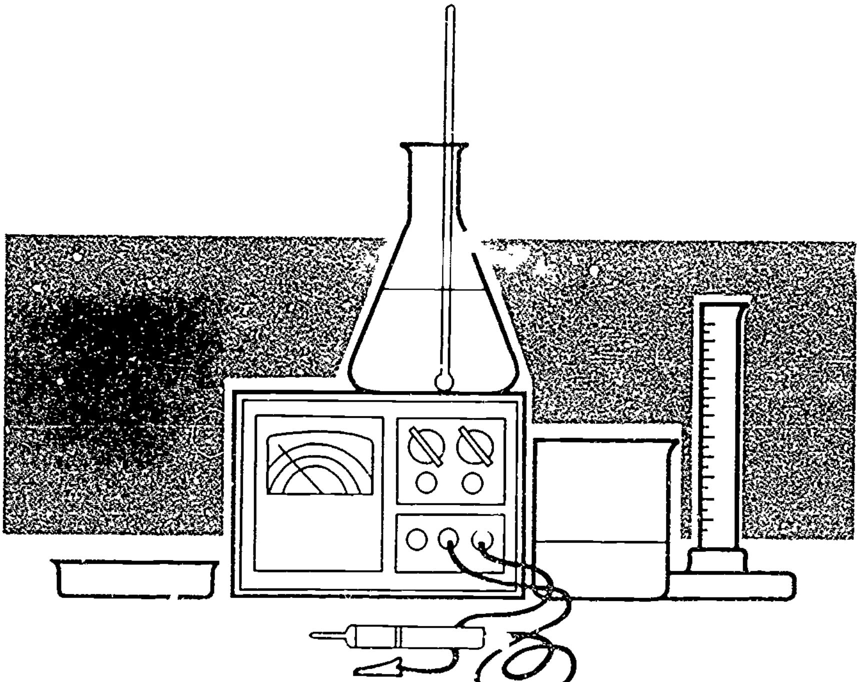
ABSTRACT

This booklet describes the assessment objectives of the sixth national assessment of science by the National Assessment of Educational Progress (NAEP). Chapters included are: (1) "Introduction" (describing the development process for the objectives and the purpose and elements of school science); (2) "The Assessment Framework" (discussing major categories and related aspects of the framework, and weightings for questions); (3) "The Nature of Science" (classifying the nature of scientific processes, values and principles, and scientific knowledge); (4) "Thinking Skills" (dealing with knowing science, solving problems, and conducting inquiries); (5) "Science Content Areas" (including life sciences, physical science, and earth and space sciences); and (6) "Background Variables." Participants in the development process are listed. Sample items representing cells of the framework are provided as examples of classifications and item formats to be included in the assessment. (YP)

SCIENCE OBJECTIVES

1990 ASSESSMENT



MARCH 1989

**The Nation's Report Card,
The National Assessment of
Educational Progress (NAEP)**

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Contents

Chapter one

Introduction

Development Process for the Assessment Objectives

In 1989-90, the National Assessment of Educational Progress (NAEP), the Nation's Report Card, will undertake the sixth national assessment of science. Since 1969, NAEP has provided periodic "report cards" to the nation, collecting and interpreting information on students' knowledge, skills, and attitudes in most subjects in the school curriculum. In addition to science, these subjects have included reading, writing, literature, music, art, mathematics, computer competence, history, civics, and geography. Previous assessments in science were conducted during the school years ending in 1970, 1973, 1977, 1982, and 1986; thus the 1990 assessment of students at grades 4, 8, and 12 and at ages 9, 13, and 17 will provide a view of science achievement that spans 20 years.[1]

Planning for the 1990 national assessment of science began at a time of significant public concern over the quality of elementary and secondary science education in the United States. A number of studies released in the 1980s have criticized the inadequate knowledge and performance of U.S. students in the

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[1] Since 1969, NAEP has assessed students at ages 9, 13, and 17. In 1983-84, the project began sampling students by grade as well as by age.

subject and urged wide-ranging educational reforms. *Science Achievement in 17 Countries*, the preliminary report of the Second International Science Study, indicates that U.S. students at the middle- and secondary-school levels perform poorly in science compared with their peers abroad. The report concludes that several countries, including the U.S., "must be concerned about the scientific literacy of their general work force unless they remedy the situation through training programs or vocational education at a later stage."[2]

Educating Americans for the 21st Century states, "We must return to the basics, but the 'basics' of the 21st century are not only reading, writing, and arithmetic. They include communication and higher problem-solving skills, and scientific and technological literacy—the thinking tools that allow us to understand the technological world around us."[3]

The first NAEP science objectives, formulated in 1965, stated that the major purpose of science education is to develop scientifically literate individuals. In each successive science assessment, this underlying premise has been preserved, guiding the development of revised objectives that take into consideration recent developments and new emphases in the domain. The NAEP science assessments measure the extent to which students have the scientific knowledge and skills thought by NAEP consultants and reviewers to be needed in contemporary life and work.

International Association for the Evaluation of Educational Achievement, *Science Achievement in Seventeen Countries: A Preliminary Report* (Exeter, Great Britain: Pergamon Press, 1988).

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, *Educating Americans for the 21st Century: A Report to the American People and to the National Science Board* (Washington, DC: National Science Foundation, 1983).

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As with other subjects and other assessment years, NAEP's objectives for the 1990 science assessment are the result of a consensus process involving many individuals, ranging from science educators and specialists to members of the lay public. The Assessment Development Panel (see page 42 for a list of participants) began the objectives development process by revising the framework from the previous assessment and preparing an initial set of science objectives. The draft objectives were then reviewed by the Item Development Panel and by external consultants from across the country, representing various interests and concerns. The Item Development Panel, a committee of science educators, administrators, and researchers, was established to develop items for the 1990 assessment using the framework provided in these objectives (see page 43 for a list of participants). Among the reviewers for the 1990 objectives were teachers, school science coordinators, scientists, school administrators, state science supervisors, and members of the Assessment Policy Committee, NAEP's governing board. The Science Assessment Development Panel remained involved throughout the review and revision process.

The objectives presented here do not reflect the views of every individual who participated in the development effort nor are they intended as a complete or definitive specification of curriculum standards; rather, they represent a consensus of the views and concerns of the Assessment Development Panel, Item Development Panel, and external reviewers, offering an overview of learning outcomes and a framework to guide the development of assessment questions.

The Purposes and Elements of School Science

Science educators generally agree that the primary purpose of school science is to cultivate scientific literacy; however, there is far less agreement as to what constitutes scientific literacy or how such a definition might be used to guide the development of meaningful curriculum and instruction. At the very least, there appears to be a consensus among educators that school science should help students acquire the knowledge, skills, and understandings necessary to fulfill their human, social, and economic responsibilities.[4]

According to the interactive model presented in Figure 1, scientific habits of mind serve as a filter between the features of the learner—including his or her cognitive abilities, attitudes, and home and school experiences—and the outcomes of science learning. Given limited resources, the 1990 science assessment can cover only some of the many elements of scientific literacy. Those elements of the model to be included in the assessment—science knowledge, scientific habits of mind, and the ability to solve problems and conduct inquiries—are discussed below.

Science Knowledge. Students' knowledge base in science should include information not only about the natural phenomena that are the objects of study in the major scientific disciplines—life sciences, physical sciences, and earth and space sciences—

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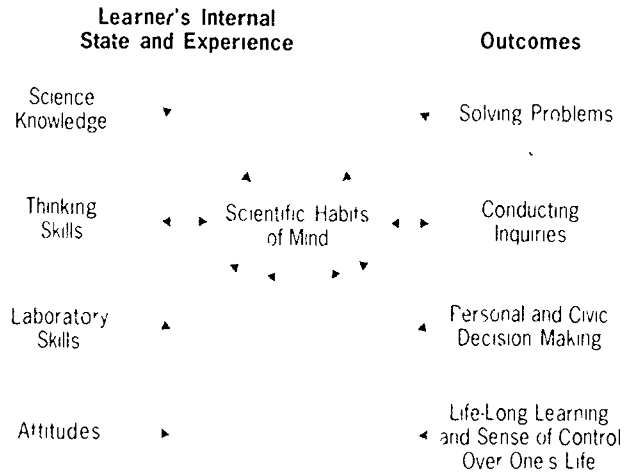
[3] Rodger Bybee, "The Sisyphean Question in Science Education: What Should the Scientifically Literate Person Know, Value, and Do — As a Citizen?" (Washington, DC: Yearbook of the National Science Teachers Association, 1985)

[4] Paul DeHart Hurd, "Perspectives for the Reform of Science Education," *Phi Delta Kappan* (January 1986)

but also the fundamental concepts, principles, and theories in these disciplines.

Figure 1: Elements of Scientific Literacy and their Interaction



Second, students' knowledge base should contain information about the nature of science, including a recognition of the characteristics of science that set it apart from other human activities—in particular, its empirical and theoretical methods, and its philosophy. Finally, students should be informed about the history of science and the interactions among science, culture, society, and technology.

Scientific Habits of Mind. The term "scientific habits of mind" includes both the ability to think scientifically and the inclination to do so beyond the confines of the science classroom. Inductive and deductive reasoning; verbal, analogical, and spatial reasoning; and creative thinking are among the primary elements of scientific thinking. Yet the propensity to apply these habits of mind beyond the science classroom depends not only on abilities but also on attitudes toward science and its relevance to life—views influenced both by experiences in school science and by personal variables, such as individual motivation and out-of-school involvement in science-related learning.

Solving Problems and Conducting Inquiries. Solving problems and conducting inquiries encompass a wide range of activities, from the novice efforts of students interacting with the natural world to the work of experienced scientists. Although these thinking skills are often exercised as a part of everyday experience, for the purposes of this assessment, discussions of students' ability to solve problems and conduct inquiries are limited to academic applications. The capacity to wield these skills in various contexts is considered by science educators to be an important indicator of science achievement.

Solving problems and conducting inquiries may be viewed in terms of methods or outcomes. Teachers may ask their students to engage in these thinking activities to develop a richer understanding of the natural world or an understanding of the concepts, principles, and theories of science. Alternatively, developing students' ability to solve problems and conduct inquiries may itself be the desired outcome of these activities.

Chapter two

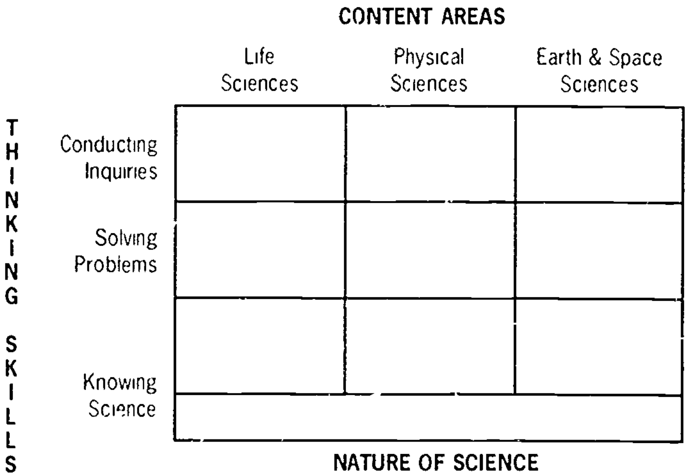
The Assessment Framework

As described in Chapter 1, scientific literacy has many dimensions, each containing numerous categories and topics. Given finite resources, the limits of self-administered measurement, the use of paper and pencil procedures, and the constraints of existing scoring and analysis technology, NAEP cannot provide valid and reliable information on student achievement in every aspect of the domain. Ideally, a national assessment in science would include a section devoted to measuring students' laboratory skills with "hands-on" science activities or investigations; however, the scarcity of funding resources has precluded work in this valuable area. Members of both the Assessment Development Panel and the Item Development Panel recommended that greater resources be made available in the future to assess students' ability to perform hands-on science tasks and to study the relationship of these abilities to general science proficiency.

Given existing technical and financial parameters, the Assessment Development Panel established a set of priorities for the assessment of student performance based on several factors, including the usual structuring of the science curriculum (i.e., according to traditional disciplines) and the anticipated utility of the findings for policymakers and science educators.

Based on these defined priorities, the panel constructed the framework for the 1990 science assessment, a two-dimensional matrix—Content Areas by Thinking Skills—provided in Figure 2.[5]

Figure 2: Framework for the 1990 Science Assessment



To guide the development of assessment items, the panel assigned weights to each of the major categories in the framework, reflecting the relative importance of each of the content and cognitive areas assessed. Cell weightings for each age group are presented on page 16. Each question designed for the

[5] This two-dimensional matrix differs from the three-dimensional matrix used in NAEP's 1986 assessment; however, the matrix is sufficiently like those used in 1986 and previous years to enable NAEP to report trends in achievement across time by incorporating a subset of previously administered questions into the new assessment.

assessment is classified into one cell of the matrix, matching the content and cognitive skills it is intended to measure.

The structure of the 1990 assessment will allow NAEP not only to report on average science proficiency for the nation and for population subgroups, but also to document students' performance on four subscales—the Nature of Science, Life Sciences, Physical Sciences, and Earth and Space Sciences.

Major Categories of the Framework

An understanding of the **Nature of Science** is the foundation of scientific literacy and thus of the assessment framework itself, supporting students' thinking skills as well as their content area knowledge. A grasp of the fundamental aspects of the nature of science requires an understanding of the methods and processes of science, the principles underlying scientific work, and the nature of scientific knowledge. Chapter 3 contains descriptions of these categories subsumed under the Nature of Science, and a listing of sample topics within each category of the kind included in the assessment.

The categories and topics that comprise the **Thinking Skills** dimension of the framework represent the range of knowledge and cognitive abilities that allow the scientifically literate individual to conduct inquiries and solve problems in various science content areas. A discussion of these thinking skills is provided in Chapter 4.

Finally, the **Content Areas** presented in this framework are the disciplines in which knowledge, thinking skills, and understanding of the nature of science are applied. The content areas included in this assessment --the Life Sciences, Physical Sciences, and Earth and Space Sciences—reflect the traditional disciplines of science. Chapter 5 presents a discussion of each of these disciplines, together with a list of sample topics illustrative of those included in the assessment.

Related Aspects of the Framework

Although the **history of science** is not included as a separate dimension in the framework, the Assessment Development Panel believed that students should be cognizant of the major developments in science history. A number of assessment questions were therefore designed to measure students' familiarity with persons and events that have helped shape contemporary scientific understanding in various content areas.

The panel also believed that the assessment questions should reflect a variety of **contexts**; thus, students will be asked age-appropriate questions pertaining to scientific, personal, and societal issues.

Because the need to understand and adapt to new technologies plays a major role in contemporary life and work, a series of items within the assessment pertains specifically to **technology** and its uses. In the context of this assessment, technology encompasses the applications of knowledge and information, methods and tools, and processes and products.

A final subset of questions in the assessment integrates concepts from science with **mathematical abilities and content**. For example, students may be asked to use their procedural knowledge of measurement, data analysis, or statistics to solve science problems.

Although these dimensions—history of science, context, technology, and mathematical abilities and content—will not be reported on distinct subscales, an examination of students' responses to questions in these areas will permit a more detailed view of their understanding of science.

Weightings for Assessment Questions

Any assessment of students' science knowledge can cover only a small part of the domain of science education provided across the school years. Therefore, the panel needed to prioritize the content and cognitive areas included in the assessment. Weighting decisions were based on information about the typical science curriculum at each grade/age level, on NAEP's legislatively-mandated obligation to provide information about trends in science achievement, on measurement requirements for reporting on content area subscales; and on the views of the Assessment Development Panel, Item Development Panel, and NAEP consultants. The distribution of topics and items within each content area was not intended to prescribe curriculum standards; rather, the percentages were used to construct a complete and balanced assessment instrument at each grade.

As presented in Tables 1 and 2, weights were assigned separately for each grade level because the emphases and expectations appropriate for fourth-, eighth-, and twelfth-grade students are different. For example, although the same percentages of questions were assigned to knowing science, solving problems, and conducting inquiries at all three grades, fourth graders' performance in these areas is expected to differ in cognitive sophistication from the performance of older students

In addition, individual students may apply different knowledge or cognitive processes to answer a given assessment question, for example, one student may rely on his or her knowledge of certain facts, while another who does not have that information may arrive at the correct answer using a different approach. The classification of each assessment question was based on the judgments of NAEP staff and consultants as to the knowledge and cognitive processes that an average student in the target population would be likely to use when answering the question.

TABLE 1

Thinking Skills: Approximate Percentage Distribution of Assessment Questions

Category	Grade 4	Grade 8	Grade 12
Knowing Science	40	40	40
Solving Problems	40	40	40
Conducting Inquiries	20	20	20
TOTAL	100	100	100

TABLE 2

Nature of Science and Content Areas: Approximate Percentage Distribution of Assessment Questions*

Category	Grade 4	Grade 8	Grade 12
Nature of Science	10	10	12
Life Sciences	30	30	32
Physical Sciences	30	30	34*
Earth and Space Sciences	30	30	22
TOTAL	100	100	100

*At age 17, the Physical Sciences category includes approximately 17 percent Chemistry and 17 percent Physics questions.

Based on the weightings established, the Assessment Development Panel, Item Development Panel, and additional consultants began to write items for the assessment. All new items were subsequently screened by subject-area and measurement specialists, subjected to ETS sensitivity and editorial review, thoroughly field tested, and revised as needed subsequent to each of these stages of review.

Because the assessment cannot include items on all appropriate topics, the final selection of assessment questions was guided by the Assessment Development Panel and the Item Development Panel. The selection was based on the careful balancing of a number of requirements, including:

★ the need to repeat items from previous assessments to enable reporting on trends in science achievement across time;

★ the need to meet distribution specifications set by the matrix dimensions of content and thinking skills, and to integrate th[illegible]r priorities defined by the panel—that is, inc[illegible] items that pertain to the history of science, context, technology, and mathematical content and abilities; and

★ the need to offer items over a wide range of difficulty.

The final choice of questions reflects the professional judgments of NAEP staff and consultants as to the quality of individual items and the centrality of the thinking skills and content that each measures.

Chapter three

The Nature of Science

An awareness and understanding of the nature of science is fundamental to scientific literacy. Recognizing that there are various ways of knowing within, between, and beyond the disciplines of science, the phrase *"science as a way of knowing"* summarizes the views of NAEP consultants as to what students should understand about the nature of science. "A way of knowing" refers not only to a course of action, but also to habits of mind, protocols, or inclinations toward certain behaviors. An understanding of the nature of science, therefore, consists of not only an understanding of scientific methods and processes, but also of the principles and knowledge that drive scientific work.[6] Three aspects of the nature of science to be included in the 1990 assessment—processes, principles, and knowledge—are discussed below

The Nature of Scientific Processes

Scientifically literate individuals should be aware of a variety of processes essential to scientific work. The five categories of scientific methods and processes highlighted in these objectives were drawn

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[6] J. Moore "Science as a Way of Knowing Evolutionary Biology" *American Zoologist* 24 2 (1984) p 467

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primarily from the NAEP report *Learning by Doing* and from an outline produced in 1964 by the Commission on Science Education for the American Association for the Advancement of Science.[7]

Observing, classifying, and inferring. Observation—using the senses to obtain information about the world—is a fundamental part of scientific inquiry. Because they can observe only a limited number of objects and events at any given time, individuals typically impose (consciously or subconsciously) a system of organization or classification as they decide what to observe. Based on the system of classification chosen, observations are used to form inferences, construct explanations, or draw conclusions from available data.

Interpreting data. Interpreting data involves finding patterns and meaning in a collection of observations, leading the observer to develop hypotheses, formulate generalizations, or explain phenomena. For the scientist, these activities may require using mathematical concepts and operations to manipulate variables.

Formulating hypotheses. To formulate a hypothesis is to propose an explanation for observed conditions or events which may then be subject to empirical testing and validation.

Designing experiments. Designing an experiment entails planning the methods and procedures that

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National Assessment of Educational Progress, *Learning by Doing: A Manual for Teaching and Assessing Higher Order Thinking in Science and Mathematics* (Princeton, NJ: Educational Testing Service, May 1987).

Arthur Livermore, "The Process Approach of the American Association for the Advancement of Science Commission on Science Education," *Journal of Research in Science Teaching* (1964).

can be used to gather data needed to answer a question, support a hypothesis, or challenge a theory.

Conducting inquiries. The process of conducting inquiries integrates the methods and processes of science, the values of science, and the skills of scientists in discovering new knowledge. In addition, conducting inquiries involves such skills as interpreting data in light of experimental hypotheses and extant knowledge, controlling variables, defining terms, formulating models, and communicating results (i.e., publicizing findings).

Rather than attempt to define a complete or definitive set of topics for these categories—an impossible undertaking—the panel designated topics illustrative of those that might be incorporated into the assessment. These sample topics were reviewed by science educators and other external consultants to evaluate their appropriateness for students in each designated grade level. Because not all topics are suitable for all age levels, the lists that follow use a bullet (•) in the column under a particular grade to indicate that some aspect of that topic or concept is a potential source of questions for that grade level.

The Nature of Scientific Processes: Topics Classified by Grade Level

	Grade Level 4	8	12
The processes of science include observing, classifying, and inferring			
Observation is fundamental to science	•	•	•
Observation may involve any of the senses	•	•	•
Classification is important . . .	•	•	•
There are many different ways to classify	•	•	•

	Grade Level 4	8	12
Classifications impose order		•	•
Inferences can be made and conclusions can be drawn from observations and classifications		•	•
The processes of science involve interpreting data			
Conclusions are based on the scientist's interpretations of data	•	•	•
Interpreting data may include noting whether there have been any unexpected results	•	•	•
Predictions and implications are based on interpretation of data	•	•	•
Mathematical operations are an important tool in data interpretation	•	•	•
Determining the significance of results is a form of interpreting data		•	•
The processes of science involve formulating hypotheses			
Hypotheses are plausible explanations of observations, facts, or results	•	•	•
Hypotheses are testable	•	•	•
Testing hypotheses often leads to the formulation of new hypotheses for investigation		•	•
The processes of science involve designing experiments			
Conducting inquiries involves looking for patterns	•	•	•
Experimentation involves choosing appropriate tools and techniques	•	•	•
Experimentation involves gathering data	•	•	•
Experimentation involves testing hypotheses	•	•	•
One experiment will often lead to another	•	•	•
Experiments and the application of the results of experiments may have benefits, costs, and risks that must be identified and reflected upon		•	•
Experiments are based on well-stated hypotheses		•	•
Data from experiments are used to challenge or support theories		•	•
Experiments involve identifying and selecting dependent and independent variables			•
Models are often used to formulate hypotheses			•

The Nature of Values and Principles Underlying Scientific Work

An understanding of the values and principles that shape scientific work is a necessary but not sufficient condition of scientific literacy; science education should also develop students' inclinations to apply these in their interactions with the natural and technological world. The following values and principles incorporated in the 1990 assessment were adopted from the report, *Education and the Spirit of Science.*[8]

Knowledge is valued. Knowledge is an outcome of scientific work; students should therefore consider the investment of time and resources in pursuit of scientific knowledge to be a worthy goal.

Questioning is essential. Developing and refining scientific knowledge requires questioning current knowledge. The scientific position is that authoritative statements, beliefs, and truths are accepted only to the extent that evidence supports them. All things are subject to scrutiny and revision.

Data are fundamental. The bases for refining and expanding scientific knowledge are data, and the processes of acquiring and ordering data are fundamental to theory construction. Data do not become useful until they are observed and framed into qualitative or quantitative statements.

Verification is essential. The validity and accuracy of scientific findings are open to review. Under appropriate circumstances, scientists should provide necessary information to allow other scientists to replicate their experiments.

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[8] National Education Association, *Education and the Spirit of Science* (Washington, DC: National Education Association, 1966)

Logic is respected. There is a respect in science for logical reasoning which allows scientific knowledge to be constructed and revised.

Illustrative sample topics on values and principles underlying the scientific enterprise follow.

The Nature of Values and Principles Underlying Scientific Work: Topics Classified by Grade Level

	Grade Level 4	8	12
Knowledge is valued			
Facts and data are the result of scientific work	•	•	•
Knowledge is supported by evidence	•	•	•
Expanding knowledge is the goal of scientific work		•	•
The scientific community values knowledge supported by evidence more than knowledge supported by belief		•	•
Questioning is essential			
Scientific knowledge is open to question and revision	•	•	•
Scientists are obligated to question the findings of other scientists	•	•	•
Data are fundamental			
Scientists use facts and data to assess their theories	•	•	•
Scientific disputes are resolved by facts, not beliefs	•	•	•
Analysis of data may be quantitative or qualitative		•	•
Acquiring and ordering data are fundamental to the construction of scientific explanations			•
Verification is essential			
Scientists experiments may be repeated by other scientists	•	•	•

	Grade Level 4	8	12
Scientists should be able to demonstrate how they obtained the data they use to support their theories		•	•
The validity and accuracy of scientific findings are open to review			•
Logic is respected			
Scientific data should be presented in ways that are understandable	•	•	•
The connections between scientific data and scientific theories must be reasonable to the scientific community	•	•	•
Scientists require that empirical findings and scientific theories be constructed logically			•

The Nature of Scientific Knowledge

Scientific knowledge is in a continuous state of transformation, but in recent decades, changes in existing data and concepts have occurred at increasing rates and in many new directions. As scientific knowledge is refined and elaborated, new theories are generated, replacing extant ones. Interpretations of scientific knowledge also may change. Many methods and techniques can be used to further our knowledge of science. Thus, there is no single "scientific method" to be learned, as frequently described in science texts, but rather a multiplicity of methods.

In 1990, NAEP will expand the efforts of previous assessments to measure students' understanding of the nature of scientific knowledge, according to five major tenets:

Scientific knowledge is tentative. Because it is constantly changing, the body of scientific knowledge is neither absolute nor complete. What is known in science enables one to make logical predictions and explanations and to integrate the scientific processes needed to generate and resolve new questions.

Scientific knowledge is public. Scientists generally publicize new knowledge and the methods used to discover that knowledge to further advancements in science and permit their colleagues to evaluate their work.

Scientific knowledge is empirically based. Scientific knowledge encompasses facts, principles, concepts, and theories. Observation and experimentation are the basis for expanding and revising the body of scientific explanations, and the assessment of these explanations is based on observable data.

Scientific knowledge is based on replicable observations. Scientists working in different places, at different times, and under comparable conditions should be able to repeat observations and experiments and derive the same findings from these activities.

Scientific knowledge is cumulative. Scientific knowledge from the past is the basis for present knowledge, which sets the stage for the development of future knowledge. Historical knowledge should be related to the context of the period in which it existed, and contemporary scientific knowledge should be understood in relation to the current social, technological, and political contexts.

A set of illustrative sample topics on the nature of scientific knowledge follows.

The Nature of Scientific Knowledge: Topics Classified by Grade Level

	Grade Level 4	8	12
Scientific knowledge is tentative			
Scientific knowledge can change	•	•	•
New evidence can change current explanations for phenomena	•	•	•
Scientific knowledge is public			
Scientists should report exactly what they observe	•	•	•
Scientific knowledge is reported publicly		•	•
Scientists should report both the data supporting theories and the methods used to obtain the data			•
Scientific knowledge is empirically based			
Observation and experimentation are the basis for acquiring scientific knowledge	•	•	•
Scientific knowledge must be reassessed through repeated observations		•	•
Scientific knowledge is based on replicable observations			
Scientists working in different places or at different times under comparable conditions should be able to repeat experiments and get consistent results	•	•	•
Evidence derived from observations and experiments should be replicable by other scientists		•	•
Scientific knowledge is cumulative			
Scientific knowledge is accumulated over time	•	•	•
Contemporary theories may be based on knowledge accumulated over time		•	•
The accumulation of scientific knowledge may be influenced by social, political, methodological, and technological factors		•	•

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Chapter four

Thinking Skills

In its 1987 report, *Improving the Assessment of Student Achievement*, the Alexander-James commission recommended that NAEP devote greater attention in future assessments to measuring students' higher-order thinking skills, particularly in mathematics and science.[9] In doing so, the commission joined a growing cast of educators, legislators, researchers, and employers in calling for efforts to strengthen the higher-order thinking skills of American students.[10] Despite widespread agreement that higher-order thinking must be improved, there is little agreement as to what these skills are, much less how they can be taught or measured.[11] While there is some evidence that hands-on activities strengthen important cognitive skills, there is a need for further research to demonstrate the appropriate uses of hands-on activities in science instruction and to

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[9] Lamar Alexander and H. Thomas James, *The Nation's Report Card: Improving the Assessment of Student Achievement* (Washington, D.C.: National Academy of Education, 1987)

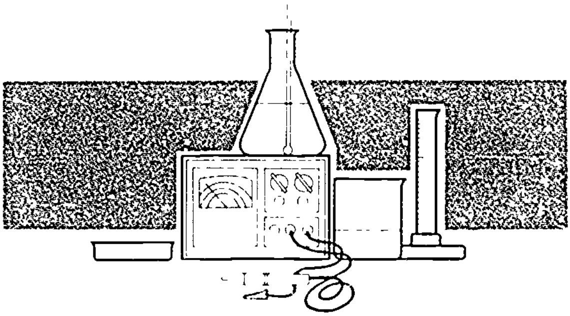
[10] The National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, *Educating Americans for the 21st Century* (Washington, DC: National Science Foundation, 1983)

[11] Lauren Resnick, *Education and Learning to Think* (Washington, DC: National Academy Press, 1987)

explore the relationship between these activities and science proficiency.[12]

Accordingly, NAEP conducted a 1986 pilot assessment of higher-order thinking skills in science and mathematics which required students to work with various types of hands-on equipment. Students were asked to manipulate materials such as circuits, beakers, blocks, and small animal vertebrae, organize data, make and interpret observations, formulate hypotheses, and conduct investigations, all of which are likely to be relevant to a wide range of tasks and responsibilities outside of the science domain.[13]

Although there are inadequate resources at this time to include hands-on items in the 1990 science assessment, efforts will be made to measure students' use of some of these skills based on pencil and paper items. These items are presented in a variety of formats, including multiple-choice, short answer, figural response, and essay. Reiterating the framework in Chapter 2, each question in the assessment



[12] J. Shymansky and John Penick, "Teacher Behavior Does Make a Difference in Hands-On Science Classrooms," *School Science and Mathematics* 18 (1981), pp. 412-22.

[13] National Assessment of Educational Progress, *Learning by Doing: A Manual for Assessing Higher-Order Thinking in Science and Mathematics* (Princeton, NJ: Educational Testing Service, 1987).

is classified according to both the thinking skill and the content area it subsumes. This design is based on a definition of higher-order thinking that is discipline-based, under the belief that thinking skills should be taught (and therefore measured) in conjunction with subject content, rather than in isolation. The three categories of thinking skills included in the 1990 science assessment are:

★ knowing science;

★ solving problems; and

★ conducting inquiries.

These thinking skills are discussed below.

Knowing Science

Questions in the knowing category are designed primarily to measure factual knowledge. Successful performance depends on students' ability to recall specific facts, concepts, principles, and methods of science, show familiarity with scientific terminology; recognize basic ideas in different contexts; translate information into other words or formats; and use abstractions in related situations. Scientific knowledge is critical, because conducting investigations, solving problems, and making successful decisions in science require familiarity with facts, generalizations, and processes.

Solving Problems

Questions asking students to solve problems test their ability to combine factual knowledge with appropriate rules, formulas, and algorithms for specified purposes. Successful performance requires that students apply scientific facts and principles; interpret information or data using ideas from the natural sciences; and recognize the relationship of concepts, facts, and principles to phenomena observed and data collected.

Solving problems generally refers to those thinking activities in which algorithms may be applied in resolving a given question or problem. These problems often have well-defined goals, are presented via text and diagrams, and are textbook- or teacher-initiated, rather than self-initiated. Responses to such problems are typically limited to a word, number, or phrase, and only occasionally require an extended verbal or written response. Some of the questions in the 1990 assessment that require students to solve problems are of the kind typically found at the ends of chapters in science textbooks; others ask students to use scientific knowledge and understandings to solve problems simulating situations that might arise in real life.

Conducting Inquiries

Inquiries arise out of experience with the natural world and, in contrast to solving problems, the goals of these activities are generally set and adapted by the inquirer. Successful performance depends on students' ability to employ the higher-order skills needed to implement an investigation and develop findings. Inquiry questions included in the 1990 science assessment are designed to measure aspects of students' ability to generate researchable questions based on available information. These aspects may include framing a researchable question; analyzing available information in a manner consistent with the body of scientific concepts and principles; evaluating the best analytic or experimental procedure given specified conditions; organizing a series of logical steps, executing an experiment; formulating explanations; and drawing conclusions on the basis of available data.

Chapter five

Science Content Areas

The disciplines of science are interconnected in many ways; however, individual content areas are distinguished in the assessment framework for the purposes of measurement and discussion. As described in Chapter 2, the content dimension of the framework organizes questions according to the three traditional disciplines of science:

★ Life Sciences

★ Physical Sciences

★ Earth and Space Sciences

The Assessment Development Panel defined salient concepts within each category to guide the development of assessment questions, and these concepts were used as the basis for developing lists of sample topics appropriate at each grade level.

Life Sciences

Concepts in the life sciences can be placed along a continuum, ranging from the topic-specific to the highly integrated and interdisciplinary. Most students gain some topic-specific knowledge and understandings in this content area through life experiences; thus, some topic-specific questions—such as asking students to classify plants and animals—are most appropriate at the earlier grade levels. In contrast, items for older students—for example, questions dealing with energy transformations or genetics—require integration of knowledge from several disciplines, as these students are assumed to have mastered a detailed knowledge of the simpler (i.e., topic-specific) categories.

The major categories of topics in the life sciences included in the 1990 assessment include cellular and molecular biology, energy transformations, genetic continuity and development, evolution, diversity and systematics, structure and function of organisms, behavior, and ecology. Illustrative sample topics within each of these categories follow.

Life Sciences: Topics Classified by Grade Level

	Grade Level 4	8	12
Cellular and Molecular Biology			
Cellular theory of life	•	•	•
Cell structure and function		•	•
Life as a chemical process		•	•
Regulators of life processes		•	•
Biochemistry of genetics (DNA and RNA)		•	•
Energy Transformations			
Societal issues: products from living organisms	•	•	•
Major energy sources and reactions in organisms (photosynthesis and cellular metabolism)	•	•	•
Biochemical reactions . . .			•
Genetic Continuity and Development			
Reproduction as the fundamental biological process that provides for the continuance of life	•	•	•
Life cycles	•	•	•
Gene theory of heredity (chromosomes, genes, DNA, mutations)		•	•

	Grade Level 4	8	12
Strategies of reproduction—asexual and sexual		•	•
Societal, technological and ethical issues		•	•
Evolution			
Evidence for evolution (fossils, geological records, comparative studies)	•	•	•
Natural selection and response to changing environments	•	•	•
Historical perspectives			•
Diversity and Systematics			
Major divisions of biology (i.e., Five Kingdoms)	•	•	•
Classification schemes (i.e., structural or evolutionary relationships)	•	•	•
Taxonomy (evolutionary or chemical) of major groups (microorganisms, protists, plants, animals)			•
Structure and Function of Organisms			
Living and nonliving things	•	•	•
Organisms as systems	•	•	•
Hierarchy of structure and function	•	•	•
Structural features of organisms	•	•	•
Good health practices	•	•	•
Equilibrium in living things (homeostasis)		•	•
Behavior			
Response of living things to stimuli	•	•	•
Animal behavior as a form of adaptation	•	•	•
Basis of behavior (genetic, physical)		•	•
Animal models and human behavior		•	•
Ecology			
Interaction/interdependence of biotic and abiotic factors	•	•	•
Energy flow and food webs	•	•	•
Essential requirements for life—food, certain temperature conditions, moisture, light and oxygen (limiting factors)	•	•	•
Symbiosis/prey-predator relationships	•	•	•
Social issues related to the environment (water crisis, pollution, world population, etc.)	•	•	•
Adaptations to the environment (structural, functional, behavioral)	•	•	•
Biogeochemical cycles		•	•

Physical Sciences

The physical sciences deal with the fundamental components of the natural universe—space, time, matter, and energy. Students should be aware that human understanding of the nature of matter has evolved over the course of history. Beginning with the Greek concept of four fundamental elements, through the discovery and organization of the elements into the periodic chart, the idea was sustained that all matter is composed of small particles in a state of continual motion, as summarized by the kinetic molecular theory of matter. As the search for elementary particles continued, the kinetic molecular theory was eventually replaced by the quantum-mechanical view of matter and energy. A sense of this history of ideas provides a foundation for understanding current scientific work.

Students should also understand that the universe is not static; rather, matter and energy are continually being transformed in space and time, producing chemical and physical changes. A grasp of the laws of mechanics, and the interaction of light and matter, provides a way of understanding that among all of nature's transformations, a few invariable (conserved) quantities are known to exist, including mass-energy, electrical charge, and linear and angular momentum. In addition, an understanding of energy—more specifically, the laws of thermodynamics—permits one to predict if and in what manner a change will occur.

The six sets of topics included in the 1990 science assessment are motion, conserved quantities, waves, particulate nature of matter, properties of matter, and changes. Illustrative sample topics within each category follow.

Physical Sciences: Topics Classified by Grade Level

	Grade Level 4	8	12
Motion: Macro- and Microscopic Objects and Particles			
Describing motion (location, speed and velocity, acceleration)	•	•	•
Explaining motion (gravitational and electrical forces, equilibrium)		•	•
Relativistic effects			•
Conserved Quantities			
Energy	•	•	•
Matter	•	•	•
Electric circuits	•	•	•
Thermodynamics		•	•
Momentum		•	•
Charge		•	•
Waves			
Geometric and physical optics	•	•	•
Sound	•	•	•
Electromagnetic waves	•	•	•
Particulate Nature of Matter			
Temperature and heat	•	•	•
Kinetic theory of matter	•	•	•
Fundamental particles	•	•	•
Bonding			•
Properties of Matter			
Solutions	•	•	•
States of matter	•	•	•
Periodic table of elements		•	•
Changes			
Physical	•	•	•
Chemical		•	•
Nuclear			•

Earth and Space Sciences

Knowledge and understanding of key concepts in the Earth and space sciences provides students with a more informed view of their place on Earth, and of Earth's place within the universe. These concepts, in turn, build students' capacity to participate in public decisions, particularly those concerning environmental issues.

Earth's place within the universe, plate tectonics, water and rock cycles, and the Earth's history are the Earth and space science topics to be included in the 1990 assessment. Illustrative sample topics follow.

Earth and Space Sciences: Topics Classified by Grade Level

	Grade Level 4	8	12
Introduction to the Study of Earth and Space Sciences			
Understanding Earth systems	•	•	•
Tools for study (time, maps, compasses, and profiles)	•	•	•
Earth in space and time (contemporary and historical perspectives)	•	•	•
Interaction of spheres (hydrosphere, lithosphere, atmosphere)	•	•	•
The Earth's Place in the Universe			
The Earth-moon sun system	•	•	•
The solar system (dimensions, motions, and interactions)	•	•	•
Astronomical observations	•	•	•
Dimensions, motions, and interactions within the universe (stars and galaxies)		•	•
Quantity and quality of starlight		•	•
Origin and evolution of the universe		•	•
The Dynamic Earth: Plate Tectonics			
Earthquakes and Earth's interior	•	•	•
Natural hazards	•	•	•
Continental origins and continental drift		•	•

	Grade Level 4	8	12
Origin of oceans and changing ocean basins		•	•
Origin and evolution of the theory of plate tectonics		•	•
Evidence for plate tectonics and explanation for landscape changes		•	•
The Water Cycle			
Energy and the water cycle	•	•	•
Weather and climate	•	•	•
Bodies of water on and within the land	•	•	•
Water quality	•	•	•
Water cycles within the oceans		•	•
Origin and evolution of the atmosphere and ocean water		•	•
The Rock Cycle			
Earth materials (rocks and minerals)	•	•	•
Agents of weathering and erosion	•	•	•
Rocks within mountains	•	•	•
Land use	•	•	•
Sedimentation		•	•
Mountains within the seas		•	•
Evolution of landscapes and seascapes		•	•
The Earth's Biography			
Life (past, present, and future)	•	•	•
Reading the record in the rocks of the Earth	•	•	•
Dating of materials	•	•	•
Time and its measurement geologic clocks and scales		•	•
Development of continents across time		•	•

Chapter six

Background Variables

In addition to monitoring trends in science achievement, NAEP collects valuable background information on the context for science learning. Responses to these non-cognitive questions provide further indications of the health of science education in the United States—for example, by providing infor mation on trends in science course-taking for high-school students. Background information is also useful in determining the distribution of educational resources across populations of students and in studying the characteristics of and instruction asso-ciated with students' performance.

For the 1990 science assessment, NAEP will develop two student background questionnaires for each of three grades to be included in the assessment (grades 4, 8, and 12). The first, developed with the guidance of NAEP's Policy Analysis and Use Panel, is a five-minute questionnaire designed to collect basic demographic information as well as indicators of students' socio-economic level and home support for learning.

The second questionnaire, developed with guid-ance from the Science Assessment Panel and Item Development Panel, contains items directly related to aspects of our educational system that affect the learning of science. Because limited time is available to collect such background information, decisions about which areas to include were difficult. However, keeping in mind the parameters of trend information, current research, and the validity of information collected in a self-report format, the NAEP science consultants decided to focus on five contextual areas related to science achievement. These areas are summarized below.

Time Spent Studying Science. Time spent studying science and science course-taking are important indicators of educational quality because of their well-established effects on student achievement.[14] All students are asked how often they have science lessons and how much time they spend on science homework each week, while older students are also asked about the number and kinds of sciences courses they have taken.

Instructional Practice. Information on students' exposure to subject matter, however useful, must be supported with information about uses of class time. While students' perceptions may or may not agree with those of their teachers, students' observations are a key to understanding the end result of various educational delivery systems and instructional practices. Given the current view that students should learn science through experience, a number of questions in this category relate to how often students do experiments, work with manipulatives, and engage in various activities in their science classes. Other questions focus on the use of instructional aids such as films, videotapes or videodiscs, computers, and calculators.

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[14] Richard Murnane and Senta Raizen, *Improving Indicators of the Quality of Science and Mathematics Education in Grades K 12* (Washington, DC National Academy Press, 1988)

Finally, NAEP will attempt to collect information on the extent to which students use textbooks, work on science problems with other students, write reports, and are asked by their teachers to hypothesize and interpret data. The construct to be explored is the extent to which students' science instruction emphasizes the processes of science.

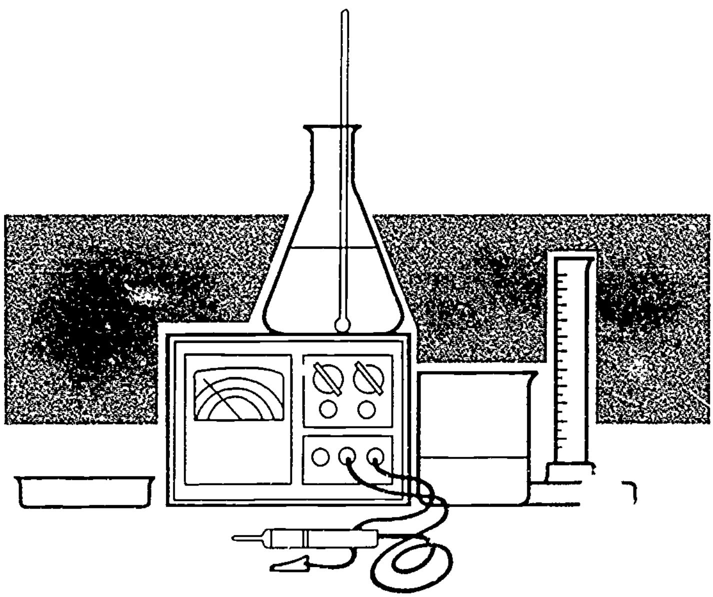
Laboratory Activities. Questions in this category are closely related to those on instructional practices, but since laboratory activities are an integral component of science instruction, they are discussed separately here and in more detail. NAEP consultants advised collecting information about the amount of time spent in the laboratory and about experience using laboratory equipment, from mirrors and magnets to wave tanks and electrophoresis equipment. Not all students have been asked to use all types of science equipment and apparatus in their classrooms; however, by including a variety of questions, the assessment can provide an estimate of students' equipment use in general, as well as the extent to which they come into contact with relatively sophisticated apparatus. Questions on laboratory safety also are included in this category.

Attitudes Toward Science Learning. Positive attitudes toward subject area learning are thought by most educators to be an important outcome of schooling.[15] Because students' attitudes toward science learning and their intentions to pursue additional science studies are likely to have an impact on tomorrow's labor force and citizenry, it is useful to gauge students' understanding of the value

[15] Richard Murnane and Senta Raizen, *Improving Indicators of Science and Mathematics Education in Grades K-12* (Washington, DC: National Academy Press, 1988).

of the discipline and their future commitment to science studies. Accordingly, the 1990 science assessment will collect information on students' attitudes toward science learning. This information also may be compared with science achievement as measured in the assessment.

Science Experiences. Questions in this category are designed to collect information on students' exposure to or involvement in informal science learning activities in or out of school, such as taking care of plants and animals, studying the weather, and experimenting with moving objects such as pulleys or pendulums. These data may then be compared with information on students' science proficiency and on their formal science education.



Participants in the development process

The National Assessment appreciates the efforts of all individuals who contributed to the development of the 1990 science assessment and who reviewed successive drafts of the objectives. NAEP could not have developed the objectives and the assessment without the substantial involvement of these people.

Special thanks are due to members of the Assessment Development Panel and the Item Development Panel who developed the framework and specifications for the assessment, were responsive to the series of reviews, and spent long hours evaluating and revising questions.

The National Assessment extends its deep appreciation to all participants.

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Appendix

Sample Items

The following sample questions represent various cells of the framework presented in Chapter 2, providing examples of classifications and item formats to be included in the assessment. These questions are for illustrative purposes only, and do not constitute a complete or balanced assessment.

NATURE OF SCIENCE

Thinking Skill:
Knowing Science

Grade Levels: 4, 8, 12

	Always True	Sometimes True	Never True
Scientists should report exactly what they observe	*		
Belief is the main basis for scientific knowledge			*
Knowledge is the goal of scientific work	*		
Scientific knowledge can be questioned and changed	*		
Knowledge discovered in the past is used in current scientific work	*		
Scientists who do experiments find answers to their questions		*	

*Correct answers for multiple choice items are indicated by an asterisk (*)

Grade Level: 4

Which of the following questions would be easiest to answer with an experiment?

(A) What makes a metal magnetic?
*(B) Which is the stronger of two magnets?
(C) What makes a magnet attract paper clips and not paper?
(D) What are the steps involved in making a magnet?

The methods of science can be used to answer all of the following questions EXCEPT

*(A) Are puppies more beautiful than spiders?
(B) How many oak trees grow in Pennsylvania?
(C) Which laundry detergent cleans best?
(D) What are the effects of lead pollution on trout?

Grade Levels: 8, 12

Which of the following hypotheses would be the easiest to test for validity in a given school?

(A) Science courses are more difficult than other courses
*(B) On the average, students grades in science are lower than their grades in other courses
(C) Science courses require more homework time than other courses
(D) Science courses are more interesting than other courses
(E) To a greater extent than in other courses, science grades are more dependent on ability than effort

	Always True	Sometimes True	Never True
There may be different methods of solving a single scientific problem	*		
Different scientists may give different explanations about the same observations		*	
Scientists can criticize each other s work .	*		

*Correct answers for multiple choice items are indicated by an asterisk (*)

Grade Level: 12

	Always True	Sometimes True	Never True
A scientist can state his or her findings as conclusive			*
Acquiring and ordering data are fundamental to the construction of scientific theories	*		
Scientists change their ideas when new information becomes known		*	
Statements concerning laws in science are subject to change	*		
Experiments require controls	*		

For more than 40 years biologists have thought that the gene for sex determination in humans is on the Y chromosome. In 1987, a biologist reported results from experiments showing that the sex determining gene may also be on the X chromosome. Which of the following would be the scientific community's most reasonable response to this report?

(A) Reject the report because it conflicts with the accepted model
(B) Accept the report because the experiments were published in a well-respected scientific journal
*(C) Suspend final judgement until others have had a chance to repeat the experiments
(D) Find out how long the biologist who wrote the article has been working in this field
(E) See whether the media covers the story

*Correct answers for multiple choice items are indicated by an asterisk (*)

LIFE SCIENCES

Thinking Skill:
Knowing Science

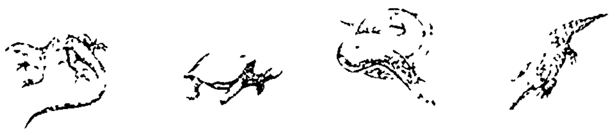
Grade Level: 4

Which of the sets of animals pictured below would biologists put together in the same class or group?

(A) 

(B) 

(C) 

*(D) 

Which of the following is a main difference between green plants and animals?

(A) Only animals are alive

(B) Only animals need air to stay alive

(C) Only plants need water and vitamins to stay healthy

*(D) Only plants produce their own food using energy from sunlight

*Correct answers for multiple choice items are indicated by an asterisk (*)

Grade Level: 8

All of the following changes are caused by changes in the environment EXCEPT

(A) birds migrating in the fall
(B) grasslands dying in a drought
(C) a fish dying in a pond that becomes acidic
*(D) a root growing downward in response to gravity

Which of the groups of animals listed below would a biologist classify as most closely related?

*(A) fly, moth, bee, beetle
(B) clam, starfish, snail, crab
(C) turtle, snake, spider, monkey
(D) bat, robin, flying squirrel, butterfly

In the environment, some ecosystems change over time in a process called succession. Which of the following changes is an example of succession?

(A) Embryo to fetus to baby
*(B) Pond to meadow to woodland
(C) Seed to pine tree to pine cone
(D) Egg to caterpillar to butterfly

Grade Level: 12

Which of the following is true of bacteria?

(A) They have mitochondria
(B) They usually reproduce sexually
(C) They are only present in diseased plants
*(D) They may assist in the breakdown of substances
(E) They are responsible for AIDS and smallpox

A man will pass his X chromosome to

(A) all his children
*(B) all his daughters
(C) all his sons
(D) half his sons only
(E) half his daughters only

*Correct answers for multiple choice items are indicated by an asterisk (*)

Scientists can determine how closely different species of animals are related to one another by measuring how similar they are in which of the following respects?

(A) Size
(B) Distribution
*(C) Genetic material
(D) Migratory patterns
(E) Responses to stimuli

The viceroy butterfly is an example of mimicry because

(A) it feeds on the nectar of flowers
(B) its reproduction involves complete metamorphosis
(C) it migrates in winter to favorable environmental conditions
(D) its physical structures are characteristic of other insects
*(E) its markings are similar to the distasteful monarch butterfly

Which of the following is an example of succession in an ecosystem?

(A) A deer attracts ticks which then suck the deer's blood.
*(B) Trees replace the shrubs that had earlier replaced the grasses
(C) Disease kills off snowshoe hares then the wolf population falls
(D) Woodpeckers make nests, then bluebirds use the abandoned nest holes

*Correct answers for multiple choice items are indicated by an asterisk (*)

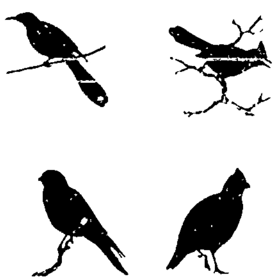
Thinking Skill:
Solving Problems

Grade Level. 4

Use the diagrams below to answer the next two questions

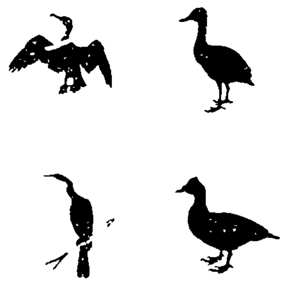
All of these are birds that usually live on land

Group A



All of these are birds that usually live near water

Group B



In which group (A or B) would you place the bird shown below? (B)

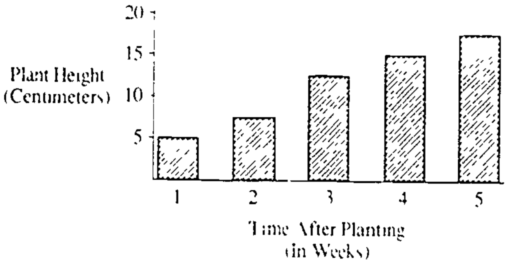
Why did you place the bird in that group? ____________________

____

____

____

*Correct answers for multiple choice items are indicated by an asterisk (*)



A fourth-grade class planted flower seeds on a Friday. Every Friday the class measured the plants and recorded how tall the plants were on the graph shown above. Between which two measurements did the plants grow the most?

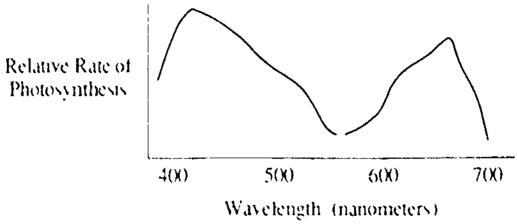
(A) Weeks 1 and 2
*(B) Weeks 2 and 3
(C) Weeks 3 and 4
(D) Weeks 4 and 5

Grade Level: 8

Matthew had a cold. After four days of eating fresh fruit, his cold was gone. Matthew decided that the fruit had cured him. Is his conclusion justified?

(A) No, because he was the only person to observe this fact
*(B) No, because other variables were not controlled
(C) Yes, because it is based on an observed fact
(D) Yes, because there is no way to disprove it

*Correct answers for multiple choice items are indicated by an asterisk (*)

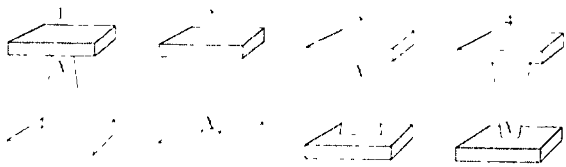


Plants get energy for photosynthesis by absorbing light. As shown above, plants photosynthesize at different rates depending upon the wavelength (color) of light they are given. If you were to grow plants under lights of different wavelengths, which of the following wavelengths of light would probably give the best growth?

*(A) 450 nm
(B) 500 nm
(C) 550 nm
(D) 700 nm

*Correct answers for multiple choice items are indicated by an asterisk (*)

The following three questions are based on the following experiment and diagram



Average Units of Auxin recovered from unshaded blocks after 5 hours: 10 0 0 10

Sections of stem, 4 centimeters in length, were cut from just below the growing tips of a number of plants. As indicated in the diagram, small blocks of agar containing equal amounts of auxin (shaded in the diagram) were placed on one end of each stem section. Agar blocks without auxin (unshaded in the diagram) were placed at the other end of each stem section. One half of the stem sections were placed in an upright position, the other half were upside down. The tip end of the stem is indicated by an X. After 5 hours in the dark, an analysis was made to determine the amount of auxin in the blocks which had originally contained no auxin (unshaded). The average amount of auxin obtained from these blocks after 5 hours is shown below each figure.

Which of the following was a variable factor in the design of the experiment?

(A) Amount of light available
(B) Amount of auxin added to the shaded agar blocks
(C) Amount of auxin recovered from the clear agar blocks
*(D) Position of the agar block with respect to the growing tip

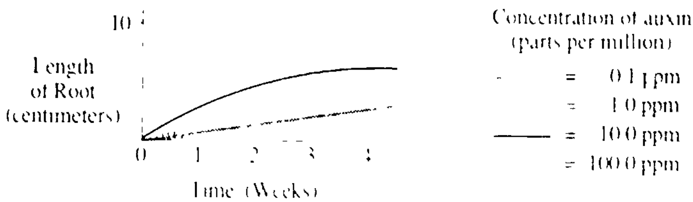
If diffusion were the primary factor in the movement of auxins in the stem, then auxin introduced into the middle of a plant stem should move from the middle toward

(A) the tip only
(B) the root only
*(C) both the tip and the root
(D) neither the tip nor the root

*Correct answers for multiple choice items are indicated by an asterisk (*)

Auxin causes cell elongation If the hypothesis that the movement of auxin from the tip down the stem is due only to gravity were true then a plant grown upside down should show

*(A) no elongation of any cells in the stem
(B) elongation of cells nearest to the root end
(C) elongation of cells just above the growing tip
(D) elongation of the cells in all parts of the stem



The plant hormone, auxin, was applied to cuttings of a rosebush in order to stimulate roots to grow Extrapolating from the data on the graph, at 6 weeks the longest root system will most likely occur at which concentration of auxin?

(A) 0 1 ppm
*(B) 1.0 ppm
(C) 10 0 ppm
(D) 100 0 ppm

*Correct answers for multiple choice items are indicated by an asterisk (*)

Thinking Skill:
Conducting Inquiries

Grade Level: 4

A scientist discovers a new type of fish and wants to learn more about it while it is alive. How should the scientist do this?

(A) Go to the library and read about fish
(B) Watch television programs about fish
*(C) Observe the fish
(D) Dissect the fish

Which of the following questions would be the easiest to answer with experiments?

(A) How fast can animals run?
(B) What makes an animal run fast?
*(C) Which is fastest, a lizard or a snake?
(D) What is the fastest animal in the world?

Grade Level: 8

A girl wanted to find out whether ants prefer to be in light or darkness. Which of the following should she do?

(A) Place one group of ants in the light, wait awhile, then place them in the dark
(B) Take two groups of ants, place them in the dark for a while, then place them in the light
(C) Place one group of ants in the dark and another group in the light
*(D) Place one group of ants in a location with both light and dark areas, and let them choose between the two areas

*Correct answers for multiple choice items are indicated by an asterisk (*)

Megan wanted to study the effect of exercise on her friend's heart rate. To conduct this study, she could combine the procedures listed below in a number of ways. Which of the four-step plans listed below would be the best approach?

I Have friend sit for 5 minutes
II Measure pulse rate of friend
III Have friend run in place for 2 minutes

*(A) I, II, III, and II
(B) II, III, I, and III
(C) II, III, I, and II
(D) III, II, I, and II

Grade Level: 12

Which of these questions would be the easiest to answer with experimentation?

(A) What are the effects of hormones on living organisms?
(B) What are the effects of adrenalin on toads?
*(C) Does the injection of adrenalin into the muscles of an adult toad cause a temperature change in the animal?
(D) Does the injection of adrenalin have an effect on the muscles of living organisms?

Which one of the following hypotheses concerning leukemia would be the simplest to test scientifically?

(A) Leukemia in human beings is caused by radiation
(B) Leukemia is the same in all mammals
*(C) Gamma radiation can cause leukemia in white mice
(D) Leukemia in humans is caused by feline leukemia

*Correct answers for multiple choice items are indicated by an asterisk (*)

Which of the following would be the best procedure to determine the minimum concentration of sucrose that a fly will eat after it has been denied food for two days?

(A) Start feeding a fly on 1 molar sucrose, then transfer it to lower concentrations of sucrose and observe its behavior
(B) Start feeding a fly distilled water, then transfer it to solutions of increasing concentrations of sucrose and observe its behavior
*(C) Surround a fly with many sucrose solutions of different concentrations and observe its behavior
(D) Dilute the sucrose while a fly is feeding and notice the concentration at which it stops feeding.

PHYSICAL SCIENCES

Thinking Skill:
Knowing Science

Grade Level: 4

Which of the following is closest to your height?

(A) 10 inches
(B) 5 centimeters
*(C) 1 meter
(D) 1 kilometer

A battery produces electrical energy primarily due to

*(A) chemical changes
(B) energy from the sun
(C) changes in temperature
(D) wires connected in a circuit

The average room temperature in most buildings is closest to which of the following?

(A) 0 Celsius
*(B) 20 Celsius
(C) 50 Celsius
(D) 70 Celsius

*Correct answers for multiple choice items are indicated by an asterisk (*)

Grade Level: 8

An object that is accelerating has which of the following characteristics?

(A) Volume that is expanding
*(B) Velocity that is changing
(C) Direction of motion that is changing
(D) Temperature that is decreasing

Which of the following is sure to occur to light striking the surface of a transparent object at an angle other than 90°?

*(A) The path of the light is bent
(B) Most of the light is absorbed.
(C) The light is reflected 180°.
(D) The frequency of the light changes

Which of the following is a correct statement about evaporation and boiling of water?

(A) Evaporation occurs at temperatures higher than 100° Celsius but boiling can occur at all temperatures
*(B) At a certain pressure, evaporation can occur at many different temperatures, but at a constant pressure, boiling usually occurs at a definite temperature
(C) Boiling can only take place in a closed container but evaporation can only take place in open containers
(D) Evaporation can only occur from a boiling liquid

Grade Level: 12

Which of the following atomic properties increases as one proceeds down a family of the periodic table?

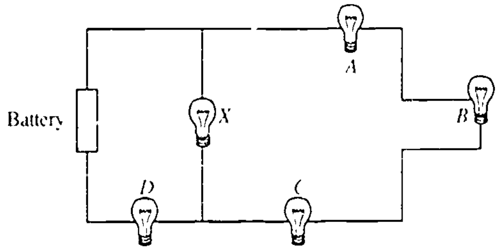
I Atomic radii of the atom
II. Electronegativity of the atom
III Nonmetallic character of the atom

*(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I, II and III

*Correct answers for multiple choice items are indicated by an asterisk (*)

Thinking Skill:
Solving Problems

Grade Level. 4



(*A*, *B*, *C*, *D*, and *X* represent light bulbs.)

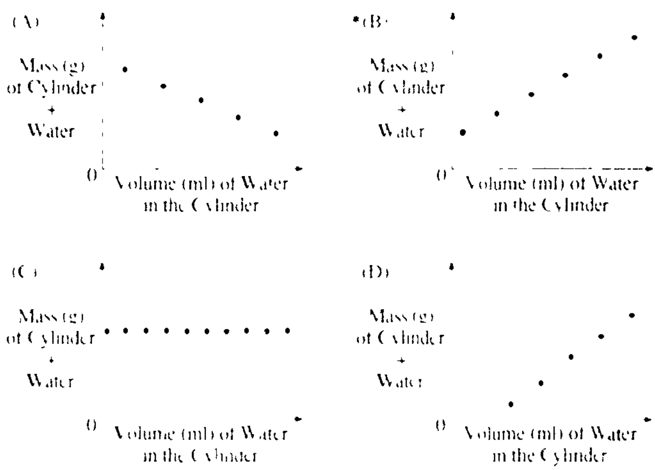
In the circuit shown above, light bulb X will go out when which of the following light bulbs is removed from its socket?

(A) A
(B) B
(C) C
*(D) D

*Correct answers for multiple choice items are indicated by an asterisk (*)

Grade Level. 8

In an experiment, a student fills a graduated cylinder with various levels of water. For each level the total mass of the water and the cylinder is measured. The student then plots a graph of the total mass in grams of the cylinder and water versus the volume of the water in milliliters. Assuming the measurements and graph are correct, which graph shows the results of the experiment?



Grade Level. 12

Assume that you find yourself in a strange imaginary world where the maximum number of atomic sublevel orbitals in an energy level (i.e., for any principal quantum number) is as follows: one s, two p, and three d. All other atomic properties are the same as the atoms in our world. In this strange world, what is the formula for a binary compound formed by combining element A (with 9 electrons) and element B (with 12 electrons)?

(A) AB
*(B) A,B
(C) AB
(D) A B
(E) AB

*Correct answers for multiple choice items are indicated by an asterisk (*).

Thinking Skill:
Conducting Inquiries

Grade Level: 4

Paul is trying a new recipe for making cookies and wonders what vanilla would add to the flavor of the cookies. What would be the best way for Paul to test this?

*(A) Make some cookies with vanilla and some without, then taste both kinds
(B) Leave out some of the sugar so he can taste the vanilla better
(C) Leave out the vanilla and then taste the cookies
(D) Have a friend taste a cookie

Grade Level: 8

As a candle burns, it loses weight. If you wanted to find out more about this weight loss, which of the following questions would you ask?

(A) How big is the candle?
(B) How large and how hot is the flame?
(C) How long will a candle burn without oxygen?
*(D) How much does the candle weigh before and after it has been burning for 2 minutes?

A student brings his dog Winchester to science class so that the class can conduct an experiment to see which of four dog foods Winchester prefers to eat. What would be the best way to do this experiment?

*Correct answers for multiple choice items are indicated by an asterisk (*)

Grade Level: 12

An astronaut experiencing "weightlessness" is handed two identical looking boxes. One of the boxes is hollow and the other is completely filled with a solid block of lead. How can the astronaut determine which is which?

(A) Hold the boxes at arm's length, one in each hand
(B) Use a standard equal arm laboratory balance
*(C) Try to shake each box
(D) Drop the boxes

EARTH AND SPACE SCIENCES

Thinking Skill:
Knowing Science

Grade Level: 4

Which of the following is an example of condensation in the water cycle?

(A) Streams flowing into rivers
*(B) Clouds forming in the atmosphere
(C) Puddles disappearing on a hot day
(D) Drops of water falling through the air

Most of the erosion that occurs on Earth is caused by

(A) wind
*(B) water
(C) earthquakes
(D) ultraviolet light

A weather station reports that there will be a Northwest wind today. This means that the wind will blow toward the

(A) Northwest
*(B) Southeast
(C) Northeast
(D) Southwest

*Correct answers for multiple choice items are indicated by an asterisk (*).

What is the Sun?

(A) A black hole
(B) A comet
(C) A moon
(D) A planet
*(E) A star

Grade Level: 8

Gravitational attraction in the solar system helps the planets to do which of the following?

(A) Rotate on their axes
(B) Move in straight paths
*(C) Remain in orbit around the Sun
(D) Slowly increase the velocities of their orbits

The warm summer season in the northern hemisphere is caused mainly by

(A) Earth's nearness to the Sun
(B) solar flares that are more common between May and August
(C) changes in prevailing winds across the northern hemisphere
*(D) the angle at which sunlight strikes the northern hemisphere

Which of the following is generally lower at the top of a mountain than at the base?

(A) Latitude
(B) Wind speed
*(C) Temperature
(D) Light intensity

Which of the following have contributed to the presence of thousands of craters on the surface of the Moon?

I. Meteorite impacts
II. Volcanic eruptions
III. The lack of atmosphere

(A) I only
(B) II only
(C) I and III only
(D) II and III only
*(E) I, II, and III

*Correct answers for multiple choice items are indicated by an asterisk (*)

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Which of the following is the most valid information to support the idea that the Earth revolves around the Sun?

(A) A solar eclipse
(B) The cyclic appearance of comets
*(C) Parallax of the background stars
(D) Day and night occurring on Earth

Which of the following is the most precise way of dating Earth material?

(A) Average rate at which the oceans increase in salinity
(B) Average sedimentation rate of materials deposited in water
(C) Average sedimentation rate of materials deposited by wind
*(D) Average age of certain earth materials based on radioactive decay

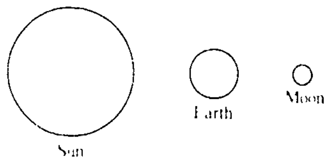
*Correct answers for multiple choice items are indicated by an asterisk (*)

Thinking Skill:
Solving Problems

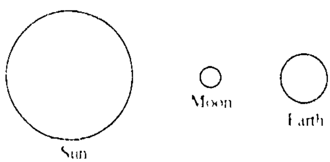
Grade Level: 4

The many full moons that occur during a year are caused by the Sun shining on the Moon. Which of the following shows the correct positions of the Sun, Earth, and Moon when we see a full moon?

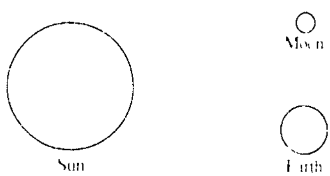
*(A)



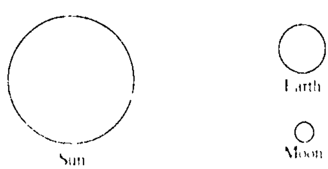
(B)



(C)



(D)



*Correct answers for multiple choice items are indicated by an asterisk (*)

Grade Levels, 4 and 8

The hardness of a mineral can be determined by comparing the sample to a standard hardness scale. A softer mineral cannot scratch a harder mineral. Use the hardness scale below to answer the following question.

Mineral Hardness Scale

Least hard							**Most hard**
1	2	3	4	5	6	7	8
Talc	Gypsum	Calcite	Fluorite	Quartz	Topaz	Corundum	Diamond

Quartz will not scratch which of the following materials?

(A) Gypsum
(B) Calcite
(C) Talc
*(D) Corundum

Grade Level, 8

It is thought that the salinity of the Earth's oceans has increased throughout geologic time. Which of the factors below could affect ocean salinity?

I. The solubility of rocks
II. The formation or melting of glaciers
III. The burning of meteors as they enter the Earth's atmosphere

(A) I only
(B) II only
(C) III only
*(D) I and II only
(E) II and III only

*Correct answers for multiple choice items are indicated by an asterisk (*).

Many kinds of evidence have been collected to support the idea of plate tectonics. What is the proper order (from most compelling to least compelling) of the following types of information in support of plate tectonics?

I Shape of the continents
II Fossil matches across continents
III Magnetic strips on the ocean floor

(A) I, II, and III
(B) II, III, and I
(C) III, I, and II
*(D) III, II, and I

Adiabatic cooling results when a mass of air expands. Which of the following is a correct statement about the tendency for rain to occur most frequently on the windward side of mountains?

(A) It has no relationship to adiabatic cooling
*(B) It is an example of adiabatic cooling
(C) It is a cause of adiabatic cooling
(D) It is a theory of adiabatic cooling

Many scientists have reported that atmospheric concentrations of CO_2 have been steadily increasing over the past 100 years and this increase is causing a global increase in the average temperature on Earth. What measurements or experiments would you do to prove or disprove their hypothesis?

*Correct answers for multiple choice items are indicated by an asterisk (*)

Thinking Skill:

Conducting Inquiries

Grade Level, 4

You live in a town near the Virginia coast and have a friend who lives in a town in the center of Tennessee. This friend tells you that it's colder in his area in the middle of winter than it is in your area because land cools faster than water. How would you design an experiment to test your friend's statement?

Grade Level, 8

Planet X is a planet similar in size to Earth. Two 5 pound rock samples were collected from widely separated points on Planet X and when the samples were analyzed they turned out to be the same rock type. Based upon this information, which of the following is the most valid conclusion regarding the overall surface rock type on Planet X?

(A) The surface of Planet X has a uniform rock type.
(B) The surface of Planet X has different rock types.
(C) The surface of Planet X is primarily composed of granite and quartz.
*(D) The data are insufficient to draw a conclusion about overall surface rock type.

All of the following processes have provided much information about the deep interior of the Earth EXCEPT

*(A) oil well drilling
(B) analyzing meteorites that fall to Earth
(C) seismic waves traveling through Earth
(D) magnetic field changes on Earth

*Correct answers for multiple choice items are indicated by an asterisk (*).

Grade Levels: 8, 12

Janet wants to investigate whether the height of adult males in this country has increased during the 20th century. Of the following, which would be the best source of information?

*(A) Enlistment statistics for the Armed Forces from World War I through the Vietnam War
(B) The recorded heights of Janet's father at various ages from his birth to the present
(C) A book that examines dietary changes in the United States during the past century
(D) Janet's parent recollections about the heights of their fathers and grandfathers
(E) The dates that the first king and queen size mattresses were manufactured in this country

Grade Level: 12

Which of the following procedures would best demonstrate dew point?

(A) Measuring the rate at which a given amount of water evaporates from a dish
(B) Measuring the amount of heat required to melt 1 gram of ice
*(C) Decreasing the water temperature inside a glass until water droplets condense on the outside
(D) Using a sling psychrometer to determine the relative humidity of the air
(E) Noting the outside temperature at which condensation forms on a glass

*Correct answers for multiple choice items are indicated by an asterisk (*)