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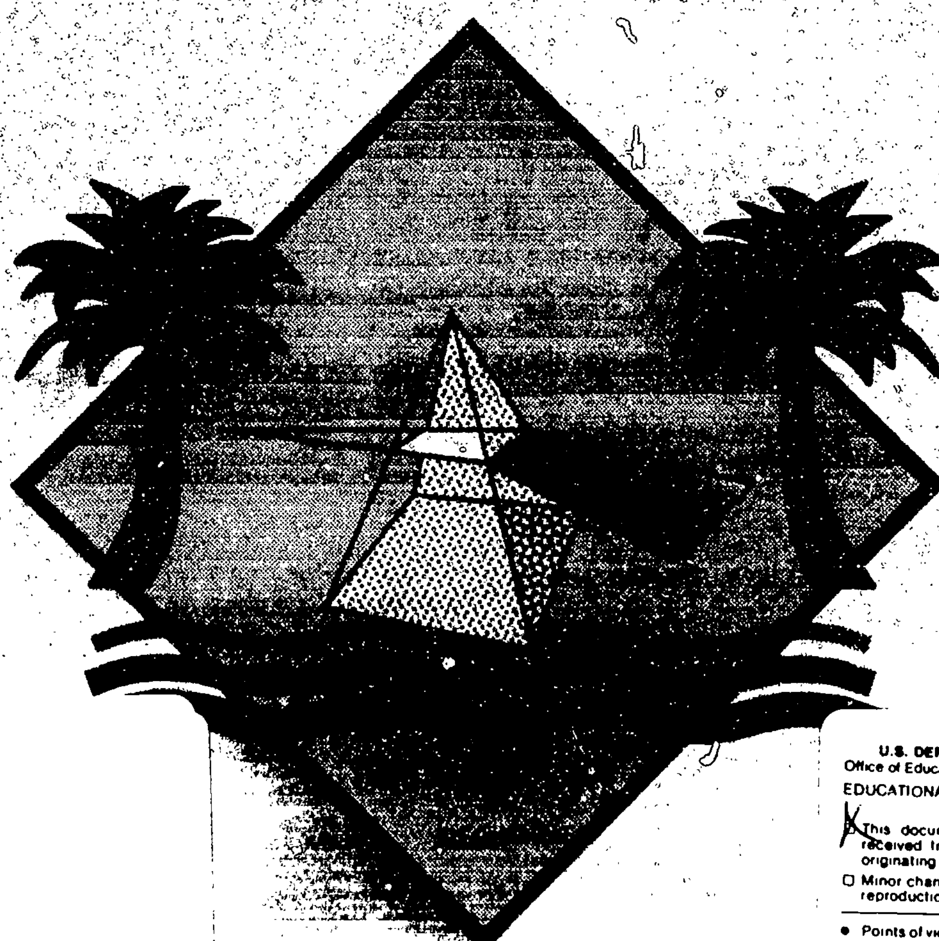
ABSTRACT

The Pacific Mathematics and Science Regional Consortium has developed standards for excellence in mathematics and science education appropriate to the Pacific regions. These standards are presented in three volumes, and the series is firmly based upon the research findings of scientists, teachers, curriculum developers, and others. This volume contains the Pacific Standards for Excellence in Science. Discussion includes the importance of science education; challenging the way science is taught and learned; new visions for science education; decisions about these standards; and how standards, frameworks, and curriculum guides are related. Underlying assumptions for the standards include the nature of science and technology, the nature of learning, the nature of science teaching, and the nature of assessment in science. The science standards are: Science as Inquiry; Habits of Mind; Scientific Connections; The Nature of Technology; Technology and Society; Matter; Energy; Motion and Forces; Planet Earth; The Universe; The Living Environment; The Human Organism; and Human Society. Appendices include a glossary of science terms and a directory for further information on the Pacific Standards for Excellence in Science. (MKR)

Pacific Standards for Excellence in Science

Developed by the

Pacific Science Leadership Team



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VISION

ALL PACIFIC CHILDREN WILL BE SCIENTIFICALLY AND MATHEMATICALLY LITERATE:

KNOWLEDGEABLE,

CAPABLE,

AND

CARING.

VISION IN ACTION

It's time for high school graduation in the year 2005. Throughout the Pacific, families have come together to celebrate a major milestone in the lives of their children. Leaders have gathered to honor the young people whose hard-earned knowledge and skills are the hope of the future for their islands. The leaders are also here to acknowledge the support the families have provided their children. Teachers are here, too, sharing the dreams of the young people whose lives they have touched. They have done their job well. Those graduating today are scientifically literate—knowledgeable, capable, and caring. The focus of so many hopes and dreams, these young men and women of each island are together nervously waiting to hear their names called, to receive recognition of their achievement, and to move forward into the future with confidence.

Looking at these young people, we see real progress toward the visions and dreams that we share for them. At an outer island high school, there are Ygnasia and Jason. Their creativity can always be counted on and their dreams for the future include further study. Jason has been studying changes in the marine environment of the island. Observations that he and other students have collected over the past two years are now part of an international database being studied by scientists who are tracking global changes and their implications. Ygnasia has studied the complex relationship between culture and science. She has documented the scientific principles embedded in food preparation practices and has recorded descriptions of how certain plants contribute to health. She and Jason are proud of their culture; they honor its values and respect the scientific wisdom of practices that have developed after generations of careful observation. Their classmates look to them for suggestions and ideas.

At another school, John is reflecting on how much he has changed the way he views science. He used to hold back in science class, waiting for other students to contribute to discussions and offer observations, always afraid that he would be called on and not be able to give the right answer to his teacher's questions. In the last few years, his teachers have encouraged him to follow his interests and to investigate questions that affect the life of his community. He has become a model of what it means to view science as inquiry. His work indicates a respect for the use of evidence and builds on logical reasoning, honesty, curiosity, openness and skepticism.

Throughout our region, young people like Ygnasia, Jason, and John are ready to leave high school. They have been empowered with intellectual tools that will assist and guide them for the rest of their lives. They are examples of the reality of scientific literacy. They have deep knowledge of science, are skillful thinkers and doers, and their deep caring for the people and environment that make up their world are examples to the young ones coming up behind them. They do not distinguish between culture and science, but know, honor, and value the wisdom of science found within and across Pacific cultures. They are scientific thinkers; using scientific habits of mind to study the world around them and their relationship to it. They have a positive attitude toward science and are able to think critically, measure accurately, deal with quantitative and qualitative data, and are empathetic and open to other points of view.

The graduates of 2005 are caring and responsible to themselves, their communities, and their environment. They seek connections between science and other aspects of their lives and are aware of some of the important ways science, mathematics, and technology depend on one another. They see the importance of communication to science and work hard to share their learning with others. They are able to organize scientific information in many ways.

Their actions too, reflect scientific literacy. The young graduates of 2005 act upon their knowledge of the living environment, human society, the universe, energy, and much more that make up our interdependent world. As they look ahead, they are eager to continue growing and learning. They have confidence in their abilities, but are also aware that being scientifically literate includes constantly checking their knowledge and assumptions against new information. They are ready to work at home, in their family, or abroad—putting into use the knowledge, capabilities, and values that are now a part of their being.

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PREFACE

The Pacific Mathematics and Science Regional Consortium was formed in 1992 with funding from the U.S. Department of Education's Dwight D. Eisenhower National Program for Mathematics and Science Education. Headquartered at the Pacific Region Educational Laboratory (PREL) in Honolulu, the consortium brings together PREL, the University of Hawaii's Curriculum Research & Development Group, the Moanalua Gardens Foundation, and the Departments of Education of the region's ten entities: American Samoa; the Commonwealth of the Northern Mariana Islands; the Federated States of Micronesia (Chuuk, Kosrae, Pohnpei, and Yap); Guam; Hawaii; the Republic of the Marshall Islands; and the Republic of Palau.

One of the consortium's first tasks was to develop standards for excellence in mathematics and science education appropriate to the Pacific region. The Pacific Mathematics and Science Leadership Team undertook this task. Their work is presented in the three-part series, Pacific Standards for Excellence.

The Pacific Standards for Excellence Series

The first two volumes of the series—*Pacific Standards for Excellence in Mathematics* and the present volume, *Pacific Standards for Excellence in Science*—identify what all students should know, be able to do, and care about as a result of their education in these two domains. The third volume, *Pacific Standards for Excellence in Teaching, Assessment and Professional Development* describes key ingredients for creating learning environments that support students as they strive for mathematical and scientific literacy.

The series is firmly based upon the research findings of scientists, teachers, curriculum developers, and others working to reform mathematics and science education. The standards for excellence proposed in these volumes set ambitious goals for mathematics and science education in the Pacific islands, while acknowledging the region as a variety of environments, cultures, and experiences. It is a "living" work designed to be refined and expanded upon as it is implemented.

Pacific Standards for Excellence in Science

Pacific Standards for Excellence in Science constructs a broad framework to guide reform of science education during the next decade. A "standard" is a recognized level of excellence; it can be used to judge quality; it describes what should be attained. The standards of excellence presented here define what all students should know, be able to do, and care about if they are to be scientifically literate.

The general principles that inform this document are listed below. They articulate a vision of the priorities and emphases that should be contained in the science curriculum and establish the parameters of excellence for science education in the Pacific.

1. Science should be presented as open inquiry engaging both teacher and students in attempting to understand the natural and designed (technological) world around us, to examine how we know what we know, and to learn how we test and revise our thinking.

2. Science should be presented in a way that acknowledges the Pacific as a region of the world that encompasses a variety of island environments, unique cultures, and scientific and technological experiences. Each of these attributes must be recognized, valued, and built upon through the science curriculum.

3. Science should be presented as connected with technology. The implications of the interactions between science, technology, and society should be included in the curriculum.

4. Science education should be connected with the students' own experiences and interests. Hands-on activities that are sequenced to enable students to build their own knowledge play a major role in making these connections.

5. Students should be given opportunities to construct important ideas in science and technology which can then be further developed through inquiry and investigation.

6. Teaching strategies should allow for several ways to learn, so that all students are successful in doing science.

7. The major disciplines of science—physical science, biological science, and earth science—should be studied each year in an integrated curriculum.

8. Textbooks should not be considered the sole source of information. Ordinary materials and equipment found at school and at home should be used to engage students in experiencing science.

9. Assessment of student learning should be aligned with classroom activities in both content and format. Student performance and investigation play the same central role in assessment as they do in instruction. Assessment and instruction should be closely interrelated.

This document was developed for teachers, administrators, curriculum planners, and other educators. As a planning tool, it can guide staff development, improvement of facilities, and decisions about technology. As school staffs, districts and other groups question curricula and propose solutions to curricular problems, the standards will serve as criteria against which to judge their ideas. They can help inform parents, legislators, community leaders, and others concerned with education. We hope that the document may also be useful to others outside our region who are interested in and concerned about science education and the development of scientifically literate citizens.

ACKNOWLEDGMENTS

Pacific Standards for Excellence in Science builds upon the efforts of a number of outstanding groups to reform science education, including the National Research Council, the National Science Teachers Association, and the California Science Curriculum Framework and Criteria Committee. The work of the American Association for the Advancement of Science (AAAS) was especially important. Our work reflects many of the ideas found in Project 2061's *Science for All Americans. Benchmarks for Science Literacy* served as the basis of the Pacific standards (adaptations from the benchmarks are made with the permission of AAAS).

Pacific Standards is the product of work by the individuals representing each of the geographic entities in the region, the Curriculum Research and Development Group (CRDG) at the University of Hawaii, and the Pacific Mathematics and Science Regional Consortium at the Pacific Region Educational Laboratory.

The Pacific Mathematics and Science Regional Consortium Advisory Board played a critical role in this effort. We thank its members for providing guidance and support to members of the Leadership Team and consortium staff. We also thank following individuals for their significant contributions to the development of *Pacific Standards for Excellence in Science:*

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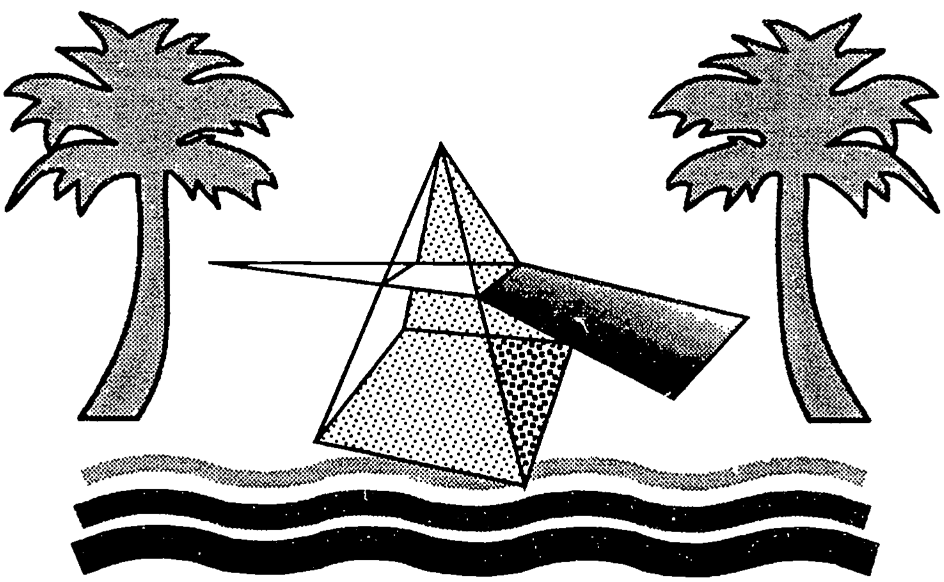
INTRODUCTION



WHY PACIFIC STANDARDS?

This document is the result of a collaborative effort by educators across the Pacific to articulate the goals that we share for science education in our region. Educators from American Samoa, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia (Chuuk, Kosrae, Pohnpei, and Yap), Guam, Hawaii, the Republic of the Marshall Islands, and the Republic of Palau agree that existing and emerging science education fails to address directly the diversity of island environments, cultures, values, resources, and needs of Pacific students.

Pacific Standards for Excellence in Science articulates the goals that we in the Pacific share for science education in our region.

We propose here a set of standards for excellence in science education in the Pacific that both corrects this failing and meets the rigorous standards of respected national professional associations: the American Association for the Advancement of Science, the National Research Council, the National Science Teachers Association, and the National Center for the Improvement of Science Education.

The standards are statements of what all students should know, be able to do, and care about as a result of their education. They are goals for students and teachers to strive for. Because our students are increasingly mobile within and outside the Pacific region, these standards are meant to ensure that all students in the region have an equal opportunity to become scientifically literate as they are becoming concerned and responsible citizens of their communities, the region, and the world.

These standards for excellence identify what all students should know, be able to do, and care about as a result of their education.

Pacific Standards for Excellence in Science defines the big ideas that we value in science. It can be used to provide direction to educators, students, parents, and others on what should be attained in science. It provides a set of criteria against which educational programs can be evaluated. It serves primarily to help Pacific educators prepare our students to become scientifically literate by the end of the twelfth grade. It can also be used to align curriculum frameworks, curriculum guides, staff development programs, and assessment strategies. We have tried to illustrate the importance of science and technology for literacy and for the development of the whole person, including career choices.

"Pacific Standards" will provide direction and express clear expectations to educators, students, parents, and others about what should be attained in science.

Throughout the document we have tried to illustrate the importance of science and technology for human development. The document can be used to generate awareness of the importance of scientific and technological literacy for the development of the whole person, including choices of careers. In addition, there is an emphasis on social issues, such as developing local and regional economies, providing a competent work force, maintaining a quality environment, using resources wisely, and improving the general welfare of human society. Specific examples in the document illustrate the importance of scientific knowledge in addressing the needs of our communities' economic and social development. By generating awareness of the importance and value of scientific and technological literacy, this document can be used to seek support for the improvement of science curriculum, instruction, equipment, supplies, facilities, and assessment.

WHY IS SCIENCE EDUCATION SO IMPORTANT?

Science enriches people's lives.

Science and technology are powerful forces that shape human life on earth. They have made our societies productive, and they continue to have enormous potential to make our lives better and richer and to keep our world safe and livable. Science education needs to help science and technology fulfill their potential by ensuring that they are used effectively, creatively, and wisely.

Science education is important because the study of science enriches people's lives. It opens the human mind to a new appreciation of the beauty and precision that surround us. An understanding of science enables people to take greater control of their lives and to face problems with courage and understanding. It liberates them to imagine new questions and to set about finding new answers.

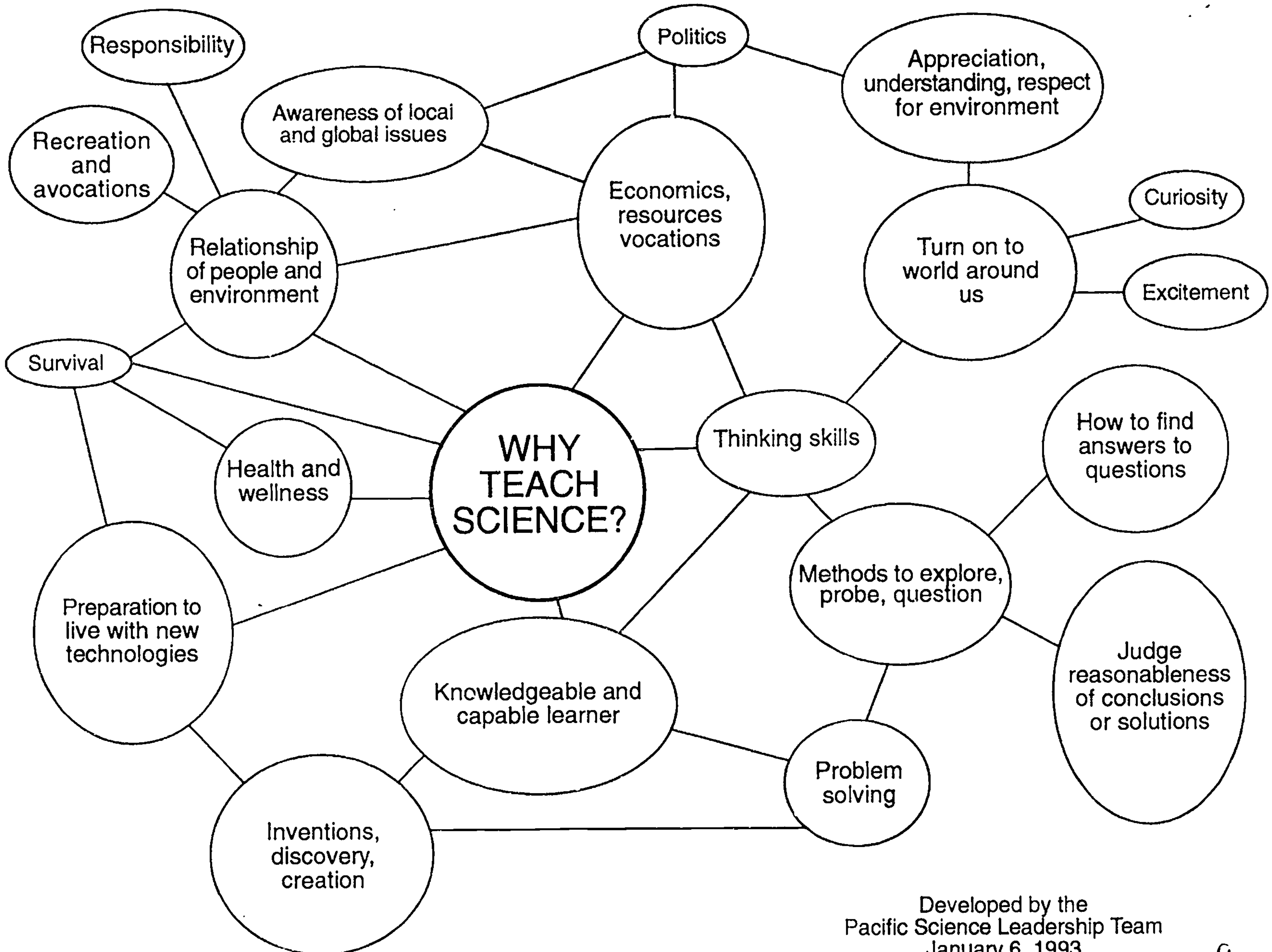
People need to be scientifically literate to function as responsible citizens.

In the face of rapid scientific and technological development across the Pacific and throughout the world, all citizens need to be scientifically literate in order to function effectively and to help create and sustain a decent, just, and vigorous society. A scientifically literate person is one who understands the key concepts and principles of science and uses scientific knowledge and ways of thinking in everyday life. Citizens today face a range of hard choices, from the personal (such as how to avoid AIDS) to the global (such as what to do about the greenhouse effect). People who understand science are better prepared to sort fact from fiction, make sensible decisions, and urge their leaders toward informed public policy choices.

People who understand science are better prepared to urge their leaders toward informed public policy choices.

A scientifically literate population is economically important.

Science education is also economically important. The Pacific region will need people who are well-grounded in science in a range of fields that are related to science, health, and technology. At the same time there will be an increasing demand for scientifically literate workers who have a basic grasp of science and technology and the ability to solve problems and think creatively in all sectors of the region's economy. Quality science education can equip students to become world-class adults in a scientific and technological society.



Developed by the
Pacific Science Leadership Team
January 6, 1993

WHY DO WE NEED TO CHANGE THE WAY SCIENCE IS TAUGHT AND LEARNED?

Science is more than a body of knowledge. It is a way of looking at the world and ordering one's experiences in it. The study of science presents an occasion to open young minds to new ideas and to equip them with the intellectual tools that will guide them as learners for the rest of their lives. Too often this is a missed opportunity!

Science is a way of looking at the world and of ordering one's experience in it.

Most schools today use a conventional approach to teaching science. This approach presents science as a fixed body of facts, principles, and definitions, ordered sequentially, and divided into disciplines such as biology, chemistry, and physics. Learning is dispensed by the teacher and the textbook, with students expected to master a range of topics by listening and reading. Instead of acquiring understanding, students learn isolated bits of information, such as the names of the parts of a plant, the location of the nucleus in a drawing of a cell, and the equation for calculating density.

The conventional way of teaching science does not work for most students.

This approach to teaching science does not work for most students. Scientists, researchers, educators, and business people agree on this point. Somewhere in the middle grades students tend to lose interest in science, and by high school many find science difficult, boring, and irrelevant. Few take advanced science courses. The result is that most adult citizens are not scientifically literate. For example, it is not uncommon to find adults who do not know that the earth revolves around the sun once a year or others who believe that humans lived at the time of the dinosaurs. Many observers now believe that, this illiteracy is due to an emphasis on covering too many topics superficially rather than in-depth learning, seatwork rather than hands-on activities, memorization rather than critical thinking; and recitation rather than well-reasoned argument.

The opportunity to learn is an important factor in the effort to achieve the goal of scientific literacy for all Pacific children.

Achieving the goal of scientific literacy means all Pacific children must be given the opportunity to learn. But many schools do not even consider science a core subject. In many elementary classrooms, science has nearly vanished from the curriculum. Often, science is not taught because teachers themselves do not feel comfortable with science and have not received the preparation and in-service training they need to become good science teachers.

Often, science does not receive the attention it needs because teachers themselves do not feel comfortable teaching it.

It is time for a comprehensive redesign of science education.

Widespread illiteracy in science has led scientists, educators, business leaders, and researchers to independently conclude that it is time for a comprehensive redesign of science education, so that it begins in the earliest grades and continues uninterrupted through grade 12. As a result, new visions for science education have been developed.

WHAT ARE THE NEW VISIONS FOR SCIENCE EDUCATION?

Science education is most effective when it captures the beliefs and "habits of mind," or methods of thinking, that guide scientists in their own explorations of the world. What are these beliefs and methods? Among them are the beliefs that the world is understandable; that ideas are not fixed but grow and change over time; that scientific knowledge is durable; and that science cannot explain all things. Science also values certain rational methods of inquiry. These include careful observation, thoughtful analysis, healthy skepticism, the blending of logic and imagination, and the development of sound and coherent predictions and explanations.

In keeping with these beliefs and methods, good science teaching encourages students to be curious, creative, open-minded, skeptical, willing to suspend initial judgments, able to collaborate with others, and be persistent in the face of failure. Research has validated several teaching strategies for developing these qualities and thinking processes. In the effective science classroom, the activity of finding out is as important as knowing the answer. For example, teachers might begin by posing questions about nature: What causes typhoons? Why do children look like their parents?

Good science teaching encourages students to be curious, creative, open-minded, skeptical, able to collaborate with others, and persistent in the face of failure.

To answer these questions, students tend to go about the tasks of observing, collecting evidence, describing, and sorting. The next round of activity might involve asking more questions, following hunches, developing hypotheses, debating, and defending conclusions to other students. By continually moving back and forth among questions, observations, and experiments, students refine and validate their hypotheses and, at the same time, develop good thinking skills.

Three major efforts are underway to abandon conventional approaches to teaching science and adopt approaches that incorporate the new knowledge about effective science education. One of these new approaches is *Project 2061* Science for All Americans, produced by the American Association for the Advancement of Science (AAAS) in 1989. *Project 2061* describes what all students should know and understand about science, and recommends teaching in ways designed to address all students' learning styles, abilities, and cultural backgrounds. In 1993, AAAS also defined benchmarks for what students should know and be able to do at specific grade levels.

Science should be taught in ways designed to address all students' learning styles, abilities, and cultural backgrounds.

Students should engage in direct experiences with the natural world before they attempt to learn terms, symbols, or equations.

Another major effort initiated in 1989 is the Science Scope, Sequence, and Coordination Project by the National Science Teachers Association (NSTA). This project recommends five specific actions for restructuring the secondary school science curriculum: (1) engage students in direct experience with the natural world before they attempt to learn terms, symbols, or equations; (2) reduce the quantity of science topics and terminology covered; (3) study science disciplines every year in a multi-disciplinary approach; (4) approach concepts, principles, and laws of science at successively higher levels of abstraction; and (5) begin science studies with practical applications of science at a personal level, introducing global applications in the upper grades. The NSTA also calls for more science study in elementary school and eliminating tracking of students. Science education is in the process of undergoing a major shift.

The National Research Council (NRC), a committee of the National Academy of Sciences, is currently developing standards for content, teaching, assessment. and professional development of teachers, programs, and school systems in science. This effort is funded by the U.S. government, which seeks to develop broad-based science standards acceptable to the states.

The striking similarities among these three independent efforts suggests a major shift in science education. The changes are summarized in Figure 2.

Figure 2: Shifts in Science Education

MOVING AWAY FROM	TOWARD
• Science for some	• Science for all
• Reading and language first	• Inquiry and activity-based instruction accessible to all
• Teacher as "imparter" of knowledge	• Teacher as facilitator of learning
• Content driven	• Constructivist approach that builds on prior knowledge
• Students as passive learners	• Students actively involved in building understanding
• Individual	• Collaborative/social
• Divorced from real world	• Science applied to students' lives
• Atomistic, disconnected study	• Holistic and connected, integrated and thematic
• Single exposure to concepts	• Spiral curriculum, sequential
• Memorization	• New modes of inquiry; thinking skills and scientific habits of mind
• Testing	• Multidimensional assessment

HOW WERE DECISIONS ABOUT STANDARDS MADE?

Pacific Standards for Excellence in Science ***identifies a key set of important ideas that provide the foundation for understanding and applying science.***

Pacific Standards for Excellence in Science identifies a key set of important ideas that provide the foundation for understanding and applying science. They are standards of excellence for all students and teachers to strive for, in order to achieve our vision of scientifically literate students who are knowledgeable, capable, and caring.

To be included, the content had to

- represent central scientific ideas and organizing principles,
- be ideas that could provide rich explanation and predictions,
- motivate students and teachers to construct significant questions,
- apply in many situations and contexts common to everyday experiences,
- be capable of being linked meaningfully to direct student observations of data or to evidence that is accessible to them.

The document describes developmental sequences indicating how the ideas of science can be developed over time.

Students' experiences in science should be organized to allow them to gradually build understandings that reflect the current state of scientific knowledge. We have, therefore, described developmental sequences indicating how the significant ideas of science can be developed over time from the earliest grades through secondary school. Guiding students in their development of an understanding of these ideas is the responsibility of educators at all grade levels.

All students should encounter thought-provoking, engaging experiences in science that focus on local resources and environments.

Although *Pacific Standards for Excellence in Science* describes understandings that all students should develop, teachers and school systems must stimulate every student to reach beyond these limited ideas. All students should encounter thought-provoking, engaging experiences in science that focus on local resources and environments, reflect personal and regional interests and expertise, and illustrate important uses and applications of science.

HOW ARE STANDARDS, FRAMEWORKS, AND CURRICULUM GUIDES RELATED?

Pacific Standards for Excellence in Science

A standard is a statement that can be used to judge quality. *Pacific Standards for Excellence in Science* describe regional goals for students and teachers to strive for. They identify what all students should know, be able to do, and care about as a result of their science education.

The standards are goals for students and teachers to strive for.

Your Curriculum Framework

Your curriculum framework is a blueprint of the elementary and secondary educational program of your entity. The curriculum includes not only the content, but also the structure, organization, balance, and presentation of the content in the classroom. A curriculum framework describes, organizes, and integrates subject matter and processes to define the learning that will enable students to achieve high-level standards of excellence in education. It also reflects and incorporates an entity's unique environment, culture, and values that contribute to achieving the standards. Curriculum frameworks, in their variety, demonstrate that there are multiple ways of organizing the curriculum to achieve common standards for education.

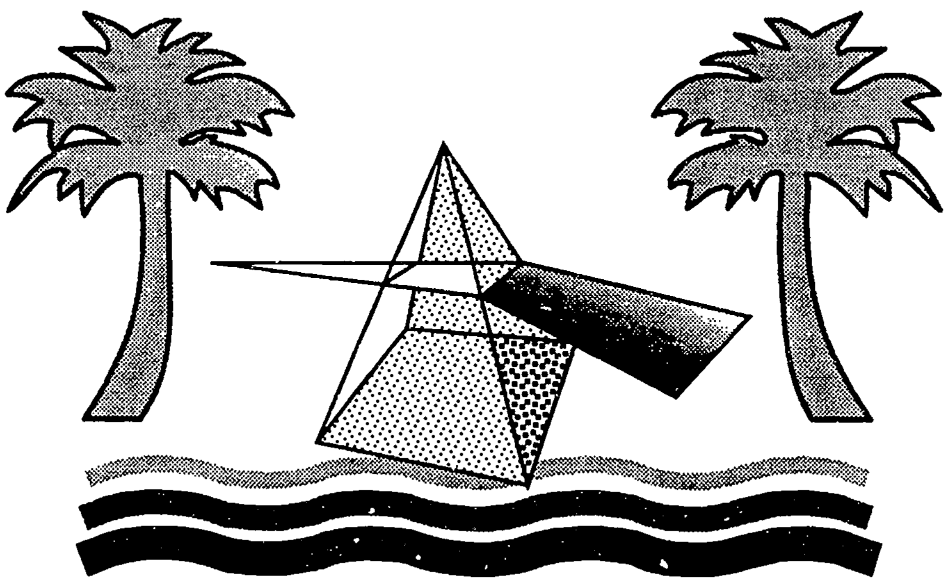
A curriculum framework describes, organizes, and integrates subject matter and processes to define more specifically the learning that will enable students to achieve standards.

Your Curriculum Guide

Your curriculum guide describes the content and organization of a particular subject area by specific grade levels. It is more specific than a curriculum framework, provides lesson plans appropriate to a specific grade level, and other information that a teacher might teach on a day-to-day basis. It aligns content and strategies within grade levels to the overall plan for elementary and secondary school described in the curriculum framework.

A curriculum guide describes the content and organization of a particular subject area by specific grade levels.

UNDERLYING ASSUMPTIONS



THE NATURE OF SCIENCE AND TECHNOLOGY

People have always produced technology. For thousands of years they have invented tools and techniques to improve their environment as they saw fit. This is the realm of technology. But the systematic search for explanations that we call science is only a few hundred years old. Both science and technology are expressions of human creativity. Progress in these fields results from the cumulative efforts of human beings with diverse interests, talents, and motives.

Science and technology are the result of the cumulative efforts of human beings with diverse interests, talents, and motives.

Science

Science is a human activity. It is one way of knowing, interpreting, and describing the world we live in. Science education should provide people with the necessary knowledge, attitudes, and skills to become rational human beings and to find meaning and contentment in their lives.

As educators, we have the responsibility to teach students what the character of science is and how it differs from other subject areas, such as mathematics, language arts, and social studies. Science shares many characteristics with these other fields of knowledge, but it also has its own unique characteristics. Like all fields of knowledge, science relies on open-ended investigation and an honest exchange of ideas. It strives to be objective. Science, however, more than any other field is guided by testable theory using established methods of investigation that any investigator can and must follow. That is why progress in science has been so rapid. Any investigator can test, verify, reject, or use new discoveries to take scientific knowledge a step further in explaining the world around us and how it works.

Science shares many characteristics with other fields of knowledge. However, more than any other field, it is guided by testable theory using established methods of investigation.

All the sciences presume that the things and events in the universe occur in consistent patterns that can be recognized as a result of thorough, careful, and systematic study. Although they all aim at producing verifiable knowledge, none claims to produce knowledge that is absolute and beyond change. Knowledge in science is always subject to change in light of new data and new interpretations of existing data. Therefore, science aims to be objective and testable.

All the sciences presume that events in the universe occur in consistent patterns that are comprehensible through careful and systematic study.

If an idea cannot be tested by experimenting and observing natural phenomena, it is outside the realm of science.

Science must be communicated accurately to others if it is to be of use.

Those who work in the field must be open-minded.

Technology is the application of knowledge to develop materials and systems that help people meet their needs and fulfill their desires.

We observe phenomena with our senses—seeing, hearing, tasting, smelling, touching. These observations are necessarily subjective, interpreted through our individual experiences and emotional points of view. Explanations of nature, however, must be objective, based on natural phenomena and observations, not on the opinions of the observer. One strategy that science has invented to control objectivity is replication. Any observation ought to be repeatable and capable of being confirmed or rejected by independent observers. This also implies another characteristic of science—it must be communicated accurately to others if it is to be of use.

Science observes and explains the natural world. A good explanation should suggest a critical experiment or observation that can determine its correctness, and it should enable the investigator to successfully predict the result of the experiment. If an idea cannot be tested by experimenting and observing natural phenomena, then it is outside the realm of science.

Science is open-ended. This means that all explanations in science are taken as tentative, not absolute. Facts and theories, no matter how firmly established in light of what is known, are never taken as proven. Science is sensible. Explanations are always subject to change in light of new observations. This self-correcting ability is the strength of science. The open-endedness of science also means that those who work in the field must be open-minded: open to reinterpretation of data, open to new observations, open to new explanations. As we learn more, we constantly revise what we know in light of new discoveries.

Science is also characterized by a set of attitudes and values, including honesty, curiosity, openness to new ideas, and skepticism in evaluating claims and arguments. Because all observations are based on human senses and expectations, results have to be reported fully. Negative results—those that do not agree with the stated hypothesis—must be reported along with data that support the hypothesis. In science, there are no "right" answers; only those that are supported by evidence.

Technology

Technology is the application of knowledge to develop materials and systems that help people meet their needs and fulfill their desires. Water catchment systems, canoes, fishing nets, spears, shelters, clothing, footwear, medicine, agriculture, ships, and schools are the products of technology. Technology includes the building of structures such as bridges, buildings, and highways; transportation including automobiles, ships, and airplanes; electrical devices such as generators, motors, and power lines;

changes in matter including metal working, petroleum refining, and manufacturing; power generation such as internal combustion engines, rockets, and nuclear reactors; agriculture; health services; and even education.

Humans use technology to meet personal needs.

Throughout history, humans have used technology to meet personal needs by creating clothing, shelters, food gathering and cooking devices, weapons for hunting and war, communication and transportation systems, and so on. It has also been used to create aesthetic and religious artifacts such as tombs, churches, paintings, and sculptures.

Today, technology affects the way we eat, breathe, work, play, move, communicate, dress, and think. It enables us to have more leisure time to relax and enjoy traveling or socializing with others. Technology has also led to new forms of art, photography, electronic music, telecommunications, and computers.

In the broadest sense, technology extends our abilities to change the world—to cut, shape, or put materials together; to move things from one place to another; to reach farther with our hands, voices, senses, and minds. In the past, new technologies were based on accumulated practical knowledge, but today they are more often based on an understanding of scientific principles that describe how things behave.

Where science seeks to explain, technology seeks to apply that understanding.

Science is based on observing, questioning, hypothesizing, designing, and carrying out experiments to test hypotheses, and derive explanations of how the world works. Its primary mission is to search for explanation. Technology employs many of the same processes; however, it seeks to utilize, modify, and manipulate the environment using the knowledge generated by the sciences. The primary mission of technology is to make things work. At times technology moves ahead of science. At other times the reverse is true. For example, humans used and controlled fire long before an explanation of combustion was developed in science. Conversely, knowledge of genetics now enables us to develop and grow new agricultural crops.

The understanding of technology, of how it operates to modify nature and create things, is crucial to educating citizens of the future.

The understanding of technology, of how it operates to modify nature and create things, is crucial to educating citizens of the future. They will live in an increasingly technological world. Employment, health, leisure, personal and political decisions will all be profoundly affected by technology. The study of technology must be part of the school curriculum.

Scientific Thinking

The content of science consists of a highly structured, complex set of facts, hypotheses, and theories. The processes of science refer to the thinking strategies that enable humans to discover the patterns of nature that we call scientific knowledge. Both are essential to science and both are essential to science education.

Scientific knowledge grows as scientists think about the natural world, act upon it in planned experiments, and develop thoughtful explanations that incorporate the results.

The skills and processes, are not only part of science, but are basic skills that all students must develop. They are described in some detail in Appendix 1.

As stated earlier, science is a human activity. Scientific knowledge grows as scientists think about the natural world, act upon it in planned experiments, and develop thoughtful explanations that incorporate the results. These processes include a wide range of skills that characterize the scientific enterprise: sensory skills, manipulative skills, communication skills, computational skills, interpersonal skills, organizational skills, imaginative skills, and decision-making skills. In addition, thinking processes enable us to dynamically interact with information obtained through our senses and construct new understandings. These skills and processes, which are described in some detail in Appendix 1, are not only part of science, but are basic skills that all students must develop in order to become active, productive members of our society. Because of their importance and because they only become highly developed through extensive practice, the development of process and thinking skills should be a significant part of every student's science experience.

THE NATURE OF LEARNING

Recent studies show that learning that is hands-on, inquiry-oriented, and cooperative is most effective.

Major advances in science education achieved during the last decade are reflected in the recommendations for change in the Pacific science program. Previous methods of teaching relied heavily on lecture and reading, with little opportunity for active, experiential learning. Recent developments in cognitive psychology, understanding of learning styles, and identification of multiple forms of intelligence emphasize learning that is hands-on, inquiry-oriented, and cooperative. We now know that learners need a large amount of experience and information to understand new concepts and to apply them in new situations. Thus, if true learning is to occur, concepts must be pursued in depth. Lectures are often not the most effective way to teach and too often result in the ability to say the right words without understanding what they mean or knowing how to apply that knowledge.

Learners build their own understandings by making connections between new information and their own existing knowledge.

Building on the educational philosophies of Dewey and Piaget, a new conception of learning has emerged that researchers call ***constructivism***. In this view, learners build their own understandings that are complex, highly organized, and strongly tied to specific subject matter. Each learner constructs his or her own knowledge by making connections between new information and their own existing knowledge.

Teaching requires patient dialogue with and among students. Discussion among learners is essential.

Learning occurs when the child becomes aware of inconsistencies in his or her prior conception of the world and is helped either to abandon or restructure these concepts. Discussion among learners is essential for them to check their understanding against that of others and to construct new concepts. Teaching, then, is not simply giving information, but requires patient dialogue with and among students and multiple opportunities to experience phenomena.

The constructivist view is linked to four related ideas: student learning styles, multiple intelligences, cooperative learning, and integration.

Learning Styles

Educators have known for a long time that students learn in different ways yet we often try to teach them all the same way.

Educators have known for a long time that students learn in different ways, and yet in school we teach as if this were not so. The concept of learning styles is very old. In more recent years, the differences in the ways people learn have been researched and described by medical doctors, psychologists, educators and those involved in managing organizations. All point to similar conclusions about the ways we perceive and process new knowledge—our learning styles.

There are a variety of ways of learning the same information and each individual has a mode of learning with which he or she is most comfortable, his or her preferred learning style. For example, Dr. Bernice McCarthy (1987) has described four basic learning styles and the particular teaching strategies that are most effective for them to learn. These are summarized in Figure 3.

If all Pacific children are to become scientifically literate, classrooms must provide a variety of experiences which address the needs of a variety of learning styles.

Because classrooms contain a variety of students, all of these learning styles may be present in every classroom. For teachers the implications of this research point to the need to use a variety of instructional strategies in the classroom. Using only one teaching strategy, no matter how skilled the teacher, results in systematically excluding as much as 70% of the class. If all Pacific children are to become scientifically literate, classrooms must provide a variety of experiences that address the needs of a variety of learning styles.

Multiple Intelligences

A major influence on views of learning has been the theory of multiple intelligences developed by Howard Gardner, a cognitive psychologist at Harvard University. Gardner challenges the view that intelligence is a single ability. He defines intelligence as the ability to solve problems or fashion products valued in at least one cultural setting. The human mind, he says, is a set of intelligences keyed to doing different kinds of tasks. He identifies them as

- **Linguistic Intelligence:** The capacity to use words effectively, whether orally (a storyteller) or in writing (a poet, or journalist). This intelligence includes the ability to use language to convince others, to remember information, and to explain ideas and understandings.

- **Logical-Mathematical Intelligence:** The capacity to use numbers effectively (a mathematician or accountant) and to reason well (a scientist or computer programmer). Logical-mathematical intelligence is called upon for activities involving categorization, classification, inference, generalization, calculation, and hypothesis testing.

- **Spatial Intelligence:** The ability to perceive the visual-spatial world accurately (having a strong sense of location and direction) and to perform transformations upon those perceptions (an interior decorator, architect, or artist). It includes the capacity to visualize and to graphically represent visual or spatial ideas

- **Bodily-Kinesthetic Intelligence:** The ability to use one's whole body to express ideas and feelings (an actor, an athlete, or a dancer) and facility in using one's hands to produce or transform things (a craftsperson, mechanic, or surgeon). This intelligence includes skills such as coordination, balance, dexterity, strength, flexibility, and speed.

- **Musical Intelligence:** The capacity to perceive, discriminate, transform (a composer), and express (a performer) musically. This intelligence includes sensitivity to the rhythm, melody, and timbre of a musical piece. One can have an intuitive and/or formal understanding of music.

- **Interpersonal Intelligence:** The ability to perceive the moods, intentions, motivations, and feelings of other people. This can include sensitivity to many different kinds of interpersonal cues; and the ability to respond to those cues in some useful way (to influence a group of people).

- **Intrapersonal Intelligence:** Self-knowledge and the ability to act on the basis of that knowledge. This intelligence includes having an accurate picture of one's strengths and limitations and the capacity for self-discipline, self-understanding, and self-esteem.

Gardner argues that traditional schooling develops only two of the seven kinds—linguistic and logical-mathematical—at the expense of the other five. Gardner insists that schools must center on persons, offering students choices, even within the same courses, and attending to each one personally so that all can enlarge their intelligences to the fullest. Examples of teaching materials and strategies that parallel Gardner's seven intelligences are described in Figure 4.

Traditional schooling develops only two of the seven kinds of intelligence—linguistic and logical-mathematical—at the expense of the other five.

Cooperative Learning

Social interaction is a critical part of learning. Working collaboratively in small groups is an instructional approach that provides children the opportunity to verbalize what they know and check it against what others know.

Social interaction through collaborative groups is a critical part of learning.

Simply put, cooperative grouping effectively promotes student learning. In studies comparing cooperative learning with competitive and/or individualistic learning, there has been no case in which cooperative learning was less effective and, in most cases, it was more effective in promoting student learning. Effective science instruction incorporates a variety of teaching strategies. Competitive activities are good for practice, recall, and review. Individual activities are appropriate when a student must learn a specific skill or concept, and attainment of that goal is important to the student. Cooperative learning is most appropriate for activities calling for problem solving, divergent thinking, and inquiry.

Integration

An extension of the emphasis of constructivism on connecting new learning to prior knowledge is an increasing recognition that science neither exists nor should be taught in isolation. Leading the current reform movement in science education, both the Association for the Advancement of Science (AAAS) and the National Science Teachers Association (NSTA) have strongly recommended that science be integrated and connected to other subject areas in elementary school and that the disciplines of science (biology, chemistry, physics, earth science) be integrated and taught each year in high school science courses. This is not only a realization of how to better teach science in elementary and secondary schools, but a reflection of how science itself has changed in the last decade, becoming increasingly interdisciplinary.

Science neither exists nor should be taught in isolation.

Further, there is an increasing recognition that the study of technology as it relates to science and society must be taught in schools. Science and technology have become inseparable. It is technology that every student interacts with every day. Yet, technology is not currently part of the school curriculum.

Figure 3: Four Basic Learning Styles

Learning Style	Characteristics	Strengths	Teaching Strategies
Innovative Learners	Innovative learners seek meaning, need to be personally involved in what they are learning, and learn by listening and sharing ideas. They are interested in people and culture and learn best through interacting with others. In fact, innovative learners must talk to one another in order to learn.	Their strengths are in innovation and imagination. They care about issues that are important to them and their goal is involvement with important issues. In classrooms, their favorite question is "Why?" or "Why not?" They tend to enter careers that involve interacting with other people, such as counseling or teaching.	Successful teaching strategies for these learners include cooperative groups, simulations, involvement in actual classroom experiences, such as skits, brain-storming, role playing, and activities that start with and connect to what they already know about phenomena.
Analytic Learners	Analytic learners seek facts, need to know what the "experts" think, and learn by thinking through ideas. They are less interested in people than in ideas. They critique information and are data collectors. They are thorough and industrious and will reexamine facts if situations puzzle them.	Their strength is in creating concepts and models. Among their goals are self-satisfaction and intellectual recognition. Grades, then, are very important to them. Their favorite question is "What?" They tend to seek jobs in science or math related fields, planning departments, and research.	They enjoy conventional classrooms where teachers give information based on facts in textbooks. Analytic learners do well in classrooms where the teacher is the information giver and the student's role is to absorb information, memorize, and pursue abstract ideas in depth.
Common Sense Learners	Common sense learners seek usability, need to know how things work, and learn by testing ideas in ways that seem sensible to them. They need hands-on activities. They enjoy problem solving, resent being given answers (they would rather figure it out themselves), and have little tolerance for unclear ideas. They learn best through their senses.	Their strength is the practical application of ideas. Their favorite question is "How does this work?" They like things orderly and systematic. Career choices include engineering, mechanics, nursing, and technology-related fields.	Teaching strategies effective with common sense learners include building things, making models, doing experiments, inventing applications, field trips, and generally testing ideas against reality.
Dynamic Learners	Dynamic learners seek hidden possibilities, need to know what can be done with things, and learn by trial-and-error and self-discovery. They are adaptable to change and relish it. They like variety and excel in situations calling for flexibility.	They tend to take risks and are at ease working with people. They often reach accurate conclusions without being able to explain how they got there. They learn by taking action and testing experience. Their goal is to make things happen. Their favorite question is "What if?" Careers include sales, and action-oriented jobs.	Effective teaching strategies for dynamic learners include giving them opportunities to choose their own course of action, experimenting with things and experience to discover new ideas, and sharing what they learn with others. They like open-ended, problem-solving situations that may have many possible solutions.

Figure 4: Multiple Intelligences

Learners who are predominately...	Think.....	Enjoy.....	Learn by....
Linguistic	in words	reading, writing, telling stories, books, tapes, dialogue, discussion and debate	reading , writing, listening and talking about it.
Logical-Mathematical	by reasoning	experimenting, questioning, puzzles, calculating, manipulative	quantifying, thinking critically, and conceptualizing about it.
Spatial	in images and pictures	designing, drawing, doodling, LEGOs, movies, slides, illustrated books	seeing, drawing, visualizing, and mapping it.
Body-Kinesthetic	through physical sensations	dancing, running, building, touching, role playing, drama, hands-on learning	building it, acting it out, touching it, dancing it.
Musical	via rhythms and melodies	singing, listening, concerts	singing it, rapping it, listening to it.
Interpersonal	by bouncing ideas off other people	leading, organizing, friends, social gatherings, community events, clubs.	collaborating with others on projects about it, teaching it to others.
Intrapersonal	deep inside themselves	setting goals, meditating, planning, time alone, independent projects	connecting it to their personal lives, making choices and decisions with regard to it.

Adapted from Multiple Intelligences in the Classroom by Thomas Armstrong

THE NATURE OF SCIENCE TEACHING

Science teaching must be consistent with the spirit and character of scientific inquiry and with scientific values. This means starting with observations and questions about phenomena rather than answers to be memorized; engaging students actively in hypothesizing, designing and carrying out investigations, collecting and using data; providing hands-on experience with tools; valuing curiosity and creativity; and frequently using a team approach to learning.

Students notice many things on a daily basis that can become the objects of scientific investigation

Science education can take place at any time and place when curiosity gives rise to a question and an answer is sought through investigation. Students notice many things on a daily basis that can become the objects of scientific investigation. Answering questions like What is that? How come—? How can we—? Why did that—? Is that like—? involves students in developing and using inquiry skills and habits of mind, as well as a knowledge base. This type of learning situation is ideal for "standards-based" science instruction. First and foremost, science education must be enjoyable. Second, it must be made available to all students and taught in such a way that all students develop confidence in doing science and technology.

The classroom environment must be safe, nurturing, and student-centered, with all students actively involved.

The classroom is the usual place where the student, his or her classmates, the teacher, and the science curriculum meet. To achieve the vision of scientifically literate Pacific children, we must create an environment that is safe, nurturing, and student-centered, and where all students are actively involved in the learning process.

The classroom teacher must act as the facilitator of learning in a student centered classroom. Teachers set the stage but the students are active participants in the learning process.

Teachers must act as facilitators of learning in student-centered classrooms. Like the director of a play, teachers set the stage, but the students are the active participants in the learning process. As facilitators, teachers should provide students with opportunities to "do" and "reflect on doing" by choosing materials and activities that are likely to develop conceptual understanding while seeking answers to problems originating from the students, their environment and the technology that surrounds them. Science-based process activities keep students involved in hands-on, minds-on experiences which lead them to understand the ideas and ways of science during the learning process.

Emphasis should be placed on doing good science. Students often feel pressured to come up with the "right" answer when doing science, so much so that they sometimes create the data they think they should be getting rather than rely on and trust their own observations. Teachers should encourage students to report the data they get, emphasize that there are no "right" answers, and point out that students' results may reveal problems with the experiment, apparatus, or conclusion. Even if data were incorrect, repeated trials and observations made by others will uncover this. When discrepancies arise, the teacher should keep an open mind and plan with students how ideas can be tested systematically and thoroughly. Such an approach emphasizes the characteristics of science (honesty, curiosity, openness, and skepticism) and that a most important part of science is that it must be communicated to be of use.

Using a variety of approaches to teaching and learning science provides all students with the opportunity to gain and express knowledge.

Using a variety of approaches to teaching and learning science addresses different learning styles and interests provides all students with the opportunity to gain and express knowledge through a number of meaningful ways. Using effective questioning techniques to connect current experience to past experiences, to appropriate science concepts, and to future activities reinforces conceptual understanding rather than rote learning. The development of problem-solving skills by encouraging the application of knowledge to new and "extending" situations, as well as the development of appropriate language and mathematical skills all enhance the learners' ability to function as an independent, life-long, learner.

We want students to enjoy science and even to consider choosing a career in a science or technology field. In this regard, science teachers should be excited about teaching science and strive to point out opportunities for careers in science. There is a place for everyone. Science careers are delightfully varied, from engineer or chemist to wildlife manager, agricultural agent, marine fisheries researcher, forester, nature guide, laboratory technician, health worker, to—best of all—science teacher.

The connections within science, between science and other content areas, and between science and society should be highlighted.

Throughout the school science experience the connections within science, between science and other content areas, and between science and society should be highlighted. The message that science teachers can bring to students is that science is a body of knowledge and a way of thinking and "doing" that is concerned with all of nature and technology. The responsibility of science teachers and the function of the science curriculum are to prepare students for the decisions they will have to make as adults—decisions about their lives, their careers, and their environment; decisions that are becoming increasingly dependent on a clear understanding of science and technology.

THE NATURE OF ASSESSMENT IN SCIENCE

Assessment is the process of collecting, synthesizing and interpreting information about individuals or groups of students in order to understand their learning and help them continue to grow. What we assess communicates what we value—the things worth learning. Our assessments must focus on important science; the understandings, capabilities and caring defined in this document. They must take place in classrooms where teaching is student centered and active, where learning is inquiry based, where criteria for judging the quality of student work are clear and known in advance, and where students have opportunities to show their learning in a variety of ways.

Students should have the opportunity to show their learning in a variety of ways.

Our Standards and Assessment

What do my students know about the living environment? What do they know about the science involved in Pacific navigation? in fishing? in food preparation? What can they do? How skillfully can they carryout scientific inquiry? Can they work well with others? Are they effective problem solvers? Do they give up when they encounter difficulties, or do they persist, seeking other routes to success? Can they think critically? Do they seek more than one possible answer to complex questions? Can they communicate about what they've learned in science? Can they make connections between their science learning in school and their lives outside of school? Can they put their knowledge and capabilities together and create products of value? What do they care about? Does their caring result in action? How well are they developing scientific habits of mind like persistence, curiosity, open-mindedness and the ability to pose questions? How skillful and accurate are their observations? Do they demonstrate caring for their island environment? Are they thoughtful decision makers, aware of the impact of their decisions on other living things?

Each of these questions, and many others, gives us opportunities for standards-based assessment. Each is related to our vision for scientific literacy. To answer such questions we need samples of student work, records of their performance on tasks and projects. We can use their logs and journals of scientific investigations and field excursions; we can record observations of their actions and use oral questions to probe their understanding. Quality assessment requires many different types of evidence to give us a clear picture of students' growing scientific literacy.

Assessment of standards-based learning requires a wide variety of instruments.

Good assessments help students grow.

Good assessments help students grow to know and understand their strengths and to clearly see the areas where they need to improve. Good assessment helps teachers enrich and adjust their instruction. Good assessments help parents and community get clear and detailed pictures of their children's learning.

Classroom Assessment

Classroom assessment is about gathering information and communication.

Classroom assessment is about gathering information to get a rich and detailed portrait of student learning, to help us answer questions about what our students are learning and how well, and to serve as the basis for communication with students, parents, and others. Classroom assessments take place every day: in our informal questioning and observations of students as they work; in the ways we monitor student's reactions to classroom activities to see if they understand; in the paper and pencil tests and assignments we use; and in the tasks we set up for students to perform.

The information gathered should help us talk with our students, with their parents, and others about their learning.

Assessment is also about communication; it is about using information gathered from a variety of activities and tasks to help us talk with our students, with their parents, and others about their learning. The quality and usefulness of our conversations depend on the quality of the assessments. Without good assessments, we guess about learning and we face the possibility of making faulty judgments about student work.

Forms of Assessment

When we gather information about our students' learning we choose and use a variety of forms of assessment. Some are formal and some informal; some are individual and some group. The following are some of the common forms of assessment:

- **Paper and Pencil Tests and Assignments.** This type of assessment includes quizzes, written tests that teachers prepare, tests that come with textbooks and worksheets, and tests that are given to all students at a specific grade level. Such tests have traditionally been used to measure whether students can think convergently, i.e., can come up with a specific right answer. Multiple choice questions, true-false, short answer, and matching questions are examples of this form of assessment. Typically they are used to learn whether or not students can recall specific information.

- **Performance Assessment.** Performance assessment is based on observation and judgment. Students must use their knowledge and demonstrate their skills as the deal with tasks that call for thinking, applying and reflecting on the quality of their work. At their most powerful, performance assessments are an integral part of instruction. Quality performance assessments include a task that results in a performance or product and clearly defined criteria that are used to describe and judge the quality of student's responses. Examples include experiments, projects, exhibitions, and portfolios. Performance assessments open the process to students as well as teachers. Students become self-assessors, using the criteria that describe levels of quality to examine and make judgments about their own products and performances.

Performance assessment is based on observation and judgment.

- **Personal Communication.** Personal communication with students is an often overlooked opportunity for assessing learning. The more instruction and assessment are integrated, the more important are the questions used by teachers and students. For example, the questions that teachers ask during class can be powerful tools for focusing student attention, stimulating thought; the responses of students provide information about their learning. Personal communication tools for assessment include oral questions, interviews, informal conversations, conferences, and group discussions.

Personal communication is an often overlooked opportunity for assessing learning.

Uses of Assessment

We use assessments to decide about students, teaching, the effectiveness of the programs and materials we are using, and about how best to encourage students to learn. Teachers use assessment data to assign grades, check whether their lessons are working, and adjust their teaching. They also may decide which students have potential for future study, and which do not. We make decisions about grouping, about which things to reteach, about which materials and teaching strategies really work, and about how successful we are as teachers.

Assessments are used to make decisions about students, teaching, programs and materials.

Our students and their families use assessment information also. Students decide day-to-day what they should study, what courses to take, or even whether to study at all. They judge their teachers and their ability to learn based on assessment information. As they move up through the grades, students use assessment data to judge their probable future success. Frequent "failures" begin to affect the way they see themselves as learners and can have lifelong effects on their belief in their ability to learn and grow.

Parents may judge their children's abilities and future on the basis of assessment information.

Parents may judge their children's abilities and future, whether to praise or scold, the effectiveness of the teacher, and their own skills on the basis of assessment information. We must be sure that our descriptions of student learning, our judgments about the quality of their work, and our decisions come from high quality assessments.

Quality Assessment

The powerful impact of assessment on students, their families, and our teaching requires that we design and use high quality assessments. Good assessments help students grow--to know and understand their strengths, to clearly see the areas where they need to improve and focus. Good assessments also help teachers enrich and adjust their instruction and help parents and community get a clear and detailed pictures of students' learning. *What is assessed communicates what we value*--the knowledge, skills and values worth learning. *The Pacific Standards for Excellence in Teaching, Assessment and Professional Development* define and describe the essential characteristics of quality assessment in mathematics and science. Here's a summary:

Assessment should focus on the science that is most important for students to learn.

- **Important science.** Assessment should focus on the science that is most important for students to learn. We need to be clear about what to assess, and students need to know what's expected of them. When there are clear learning expectations, our assessments will give useful insights into students' growth toward mathematical and scientific literacy.

Assessment should enhance learning.

- **Enhancing learning.** Quality assessment should help students learn important science. To do this, assessments need to be a part of classroom instruction, not an interruption. Learning is also enhanced when we use assessment results to improve our teaching. Assessments enhance learning when they cause students to think and act on their knowledge and capabilities.

Assessment should honor culture and provide students with opportunities to communicate in their most fluent language.

- **Honoring culture.** Our assessments of important science need to honor culture in order to illuminate learning. Including the rich science found in Pacific cultures in teaching and assessment, we can enable students to value their home knowledge, build on what they know, feel confident about their ability to become scientifically literate, and create rich portraits of their learning. To do this we must provide opportunities for students to communicate about their learning in their most fluent language, and demonstrate their learning in many ways.

- **Opportunities for success.** To assure that all Pacific students can become scientifically literate, and that assessments are not used to limit students' access to science, we must expect success from our students, take care that our assessments are as free as possible from biases that can hide learning, and give our students opportunities practice and learn how to communicate their learning in variety of ways. Students must also have choices in how they show their learning. Without opportunities to learn essential science our students cannot succeed.

Assessment should not be used to limit access to science courses.

- **Openness.** All aspects of science assessment processes should be open to review and scrutiny. When assessments are open, teachers are involved in planning and designing assessments, they know the big ideas that are the focus of assessment, and students too know what they are expected to learn and how they will be expected to show their learning. When assessments are open, parents are partners in conversations about the childrenis' learning. The purposes and uses of assessments must also be openly communicated.

All aspects of science assessment processes should be open.

- **Valid inferences.** Evidence from assessment activities should give an accurate picture of student learning. To do this, we must be clear about our assessment purposes--how we plan to use the assessment information. There must be a good match between what we want to know about our students' work and progress and the forms of assessment we use. We also need to be sure that we have enough samples of student work to make reasonable judgments about their learning, and that we have minimized biases that can mask learning.

Assessment should give an accurate picture of student learning.

- **Consistency.** All aspects of assessment should be consistent with the purposes of the assessment. Assessments should help us answer critical questions about student learning. The kinds of assessments we use should be directly related to the questions we want answered. Whether the assessment is conducted by the teacher or someone outside of the classroom, the process should be coherent and should consist of the following: (1) an assessment design that matches the purposes of the assessment, the curriculum, and the instruction; (2) a collection of assessment instruments, tasks and criteria that are designed to accomplish the purposes; (3) care and expertise in

Assessment processes should be consistent with the purposes.

all parts of the process, (4) reporting that answers our assessment questions and gives useful and clear information about student learning.

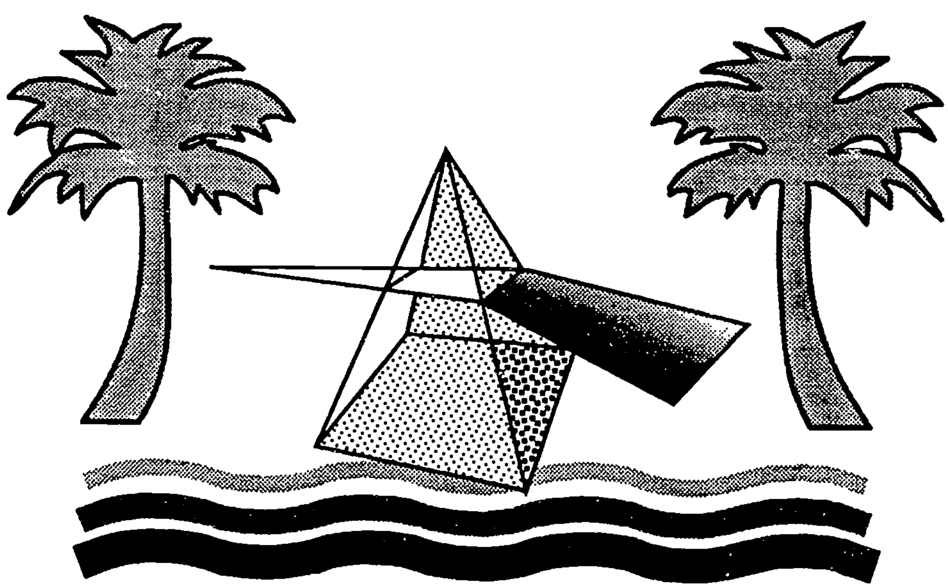
External assessments must support important science learning.

- **Alignment**. External assessments must also support science learning. Before selecting or using an external assessment, we need to check the match between the assessment and our own curriculum goals and desired learning outcomes. When there's a good match, we can gain insights from the external assessment to help learning; when there a poor match, the information will not help us improve teaching and learning.

We must have clear criteria for making judgments about the quality of student work.

- **Evaluation.** To use assessment information to evaluate learning, we must have clear criteria for making judgments about the quality of student work. Criteria must be known to students and should be used by them to improve the quality their work. Evaluation must focus on student work, and not on the personality or other personal characteristics of students.

PACIFIC SCIENCE STANDARDS



SCIENCE AS INQUIRY

The scientifically literate student understands that scientific inquiry is a particular way of learning about how the world works. Scientists question, observe, think, and experiment to investigate events and deepen our understanding of them. These approaches distinguish science from other ways of knowing.

The study of science as a way of figuring out how the world works should be an important part of any science curriculum. When people know how scientists go about reaching their conclusions and what the limitations on those conclusions are, they are more likely to react thoughtfully to scientific claims. They are less likely to accept or reject conclusions without care. Such critical thinking also enables people to make better decisions in everyday life.

When people have a good sense of how science operates, along with an understanding of the key ideas of science, they can follow the adventure story of science as it plays out in their lifetimes. They will realize that a wide variety of people participate in the scientific enterprise and that there are many opportunities for employment and enjoyment in science and science-related fields.

When people have a good sense of how science operates, along with some of the key ideas of science, they can follow the adventure story of science as it plays out in their lifetimes.

In the early grades, students should learn science by doing and enjoying it. By conducting many investigations and explaining their findings, they accumulate knowledge, skills, and attitudes which they can later draw on to reflect about the process of how science operates. As students go through school, they should be encouraged to ask over and over "How do we know this is true?"

Historical perspectives provide one way to understand how science works. Students should come to realize that much of the growth of science and technology has resulted from the gradual accumulation of knowledge over many centuries. Sometimes, however, "breakthroughs" occur that radically change how we think about the world around us.

The study of science as a way of knowing includes understanding the nature of science and how applications of scientific thinking and processes generate new knowledge. Understanding the nature of science means students know about these related concepts:

A. Scientific Inquiry. Scientific inquiry is a complex process that requires imagination, inventiveness, logic, and experimental evidence.

B. Scientific View of the World. Scientists share common beliefs and assumptions about how the world works, how we can go about finding out how it works, and how our understanding of the world can change over time.

C. Historical Perspectives. Evolutionary and Revolutionary. Great scientific and technological revolutions have transformed human thought and action; they are an essential and interdependent part of the slower, ongoing development of science.

D. Personal, Social, and Ethical Dimensions of Science. Science adheres to high standards of ethics including openness, objectivity, honesty, and accuracy. Science and society interact, each influencing the other. Science also provides a wide range of career opportunities for people from all geographical areas and cultural backgrounds.

A. Scientific Inquiry

Scientific inquiry is a particular way of learning about how the world works. It is at the very heart of science's distinctive "way of knowing."

Scientific inquiry is a particular way of learning about how the world works. Inquiry represents a set of interrelated processes by which scientists pose questions about the natural world, investigate phenomena, and develop deeper understanding. It is at the very heart of science's distinctive "way of knowing." Inquiry is much more than just doing experiments. It requires imagination, inventiveness, logic, and empirical evidence.

Scientific inquiry involves investigators working together, sharing their questions, ideas and interpretations with others. Though there are sometimes great discoveries, the steady advancement of science depends on the accumulation of knowledge bit by bit.

If students participate in investigations that approximate good science then they will develop a reasonably accurate understanding of scientific inquiry. When they engage in inquiry, they learn to choose among alternatives, determine what factors are important, and use a wide range of tools and skills. When they operate as scientists do, they use both manipulative skills and thinking skills.

Inquiry is a critical component of the science curriculum because it helps students at all grade levels

- develop an understanding of science concepts,
- "know how we know" in science,
- develop an understanding of the nature of scientific inquiry
- develop both the skills necessary to become independent inquirers about the natural world and the inclination to use them.

A first step in developing student understanding of scientific inquiry is to engage them in investigations that approximate good science. Such investigations should be based on the kinds of questions students naturally ask about the world around them. The questions need not be original or profound. Teachers can help students figure out what questions to ask and what to collect, measure, or observe in order to come up with possible answers. Year by year, the investigations should become more ambitious and more sophisticated. Before graduating from high school, students should work individually and in teams to design and carry out at least one major investigation. They should have the opportunity to frame the question, design the approach, estimate the time and costs involved, calibrate the instruments, conduct the investigation, write a report, and respond to a review by others. Such investigations may take weeks or months to conduct. They might happen in or out of school.

A first step in developing student understanding of scientific inquiry is to introduce more student investigations that approximate good science.

LOWER ELEMENTARY

Developing understanding of scientific inquiry begins in the earliest grades. Young students should be actively involved in exploring phenomena that interest them both in and out of the classroom. These investigations should be fun and exciting, opening the door to even more things to explore. An important part of students' explorations is telling others what they see, what they think, and what they wonder about. Children should have lots of time to talk about what they observe and to compare their observations with those of others.

Students should understand that everybody can do science and invent things and ideas. All team members should reach their own conclusions, however, about what the findings mean. criticism of others. This is the way good science is done.

Young students should begin to understand that people often learn about things around them just by observing carefully.

Students at this level should not be expected to give scientifically accurate explanations for their observations. Theory can wait until upper grades. But young students should begin to understand that people often learn about things around them just by observing carefully and that they can learn more by doing something to those things and noting what happens. Tools such as magnifiers, thermometers, rulers, and balances often give more information about things than can be obtained by observing them without tools. Describing things as accurately as possible is important because it enables people to compare their observations with those of others. When students disagree about each other's observations of something, it is usually a good idea to have them observe it again, instead of arguing about who is right.

MIDDLE ELEMENTARY

Students should be encouraged to observe , measure things, record data clearly in logs , and communicate.

As students get older they should be encouraged to observe more carefully, measure things more accurately, record data clearly in logs and journals, and communicate their results in charts, graphs, and drawings as well as writing. Investigations should be followed up with presentations to the entire class to emphasize the importance of clear communication in science. Class discussions of procedures and findings approximate scientific seminars and debate.

Activities which generate new questions and new investigations are at the heart of science

Students' investigations in the middle elementary grades should focus on detecting similarities and differences among the things they collect and observe. Identifying differences and puzzling events is at the heart of the scientific enterprise because they generate new questions and new investigations.

Students should be encouraged to "check what you think against what you observe." They should listen to the explanations of others and remain open to new ideas. Through such experiences, they begin to understand that in science it is all right to offer different explanations for the same observations.

UPPER ELEMENTARY/MIDDLE SCHOOL

By early adolescence, students should become more sophisticated in designing and executing valid experiments.

By early adolescence students should become more sophisticated in designing and executing valid experiments. This includes providing for controls, replication, and standards for data collection in the experimental design. Some of their investigations may last weeks or more.

By the end of grade 8, scientifically literate students will understand these facts about science:

- scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments. Investigations can focus on physical, biological, or social questions;

- results of scientific investigations are seldom identical, but if they differ greatly, it is important to try to figure out why. One reason scientists follow directions carefully and record their work is that they review this information for clues that might explain why they got different results;

- scientists' explanations about what happens in the world come partly from what they observe, partly from what they think. Sometimes differences;

- different scientists observing the same phenomenon will explain it differently. This usually leads them to observe it further, in order to resolve the differences;

- scientists tend to ignore claims about how something they know about works unless the claims are backed by evidence that can be confirmed;

- scientists differ in what phenomena they study and how they go about their work. Although there is no fixed set of steps to follow, all scientific investigations involve logical reasoning, collecting relevant evidence, and applying imagination in devising hypotheses and explanations to make sense of the collected evidence;

- what people expect to observe often affects what they do observe. Strong beliefs about what should happen in particular circumstances can prevent them from detecting other results. Scientists know about this danger of bias and take steps to try to avoid it when they design experiments and examine data. One safeguard is to have different investigators conduct independent experiments on the same question.

They will be able to

- ask good questions about the world around them,
- explore phenomena using sensory, manipulative, and process skills;
- record data clearly and accurately in logs and journals;
- design and execute valid experiments including controls, replication, and setting proper standards;
- communicate their results in charts, graphs, and drawings, as well as verbally;
- collaborate effectively with others to get a job done.

They will value

- science as one way of knowing about the world around them,
- curiosity, creativity, open-mindedness, and skepticism,
- observing carefully and seeking logical explanations.

SECONDARY

Older students are better able to deal with abstractions and hypothetical cases and should also begin to understand that theories compete for acceptance, but that only those backed by valid evidence and logical arguments are considered.

Older students are better able to deal with abstractions and hypothetical cases. Now the unfinished and tentative nature of science may make more sense to them. The nature and importance of prediction can be taken up, emphasizing the use of statistics, probability, and modeling to predict the outcome of complex phenomena. Care should be taken to distinguish scientific prediction from popular practices such as astrology and guessing the outcomes of sports events. Students should also begin to understand that theories compete for acceptance, but only those backed by valid evidence and logical argument are considered.

By the end of secondary school, scientifically literate students will understand that

- investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories;

- scientists conduct investigations in order to explore new phenomena, verify previous results, test how well a theory predicts, and compare different theories,

- scientists use hypotheses to help them discern what data is important, decide what additional data to seek, and to guide their interpretation of the data;

- sometimes, scientists can control conditions in order to obtain evidence. When they cannot do so for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns;

- traditions in science differ about what is investigated and how, but all share basic beliefs in the value of evidence, logic, and good argument that depend on intelligence, hard work, imagination, and even chance;

- scientists in any one research group tend to see things alike, so even they may have trouble being entirely objective about their methods and findings. Therefore, scientific teams are expected to search for possible sources of bias in their experimental designs and plans of data analysis.

They will be able to

- use inquiry and other scientific thinking skills in studying science and for personal growth as life-long learners,

- state testable hypotheses about natural phenomena,

- design and carry out a valid, controlled experimental project and report results to others,

- identify possible sources of error and bias in experimental results,

- apply science knowledge and skills to practical, everyday problems.

They will value

- science as a way of generating new knowledge, validating their own and others' knowledge, and using knowledge to predict effects of actions in their personal, family, and community lives;
- the excitement, enjoyment, and satisfaction of exploring and understanding the world through science;
- opportunities for work and careers in science and science-related fields.

B. The Scientific View of the World

A scientific view of the world includes these beliefs:

1. By working together over a long time, people can figure out how the world works.
2. The universe is a unified system, and knowledge gained from studying one part of it can often be applied gain knowledge about other parts.
3. Knowledge in science is both stable and subject to change.

LOWER ELEMENTARY

From their very first day in school, students should be actively engaged in learning to view the world scientifically.

From their very first day in school, students should be actively engaged in learning to view the world scientifically. That means encouraging them to question the nature of things and to seek answers—to collect, count, measure, observe, and describe things; to organize collections and observations; and to discuss findings. Getting into the spirit of science and liking it are what count most at this age Awareness of the scientific world view can come later.

Early science experiences should be designed to help children realize that the world is consistent. Students should sometimes repeat observations and investigations in the classroom and again in the school yard and at home. For example, students could be asked to compare what happens in different places when an egg is cooked, or how moving objects are affected when pushed or pulled, or what a seed looks like when it starts to grow. Students should begin to understand that when a science investigation is done the way it was done before, the results are likely to be similar, and the investigation will generally work the same way in different places.

MIDDLE ELEMENTARY

As students continue to investigate the world, their understanding of consistency can be strengthened by pointing out inconsistencies. When they observe differences in the way things behave or get different results in repeated investigations, they should suspect that something differs from one trial to another and try to find out what. Sometimes differences result from methods, sometimes from the way the world is. Unexpected results can lead to interesting new questions for investigation.

Unexpected results can lead to interesting new questions for investigation.

UPPER ELEMENTARY/MIDDLE SCHOOL

Most early adolescents would rather explore nature than consider the philosophy of science. They should therefore continue to be engaged in doing science, but be encouraged to reflect on the science that they are engaged in. This is a time to introduce the ideas of the stability of knowledge and its susceptibility to change. Explanations of phenomena change as we gain new perspectives on them. New perspectives often open the door to new discoveries, applications, and questions. The ideas of gradual change and radical, revolutionary change should be introduced.

Most early adolescents have a more immediate interest in exploring nature than the philosophy of science.

By the end of grade 8, scientifically literate students will understand that

- when similar investigations give different results, the scientific challenge is to judge whether the differences are trivial or significant. It often takes further studies to decide. Even when results are similar, scientists may wait until an investigation has been repeated many times before accepting the results as correct;

- scientific knowledge is subject to change because new information challenges prevailing explanations and new theory inspires different perspectives on observations;

- some scientific knowledge is very old, yet it is still applicable today;

- some matters cannot be examined usefully in a scientific way. These include matters of morality and other things that cannot be tested objectively and those that are matters of morality.

They will be able to

- demonstrate how to use an experiment to test the correctness of an idea,
- show how replication of experiments and events contribute to an accepted explanation of them,
- demonstrate the consistency of an explanation when applied to different phenomena, in different places, or at different times,
- seek and identify possible explanations for anomalies.

They will value

- consistency in dealing with everyday situations and problem solving,
- being open to new and more powerful explanations when new observations, data, and interpretations become available,
- some scientific knowledge is very old and yet is still applicable today;
- some matters cannot be examined usefully in a scientific way. These include things that cannot be tested objectively and those that are matters of morality.

They will be able to:

- demonstrate how an experiment can be used to test the correctness of an idea;
- show how replication of experiments and events contribute to developing an accepted explanation,
- demonstrate the consistency of an explanation when applied to different phenomena, in different places, or at different times;
- seek and identify possible explanation for discrepant events and anomalies.

They will care about and value

- the assumption of consistency in dealing with everyday situations and problem-solving.

SECONDARY

Students in secondary school are ready to learn about some aspects of science by exploring historical and current developments in science. Case studies enable them to examine, for example, the theoretical and practical limitations of science, differences in the kinds of knowledge the different sciences generate, and the tension between the certainty of accepted science and the breakthroughs that upset this certainty.

History and case studies help illustrate past and present developments in science.

By the end of secondary school, scientifically literate students will understand that

- scientists assume that the universe is a vast single system governed throughout by the same basic rules . The rules may range from very simple to complex, but scientists believe that the rules can be discovered by careful, systematic study;

- from time to time, new knowledge transforms the scientific view of the world. More often, however, changes in the body of scientific knowledge modify prior knowledge in small ways. Change and continuity are persistent features of science;

- no matter how well a theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, therefore, the testing, revising, and occasional discarding of theories never ends. This process leads to an ever-increasing understanding of how things work in the world, but not to absolute truth. Evidence for the value of this approach lies in the improving ability of scientists to reliably explain and accurately predict phenomena.

They will be able to

- describe examples of major shifts scientific knowledge, such as the Copernican revolution, theories of plate tectonics, or the atomic structure of matter;

- cite examples of current theories that shape the questions and research in science, such as evolution in biology, Big Bang theory in astronomy, or plate tectonics in earth science.

They will value

- the scientific approach—analytical, careful, collaborative, cumulative and systematic—as a way to understand and resolve personal, community, national, regional, and global problems.

C. Historical Perspectives

Insights about the nature of scientific inquiry, the ways in which scientists reason, the values underlying the work of scientists, and the historical development of scientific ideas are an important part of scientific knowledge.

When students appreciate the social and historical contexts in which science evolved, they get a more comprehensive view of the scientific endeavor and a basis for understanding how we know what we know. The historical development of scientific ideas and the values that gave rise to them are important scientific knowledge.

The history of science shows students how science has evolved. By studying it, they learn that the human drive to understand the natural environment and to predict the course of natural events is universal. Such study should highlight the interactions between science and technology. New technological devices have helped scientists to better understand the natural world, and new scientific discoveries form the basis of new devices.

The social context of science—political, economic, and cultural—shows students that science is embedded in and interacts with other forms of human activity. Learning about it helps students sense how science fits in their lives. Perhaps most important, they see how some episodes in the history of science have had profound impact on cultures throughout the world.

The historical perspective also takes into account the close relationship among the natural sciences, mathematics, social sciences, and technology. Students may reflect on the fact that the boundaries between and among these formerly distinct fields are now blurring and that new partnerships among fields are emerging (for example, biotechnology, biophysics, astrophysics, and ethnobiology).

Most of the study of the history of science should be left to secondary school. But to appreciate the significance of historical accounts, students must at least be able to follow the science involved and grasp the main view of the prevailing culture at the time. Students in the upper-elementary and middle-school grades are ready to begin exploring these ideas. This is an excellent time to compare and contrast the scientific explanations students develop (with the guidance of teachers) from their own experiences with explanations about the same phenomena developed by local cultures. Topics might include the origin of Pacific islands, the migration of birds or fish, weather phenomena, uses of plants and their products as medicines, or the wisdom of conservation and preservation methods.

To appreciate the significance of historical accounts, students must be able to follow the science involved and be able to grasp the main view of the prevailing culture at the time.

SECONDARY

By secondary school, the experience and level of development reached by students have prepared them to understand and appreciate the cumulative endeavor we call science. With a basic understanding of the underlying concepts, students can begin to appreciate the important contributions of thousands of individuals in different parts of the world to our current understanding of nature. All current thought in science was illuminated by Galileo changing our perception of our place in the universe, Newton demonstrating that the same laws apply on Earth and in the heavens, Darwin deducing a mechanism to explain the diversity and similarities of life forms, Lyell carefully documenting the incredible age of the earth, and Pasteur identifying tiny organisms as the cause of infectious disease.

With a basic understanding of the underlying science concepts, secondary students can begin to appreciate the important contributions of thousands of individuals in different parts of the world to our current understanding of nature.

Such stories are perhaps best approached in classrooms as case studies. Case studies connect science with the contexts in which it developed by situating the stories in the culture, events, religions, arts, politics, and technologies of the time. They connect the sequence of events and ideas that led to our current view, and link it to the world of the nonscientist. Take, for example, the close connection between scientific views and the development of art: it is little wonder that daVinci was both a creative artist and creative scientist. The story of the impact of Copernicus's sun-centered explanation of the universe on the prevailing religion of his time demonstrates the tension between science and religion that exists even today. The inventions and uses of technology long before scientific explanation was available to tell us what the underlying provide opportunities to demonstrate the close relationship of science and technology. Multiple sets of technologies evolved around fire long before science explained it in terms of

Stories about Pacific technologies and explanations of events can be introduced and compared with Western science.

combustion. Humans were using energy for thousands of generations before we had any scientific explanations of what energy is or how it is generated.

Similarly, it is instructive to compare Pacific technologies and explanations of events with Western science. Both are based on systematic observation, application of knowledge, and search for explanations. The Pacific technologist who builds a canoe or a shelter, grows a new crop, catches fish a new way, or invents a utensil for cooking or handicrafts, uses many of the same processes that brought science to such a high level of achievement. Comparing these two approaches to technology deepens students' understanding of science in a context that values Pacific cultures.

By the end of secondary school, scientifically literate students will understand that

- science, mathematics, technology, and culture are intertwined through time. The Copernican revolution illustrates some of the tensions that can occur between science and society when science proposes ideas that seem to violate common sense and undermine traditional values and beliefs. Its historical roots begin in early astronomy when humans first tried to explain events they observed in the skies;

- good theory provides powerful explanation and unites previously disconnected explanations. An excellent historical perspective on this idea is Newton's universal laws on gravitation and motion, which united the heavens and Earth;

- the test of scientific theory is not how nearly it matches common sense, but how well it accounts for known observations and predicts unexpected ones. Under extreme conditions the world may work in surprising ways. Thus Einstein's concept of relativity taught us that nothing can travel faster than the speed of light, that all energy has mass, and that matter itself is a form of energy;

- new theories are sometimes built on indirect evidence. Our conception of the age of the earth has changed with accumulating evidence from geology, the fossil record, radioactive dating, and biological evolution. These stories also highlight the importance of mathematics and technology in science;

- a theory's acceptance by the scientific community depends on both its explanatory power and the evidence that supports it. A recent example of this is the long controversy over plate tectonics. Evidence accumulated for many years and from many different sources before scientists would accept this idea. The theory has now revolutionized our thinking of planetary geology;

- progress in science often depends on careful measurements, precise and consistent use of language in communication among researchers, and the convergence of different lines of investigation. This is well illustrated by scientists' efforts to understand the nature of fire. This was finally accomplished because of the converging lines of inquiry by the Frenchman Antoine Lavoisier and the Englishman John Dalton;

- scientific discovery sometimes occurs by chance, and discoveries often have unforeseen applications that can affect world affairs. Such is the case of the discovery of radioactivity and its later applications in medicine, industry, and research, as a source of energy, and in the development of weapons. This case study also points out the interdependence of the disciplines of science, the role of women in science, and ethical questions of science in society;

- not all scientific advances depend on experimentation; some rely on careful observation and description combined with imaginative and creative thinking. Charles Darwin's theory of natural selection to explain the similarities and diversity of life is a good example of these aspects of science;

- science often depends on technology. Sometimes investigations designed to solve a practical problem lead to fundamental scientific discoveries. One example of the interdependence of science and technology is the discovery of microbes and the development of germ theory. Understanding microbes and their impact on living things has led to great advances in health care and disease prevention;

- new ideas in science are limited by the context in which they are conceived. They are often rejected by the scientific establishment. Some spring from unexpected findings. They usually grow slowly, through contributions from many investigators.

They will be able to

- cite examples of how science has changed over time,
- describe some of the interactions of science, technology, and society.

They will value

- the power of science to relate and explain diverse observations and events in nature,
- the self-correcting nature of the scientific process: hypothesizing, searching for evidence, collaborating, and reaching consensus;
- the human capacity to imagine explanations, remain open to different interpretations, entertain new and more powerful explanations, and create practical uses for new discoveries.

D. Personal, Social, and Ethical Dimensions of Science

Students should be exposed to the social structure, discipline and ethics of scientific enterprise.

When viewed as one of the many kinds of human activity, we see that science has greatly expanded our understanding of our world. It is a vast enterprise that provides a living for many people. As citizens in democratic polities, today's students must understand how science is organized, because their votes will influence how science is supported: the kind of science that is funded, its purpose, and the context within which it is undertaken. By the time they graduate, students should feel comfortable talking in general terms about the nature of science and should be able to understand discussions of science issues that affect them. Students in the upper grades should be exposed to three other aspects of the scientific enterprise: its social structure, its ethics, and its discipline and institutional identification.

LOWER ELEMENTARY

Science should begin in the earliest grades with students working in small teams.

Science should begin in the earliest grades with students working in small teams to ask and answer questions about their surroundings and to share their findings with other students. All team members should reach their own conclusions, however, about what the findings mean. Teachers and students can help the groups learn how to share in deciding what to do, collecting and organizing information, and making presentations. The key is for students to experience science in ways that resemble how science is actually done and that emphasize the ethics and culture of science.

Teachers should foster scientific values by praising students' curiosity and creativity even when investigations are not entirely successful. Students should understand that everybody can do science and invent things and ideas. Students also need to know that though they are part of a team, they are free to reach different conclusions from their colleagues, and that when they do they should say so and say why.

The key is for students to experience science in ways that resemble how science is actually done and that emphasize the ethics and culture of science.

Student investigations should involve live animals and plants. Students must learn to show respect for all living things. A lot can be learned about plants and animals by observing them, but care must be taken to know the needs of living things and how to provide for them in the classroom.

MIDDLE ELEMENTARY

As student research teams become better at doing science, the teacher should start to emphasize how to communicate findings. Students should learn to use more tables, graphs, and drawings to summarize data, to describe their work in enough detail to enable other students to replicate it, and to submit their work to the criticism of others. This is the way good science is done.

As students become better at doing science, more emphasis should be placed on how to communicate findings.

Teachers should introduce students to career opportunities in science through books, biographies, films, visits by scientists, and visits to science centers and laboratories where science is being done. From these resources, students should see the diversity in science—men and women of all ages from around the world practicing different sciences and working in settings as varied as isolated villages in tropical rain forests, polar ice caps, the depths of the oceans, and the outer reaches of space. They should also see that doing science involves more than just scientists. People of many different specialties are part of the enterprise. Students should understand that science and science-related careers are opportunities for themselves.

Middle elementary students should see that science and science-related careers are opportunities for themselves.

UPPER ELEMENTARY/MIDDLE SCHOOL

In the upper-elementary and middle-school grades, student investigations should include greater uncertainty. Students should begin to assess risks associated with investigations. Now they should be using computers to store and retrieve data, help in data analysis, prepare tables and graphs, write summary reports, and communicate with students elsewhere.

By the upper elementary grades, student investigations should include greater uncertainty.

By the end of grade 8, scientifically literate students will understand that

- science is an adventure that people everywhere can take part in. Doing science involves many different kinds of work and engages men and women of all ages and backgrounds. Important contributions to the advancement of science and technology have been made by different people, in different cultures, at different times;

- clear communication is an essential part of doing science. It enables scientists to inform others about their work, expose their ideas to criticism by others, and to stay informed about scientific discoveries around the world. No matter who does science, or when or where they do it, the knowledge and technology produced can eventually become available to everyone in the world;

- science provides a diversity of work opportunities. Universities, industry, business, and governments provide science-related jobs in offices, classrooms, laboratories, hospitals, farms, factories, and natural settings on every part of Earth's surface;

- most scientists conduct themselves according to the ethical norms of science. These include strongly held traditions of accurate record keeping, openness, replication, and critical review of one's work by peers. Scientific ethics include providing for the health, comfort, and well-being of animal subjects. Ethical science also considers the possible harmful effects of applying the results of research.

They will be able to

- report data accurately and without bias, including findings that contradict their hypotheses,

- give and accept criticism of ideas with their fellow students,

- achieve consensus among diverse points of view,

- identify questions yet to be investigated and suggest ways of finding answers;

- use computers to facilitate their work.

They will value

- the excitement of discovery and the adventure of the scientific enterprise,

- honesty and ethics as personal attributes.

SECONDARY

In secondary school, the joint study of history, government, and science can help students understand science as a social enterprise. Students might conduct seminars on case studies that deal with actual issues of ethics in science and the role of scientists in making social decisions. Newspapers, magazines, letters to the editor, science journals, and congressional testimony contain easily accessible material for such discussions.

In secondary school, the joint study of history, government, and science can help students understand science as a social enterprise.

Students should also become aware of the great range of scientific disciplines. It is senseless, however, to have students memorize definitions of anthropology, biology, chemistry, physics, and so on.

By the end of secondary school, scientifically literate students will understand that

- progress in science and technology depends heavily on what is happening in society, and history often depends on scientific and technological developments;

- science is organized into is organized into dozens of scientific fields or content disciplines. Each discipline of science differs from the others in what is studied, the techniques and language used, and kinds of outcomes desired. Organization of science into disciplines has advantages and disadvantages;

- scientists do research in different kinds of institutions. Universities, industry, and government are all part of the scientific enterprise. University research usually emphasizes basic research, which produces knowledge for its own sake, although much of it can be directed to practical problems. Universities are also committed to educating the next generation of scientists and engineers. Industries and businesses usually emphasize applied research, which has practical use.

They will be able to

- distinguish fact from opinion unsupported by evidence,
- identify sources of bias and opinion in personal and local controversies.

They will value

- objectivity in solving family, community, national, and regional problems,
- job opportunities in science and science-related fields, including the teaching of science.

HABITS OF MIND

The scientifically literate student can use inquiry skills effectively, hold values and attitudes characteristic of an inquiring mind, communicate ideas effectively, use critical thinking to solve problems, and exhibit an inclination to actively engage in thinking.

Attitudes towards knowledge and learning are part of one's cultural heritage. They are shaped by the same influences that form all values, attitudes, and skills; family, friends, community, religion, life experiences, and education are some of them. Science and technology both reflect and respond to general societal values. Given the importance of these two forces in today's world, it is not surprising that they have become increasingly important in the shaping of the attitudes towards knowledge and learning embedded in science—openness, objectivity, logic, and skepticism.

Just as students learn the methods and skills of science by doing science, so they learn the values and attitudes of science by applying them to science. Engaging students in science helps them develop good "habits of mind," the values, attitudes, and skills that indicate a person's outlook on learning and knowledge, ways of thinking and acting. This is one of the most important functions of education.

When students are engaged in science, they are engaged in problem solving. For instance, students working on an environmental problem search for evidence that can guide them toward a solution. They draw on their reasoning skills and extend their thinking beyond the data to consider ideas from other sources. They learn to include all the data they gather, not just the data that supports their hypothesis.

Engaging students in science helps them develop values, attitudes, and skills that influence a person's outlook on learning and knowledge, ways of thinking and acting. This is one of the most important functions of science education.

Having the inclination to solve problems effectively requires good habits of mind. Developing them is integral to becoming scientifically literate. For example, on reading that trees were being cut down to obtain an important new drug found in their bark, the scientifically literate person might wonder about the yield from a single tree, the amount of drug needed, and how long a new tree would take to grow; or whether there exists another source of the drug, whether plant and animal communities in the forest might suffer from the loss of trees, or about the complexity of the ecosystem and the possible need for computer software to model the implications of the project.

Being scientifically literate means more than understanding the basic concepts in subject matter. It also means knowing how to investigate a problem and use unbiased, logical reasoning. The scientifically literate person has these habits of mind:

A. **Science Inquiry Skills.** These are questioning, imagination, inventiveness, logic, experimental evidence, measurements, and careful observation.

B. **Scientific Attitudes and Dispositions.** The scientifically literate person is curious, creative, open-minded, skeptical, willing to suspend initial judgments, able to collaborate with others, and persistent in the face of failure.

C. **Critical Thinking.** Individuals who are literate in science judge on the evidence, distinguish fact from opinion, identify bias and incomplete argument, compare trade-offs among features, performance, durability, and cost, and make informed choices on personal issues.

A. Science Inquiry Skills

Inquiry is the process in which scientists pose questions about the natural world and seek answers and deeper understanding.

Inquiry is the process in which scientists ask questions about the natural world, then seek answers and deeper understanding. Studying science through inquiry is learning science by doing it. It engages students in investigations as they are really done—as a series of creative and systematic procedures. When students engage in inquiry, they develop sensory, manipulative, process, and decision-making skills along with the willingness to use them to become independent learners. They learn good habits of mind.

Inquiry is essential to the science curriculum at all grade levels. It rewards students' curiosity and encourages their questioning spirit.

Inquiry is essential to the science curriculum at all grade levels. It rewards students' curiosity and encourages their questioning spirit. Because inquiry is part of the scientific process, doing it develops students' understanding of scientific investigation. They learn to select and frame a question that can be explored through experimental procedures; to design the procedure, then choose and use the appropriate tools for collecting, measuring, and describing phenomena. They learn to systematically observe phenomena, record data, organize it, analyze it, conclude the investigation, and explain its findings. Students should also be able to relate conclusions to data, relate their experiments to those of others, relate their experiments to models and theories, and suggest further investigations. By engaging in inquiry themselves, students learn that the basic ideas of science are the result of inquiry processes.

Scientists know that finding answers to questions about nature means using one's hands and senses as well as one's head. The same is true in medicine, engineering, business, and many other fields. Thus scientific inquiry in the classroom should include hands-on activities, experimentation, active data collection and analysis, and invention. It could also include story-telling, song, dance and other kinesthetic activities, and construction, reflection and brainstorming, artistic representation, computer simulation, graphing, multimedia technology, and other strategies.

By engaging in inquiry themselves, students will come to understand that the basic ideas of science are the result of inquiry processes.

Through inquiry, students can also learn the value of tools. From hammers to cameras to computers, tools extend human capabilities. People may seldom use telescopes, microscopes, and the sophisticated instruments of science, but they encounter a wide range of mechanical, electrical, electronic, and optical tools. All these are ways that science goes about creating new knowledge and understanding. These processes can be used by anyone in science and in other fields. They should be reflected in the classroom as well as in science.

LOWER ELEMENTARY

Students should be engaged in investigating events that interest them both in and out of class. These investigations should be fun, opening the door new questions and explanations. An important part of students' investigations is telling others what they see, what they think, and what they wonder about. Students should have time to talk about what they observe and compare their observations with others.

In the lower elementary grades, students should learn about things by watching them carefully and doing things to them to see what happens. They can use tools like thermometers, magnifiers, rulers, and balances to get more information about things, then describe what they see and compare with others' descriptions. Activities should provide opportunities for students to use hammers, screwdrivers, clamps, rulers, scissors, and operate ordinary audio equipment. They can investigate how things work by assembling, describing, taking apart and reassembling constructions using interlocking blocks and parts. Making useful things out of paper, wood, plastic, metal, or other materials strengthens their confidence and willingness to engage in problem solving.

In the lower elementary grades students should learn about things by watching carefully, using simple tools, and describing things, and comparing with others' descriptions.

By the middle elementary grades, students should know that scientific investigations may take many forms and that explanations come partly from what scientists see and partly from what they think.

MIDDLE ELEMENTARY

The middle elementary student is ready to try to explain why things happen as they do. Young children find it difficult to distinguish between explanation and description, but at some point, they can be helped to see the difference. By the middle elementary grades, students should know that scientific investigations may take many forms, from observing what things are like, to collecting specimens for analysis, to doing experiments. They should understand that scientific explanations come partly from what scientists see and partly from what they think. They should also recognize that sometimes a scientist's explanation of an event will differ from that of his colleagues. This is all right, but each explanation must be backed by evidence and logical argument.

Activities appropriate for this age group require students to choose common materials for making simple mechanical constructions and repairing things, for example, measuring and mixing dry and liquid materials (in the kitchen or laboratory) in prescribed amounts while practicing proper safety. Students should record their observations in a notebook, distinguishing them from speculations about what was observed. Students should also begin to use calculators to process data they collect, including figuring area and volume and working with amounts of mass, time, and cost.

By upper elementary, it is time for students to become more systematic in conducting investigations.

UPPER ELEMENTARY/MIDDLE SCHOOL

By upper elementary, it is time for students to become more systematic in conducting investigations. They are ready to learn some science concepts through reading. It is neither possible nor desirable for students to learn how the world works only through their own investigations. However student investigations remain an essential part of the science experience. Students must understand that, in science, failure is more common than success. Making mistakes while investigating a problem is all right; the important thing is to learn from unsuccessful attempts.

Students at this age should also realize that there is no fixed set of steps for carrying out science investigations. A good investigation uses logical reasoning and some imagination in forming a hypothesis, carefully collects relevant evidence, then uses logical reasoning and imagination to analyze and explain the data. If more than one variable is changed, the outcome of an investigation cannot be attributed to any one of the variables.

By the end of grade 8 scientifically literate students will understand that

- inquiry is an interesting and successful way to solve problems;
- the skills developed through scientific inquiry can be used in other subject areas in school and in personal endeavors.

They will be able to

- demonstrate skill in asking valid, testable questions about the world around them,
- design investigations to seek answers to science questions,
- inspect, disassemble, and reassemble simple science apparatus and mechanical devices and describe what the various parts are for,
- use calculators and computers to compare amounts, store and retrieve information, analyze and display data and graphs, and communicate with others,
- read analog and digital scales on instruments to measure length, volume, mass, elapsed time, rates, and temperature; choose appropriate units for reporting data,
- estimate the effect on the system of changing one of its parts.

They will value

- their increasing ability to use sensory, manipulative, process, decision-making, and other skills,
- their increasing confidence as self-directed learners capable of taking initiative and responsibility for their own learning,
- their curiosity and willingness to engage in learning and problem solving.

SECONDARY

Secondary school students are prepared to deal with abstractions, models, and theories and to realize that different theories can compete for acceptance. However, only theories supported by valid evidence and strong logical argument are considered in science.

By the end of secondary school, scientifically literate students will understand that

- scientists experiment in order to test how well a theory predicts and to compare competing theories;

- when inquiry by experiment is impractical, scientists try to observe a wide range of natural events to identify patterns;

- regardless of their field, all scientists share basic beliefs in the value of evidence, logic and good argument. Progress in all fields depends on reason, hard work, imagination, and chance;

- when new ideas in science that conflict with accepted ideas, they will encounter vigorous criticism and opposition. In the long run, theories are judged by how well they explain available evidence, the range of observations they explain, and how well they predict new findings.

They will be able to

- learn the proper use of new instruments by following instructions in manuals or by taking instructions from an experienced user,

- use computers for producing tables and graphs, making spreadsheet calculations, and preparing reports of investigations,

- troubleshoot mechanical and electrical systems, checking for possible causes of malfunction, and deciding whether to change a part or get advice from an expert before proceeding,

- use tools safely to shape, smooth, and join wood, plastic, and other materials.

They will value

- applying inquiry skills in their personal lives,
- the confidence they get from being knowledgeable and reflective learners, capable of taking initiative and responsible for their own learning,
- curiosity, a willingness to learn, and readiness to attack problems.

B. Attitudes & Dispositions

Good science teaching encourages students to be curious, creative, open-minded, skeptical, willing to suspend initial judgments, able to collaborate with others, and persistent in the face of failure. In the science classroom, the finding out is as important as knowing the answer.

Children are curious from birth. The challenge for teachers is to avoid dampening curiosity while helping students focus it productively. Doing science is an excellent way to foster students' natural curiosity about scientific and technological phenomena and show them productive approaches to learning how the world works. Students will eventually see that finding good answers and solutions is as much fun as raising good questions.

By building upon students' curiosity about scientific and technological phenomena, teachers lead students to discovering productive ways of finding answers to questions about how the world works.

Students may find it difficult to balance open-mindedness with skepticism. These two dispositions seem contradictory. In science there is often tension between being open to new theories and unwilling to discard current ones. But students should learn that one can admire a proposal yet remain skeptical until good evidence is offered for it. When students explain what they observe or wonder about, teachers should insist their classmates hear them out.

Honesty is a highly prized habit of mind in the scientific community, but it is not unique to people who practice science and technology. Most children can define the principle of honesty. What it means to them in practice, however, probably comes from their seeing firsthand how it is applied in different situations. In school science, for example, students should always record and report their observations, not their speculations or expectations. In technology, students should state the limitations of their designs.

Honesty, especially in recording and reporting data, should be valued.

The development of attitudes such as respect, responsibility, and honesty can guide students in making good choices.

Positive attitudes and a willingness to act are not simply requirements of a scientific way of thinking and doing, they are essential if our Pacific children are to care about themselves, others, their environments, and cultures. We want our children to develop attitudes of respect, responsibility, and honesty; these will guide them to make good choices and decisions in life. A cooperative spirit and willingness to listen are likewise valued not only to support good teamwork in science, but also to promote cooperation in community and elsewhere.

LOWER ELEMENTARY

In lower elementary the highest priority should be to foster curiosity.

The highest priority for this grade level should be to encourage students' curiosity about the world around them. Nature easily captures students' attention. Encourage them to wonder about mathematical and technological phenomena as well. Treat questions about numbers, shapes, and artifacts with the same interest as those about rocks and birds.

As students learn to write, they should start keeping a class list of things they wonder about. Teachers can help them learn to pick from the list questions that they can answer by collecting, sorting, counting, drawing, taking things apart, or making something. Choose questions that can be answered descriptively over those requiring abstract explanations. Students are more likely to give reasonable answers to "how" and "what" rather than "why."

In the early grades, choose questions that can be answered descriptively over those requiring abstract answers.

Some questions can be raised to foster scientific habits of mind. Students should learn that a question such as "Why don't plants grow in the dark?" might better be addressed in science as "Is it true that plants don't grow in the dark?" "How do you know?" "How can we find out if it is true?" If the facts are correct, then explanations can be developed. Everyone's ideas should be valued Comparisons of which answer is best can come later. For now differing opinions should be regarded as interesting ideas.

MIDDLE ELEMENTARY

Emphasis should be placed on learning to ask interesting questions about the world that can be answered through investigation.

In the middle elementary grades, sustaining curiosity is still a high priority. Students of this age should learn to state their questions about how the world works in a form that is answerable by investigations, building and testing things, and consulting references. Whether working alone or in teams, students should record in bound notebooks what they did, what happened, and what they think the results mean. Students should be encouraged to devise explanations for their findings. They should learn that for any given collection of evidence, it is usually possible to invent different explanations, and it is not always easy to tell which is best.

The teacher should emphasize honesty in record-keeping rather than the correctness of explanations.

UPPER ELEMENTARY/MIDDLE SCHOOL

Scientific values and attitudes introduced in earlier grades can now be reinforced and developed further. Students should be given time to pursue scientific questions that interest them. Working on individual and group inquiry projects creates such opportunities in a context that encourages students to express curiosity, honesty, skepticism, persistence, and a willingness to engage in thinking.

Students of this age increasingly offer hypotheses and explanations. It is thus a good time for them to sharpen these skills. Both hypotheses and explanations are judged by reference to evidence. A hypothesis does not have to be correct—one can believe it or not. But to receive serious consideration, it should indicate what evidence is needed to decide whether or not it is true. This approach requires both openness and skepticism. Similarly, there are often several ways of explaining data. Having teams invent multiple explanations for a set of observations, or having different teams independently devise an explanation for the same data can ground discussions of the nature of scientific explanations in reality.

In the middle school grades, additional consideration should be given to offering hypotheses and explanations.

The teacher should structure activities to foster in students positive attitudes and a willingness to act. An appropriate activity for this grade level would be adopting and maintaining a beach, road, or other island environment. This can be done by individual students, in groups, or as a class. Students would select a particular island environment to study, discuss the work with classmates, and care for it during a specified period. Or they might participate in a tree planting or community clean-up project to beautify the island. The class could invite resource people to talk about or show cultural uses of particular plants for building, tool making, medicine, and so on. Field trips contrasting pristine parts of the island with those heavily affected by human activity could be used to develop dispositions toward respect and nurturing of fragile ecosystems.

By the end of grade 8 scientifically literate students will understand that

- it is important in science to keep honest, clear, and accurate records;.

- hypotheses that lead to fruitful investigation are valuable, even if they are found to be untrue. Making mistakes is part of learning;

- different explanations can be given for the same evidence, and it is not always possible to tell which one is correct.

They will be able to

- show they care and respect for living things and their environment.

They will value

- understanding their surroundings and recognizing science as a tool for doing this,

- being curious about how the world works and open to new ideas,

- respecting other people, their cultures, and all living things and taking responsibility for the environment,

- perseverance in the face of failure,

- cooperating, teamwork, interacting with and listening to others.

SECONDARY

Skepticism is a valuable response to the healthy, political, commercial, and technological claims they encounter.

Skepticism is not just a willingness to challenge unsupported statements. It is a determination to suspend judgment in the absence of credible evidence and logical argument. Students can learn its value in doing science. Given that most students will not be scientists as adults, the challenge for educators is to help students internalize this critical scientific attitude so they can apply it in everyday life. Skepticism is a valuable response to the health, political, commercial, and technological claims they encounter.

The challenge for educators is to help students internalize this critical scientific attitude so they can apply it in everyday life.

Openness to new and unusual ideas about how the world works can be further developed through case studies of historical events in science as well as continuing involvement in inquiry projects. The history of science shows that the ideas it develops are both stable and changing. This is exemplified by the Copernican Revolution. This and other case studies illustrate that ideas in science are not easily or quickly accepted. Some mixture of openness and skepticism serves most people and societies well.

Appropriate activities for high school students might include debates and discussions of local issues. Different formats reveal different perspectives and to examine an issue in some depth. For example the broad topic of environmental issues can be explored by debating environmental restrictions and conservation laws, inviting elders to discuss traditional ways of using and preserving limited island resources, or working as part of a group pooling ideas, explanations, and solutions on local environmental issues.

By the end of secondary school, scientifically literate students will understand that

- curiosity, honesty, openness, and skepticism are deeply embedded in science.

They will be able to

- be curious, honest, open, and skeptical in their own lives and value these attitudes in others,
- view science and technology thoughtfully, being neither antagonistic or uncritically positive,
- demonstrate by their actions in the community caring and respect for the environment and all living things.

They will value

- that new data or interpretations can lead to different explanations of phenomena and changes in knowledge,
- cooperating, teamwork, interacting with and listening to others,
- being empowered to participate in science and technology.

C. Critical Thinking

People are bombarded daily by claims about products, about nature, about how devices work, about their health and welfare, about what happened in the past, and what will occur in the future. These claims are put forth by experts (including scientists) and non-experts, by honest people and dishonest ones. Knowledge helps people evaluate this information. But apart from what they know about an assertion, scientifically literate people can evaluate these claims by analyzing them. The use or misuse of supporting evidence, the language used, and the logic of the argument presented offer clues for judging how seriously to take someone's claim. These critical thinking skills can be learned and, with practice, become lifelong habits of mind.

LOWER, MIDDLE, AND UPPER ELEMENTARY/MIDDLE SCHOOL

In the elementary grades critical thinking skills can be developed through the students' inquiry activities.

In the elementary grades critical thinking skills can be developed through the students' inquiry activities. These skills are not taught directly; they develop as a student accumulates experience with investigations, explaining the outcomes with evidence and logical argument. The process begins in the early grades when the student is asked "How do you know?" and attempts a reasonable answer when others ask the same question.

Statements are accepted as true when they are supported by observations, facts found in books, or other reliable sources of information that can be verified or replicated.

Students learn to accept statements as true when they are supported by observations, facts found in books, or other reliable sources of information that can be verified or replicated. They should be engaged constantly in comparing similarities and differences in the objects and events they observe, artifacts they collect, instruments they design, and data they generate. With practice, students learn to know when a comparison might be unfair because the conditions were not kept the same. When students learn to rely on evidence to support their statements, they reject such statements as "Everybody knows that..." or "I just know."

By the end of grade 8, scientifically literate students will understand that

- they should question claims based on vague assertions such as "Leading doctors say..." or on statements by celebrities or people who are not experts. The sources of such statements should be asked for evidence to support their claims.

- they should be skeptical of arguments based on biased samples, very small samples, or samples for which there was no control.

- there may be more than one good way to interpret a set of findings.

They will be able to

- use critical thinking skills to make informed decisions in their everyday lives,
- choose consumer products by comparing features and making reasonable trade-offs among features, performance, durability, and cost,
- see and criticize the faulty reasoning in arguments that mingle fact and opinion,
- lack a conclusion that follows logically from the evidence. use an inappropriate analogy,
- fail to mention whether control groups are comparable to the experimental group, or imply that all members of a group (all teenagers, doctors, patients, students) have nearly identical characteristics.

They will value

- the power of critical thinking skills for making informed choices on personal issues.

SECONDARY

Secondary school students should focus on strengthening their ability to evaluate data and claims. This skill is necessary to do good science, and is essential for making wise decisions about personal, community, social, and environmental issues.

By the end of secondary school, scientifically literate students should understand that

- when people try to prove a point, they may select only the data that support it and ignore any that contradict it.

They will be able to

- use critical thinking skills in their own lives to make informed choices on personal, family, community, state, regional, and global issues,

- insist that the assumptions behind any line of reasoning be clarified so that the accuracy of the assertion can be judged,

- identify and criticize arguments based on faulty, incomplete, or misleading use of numbers,

- suggest alternative explanations for a data set; criticize arguments that fail to present alternative explanations or that present data, explanations, or conclusions as the only possibilities; suggest alternative trade-offs in decisions and designs and criticize those in which major trade-offs are not acknowledged.

They will value

- the probability that an event of interest might have occurred by chance,

- the strength of critical thinking skills in making informed choices on personal issues.

SCIENTIFIC CONNECTIONS

The scientifically literate student actively seeks connections within the sciences and between science and other areas.

Scientific thinking enables people to organize and communicate their thoughts about the world in ways that reveal patterns, unity, and order. Science helps us see the relationships between seemingly disconnected phenomena and events. Thus we expand our knowledge and deepen scientific understanding of the world.

Science enables people to think about the world in ways that reveal patterns, unity, and order.

The ideas developed by each generation about our physical, biological, psychological, and social worlds have built on each other and interconnected to produce an increasingly comprehensive and reliable understanding of humankind and its environment. Science has played a role in making these linkages. Along with its particular ways of observing, experimenting, validating and thinking, science is about seeking connections.

Science is about seeking connections.

A powerful idea in science is that all the disciplines of science and most areas that we think of as outside the domain of science are, in fact, connected by conceptual themes. These themes link, for example, traditional disciplines such as the physical, life, and Earth sciences, and extend to other subjects such as technology, mathematics, geography, and social studies. Thematic linkages have proved to be a fruitful approach to thinking about and explaining the natural and designed world.

Students should be encouraged to look carefully for connections so they can perceive relationships among the sciences, culture, and daily life. The scientifically literate student is engaged in

Students should be encouraged to look for relationships among different science systems, culture, and daily life.

A. **Seeking Connections Among the Sciences**. Although each discipline of science seeks knowledge and understanding in its own way, common themes connect them all.

B. **Seeking Connections Between Science and Other Subject Areas.** Science shares unifying themes with other subject areas including mathematics, technology, social studies, and language arts.

A. Seeking Connections Among the Sciences

It is this willingness and ability to look for connections that helps us make sense of the world.

A scientist's search for information within one discipline of science often leads to examining concepts and information from other fields of science and from disciplines outside of science. It is this willingness and ability to look for connections that helps us make sense of the world.

An approach to helping students seek connections is to organize learning around common themes. Themes are ideas that integrate the concepts of different scientific disciplines in ways that help students make connections and answer powerful questions about their world. Themes transcend disciplinary boundaries and prove useful in explanation, theory, observations, and design. The ideas of measurement, form and function, and interactions are such themes.

Themes are ideas that integrate concepts in ways that help students make connections and answer questions about their world.

Measurement

Explanations in science are clarified by expressing some observations as measurements. Measurement provides precision in observations and makes possible the comparison of different scientific explanations. Students should develop skill measuring accurately, using units of measurement appropriately, and estimating measurements.

Form and Function

Systems have characteristics, shapes, and properties which define their form. Systems also may accomplish tasks and perform activities; they perform functions. When investigating the natural and designed world, students should be able to explain function by form and, conversely, form by function.

Interactions

Most people tend to think of the properties of a system as belonging to the individual parts of it rather than arising from the interaction of the parts. Sometimes this is true. For example, a politically conservative organization may be entirely made up of conservative individuals. But some features of a system are unlike their parts. Sugar is sweet, but its component parts (carbon, oxygen, and hydrogen) are not. A system property that arises from the interaction of the parts is a difficult idea to grasp.

At the most basic level, units of matter interact. Organisms, populations, the atmosphere, and the lithosphere interact. Interactions occur on scales ranging from elementary particles, to continents, to planets, and to galaxies. Students should develop the ability to apply the concept of interaction to materials, objects, events, organisms, and systems in the world. The more they understand about interactions, the better they can predict changes in systems and develop the major conceptual idea that interactions conserve energy and matter, and equilibrium is the ultimate result of interactions.

LOWER ELEMENTARY

Encouraging students to consider and raise questions about their world, to tell others what they see and think, and to wonder about their environment will help them value connection-making. Among young children, ideas of same and different can be a natural starting point. Open-ended questions that link the living and physical environments and that gradually stretch their ability to make connections are appropriate at this level. For example, asking young children "How are trees and houses alike? How are they different?" or "What's the same about . . .?" encourages them to seek and make connections.

Encouraging students to consider and raise questions about their world will help them value connection-making.

Young students should use simple procedures and instruments to estimate and measure some of the properties of objects, organisms, systems, or events. Measuring enables students to understand attributes such as length, weight, area, volume, time, temperature, and angle.

In the elementary grades, students can identify the forms of different materials and the functions of different components of systems. For example, the connection between form and function might be introduced using their hands as objects of study.

Students can observe interacting systems in the environment. Two important features of interaction can be introduced in the early years. First, there is usually evidence for interaction. For example, sound, heat, and visible changes often are produced by interaction. Second, children can begin sorting out the cause-effect relationship in interactions.

MIDDLE ELEMENTARY

Students should practice identifying the parts of things and how one part connects to and affects another. Classrooms should have a variety of objects that can be assembled and disassembled such as gears, toy vehicles, blocks, hand tools, familiar hardware devices, and so on.

In the middle grades, students' use of measurement should extend to estimating measurements, selecting appropriate units and tools, and understanding the concepts of perimeter, area, angle, capacity, weight, and mass. Students can explore the use of statistics and probability in the context of science investigations and design problems. Students can collect, organize, and describe data; construct, read and interpret tables, charts, and graphs; and perform simple statistical analysis, such as determining the range or average in a data set. Computers can be used to display results in graphs and simulations.

As students study the properties of objects, organisms, and materials, they can be introduced to the idea that the way objects look, feel, and sound often relates to the actions they perform. They can see this in, for example, the form of leaves and the design of pencils.

Students should learn to recognize the ways systems interact with one another.

Students should learn to recognize the ways systems interact with one another, and they also should be able to predict what will happen as a result of continued interaction. They should be able to keep track of, or least infer, the transformation of matter and energy in interactions within and among systems.

UPPER ELEMENTARY/MIDDLE SCHOOL

Probability is the measurement of the likelihood of an event. Students in the upper elementary must be involved in activities and investigations that help them develop an understanding of the numerical expression of a probability, the events that give rise to these numbers, and the fact that more or less data influences the measure of certainty. In the course of using probability, students can compare experimental results with mathematical expectations, and apply probability to personal and social issues.

Students can apply the concept of form and function to their investigations.

Students can apply the concept of form and function to their investigations. In doing this, they expand their perspective of the concept and combine it with other concepts, such as systems, organizations, and interactions. Students can look for form-and-function relationships in common materials, such as bicycles, and cultural artifacts.

Interacting units tend toward states in which energy content is a minimum and the energy distribution is most random. In the process of reaching this state, matter and energy transform, but the sum of matter and energy remains constant. Without exception, two principles, the first and second laws of thermodynamics, apply to all interactions. The first law states the principle of conservation of matter and energy. The second law states that heat will flow from warmer to cooler systems, but the reverse will not occur.

By the end of grade 8, scientifically literate students will understand that

- measurement provides precision in observations and distinguishes science from other ways of knowing;
- connection between form and function exists across disciplines; it gives us a way of looking at and understanding the world;
- interactions occur on scales ranging from elementary particles to galaxies;
- in transformations of matter and energy, the sum of matter and energy remains constant.

They will be able to

- measure the properties of objects, organisms, systems, and events using appropriate tools and units,
- estimate measures with a high degree of accuracy,
- use tables, graphs, and charts to describe data and apply statistical procedures in their analysis,
- apply the concept of form and function to their investigations;,
- apply the concept of interaction to materials, objects, events, organisms, and systems,
- predict changes in systems as a result of interactions.

They will value

- connections that help unite ideas in science and build personal understanding.

SECONDARY

Students should develop a sophisticated understanding of measurement.

High school students should develop a sophisticated understanding of measurement and use it in science investigations and science-related issues. They should be able to estimate error in measurement and make accurate and precise use of graphs, tables, and charts in presenting data. As they investigate scientific phenomena and study the designed world, they should use statistics to develop inferences from data summaries, measure central tendency, determine variability, correlate variables, and sample populations.

Students can examine form and function in their studies of the levels of organization within physical, life, and Earth systems. In life sciences, for example, students should make the connection that form and function of cells, tissues, organs, organisms, and ecosystems result from cumulative natural selection.

High school students should be able to track the transformation of matter and energy in the natural and the designed world.

High school students should be able to track the transformation of matter and energy in the natural and the designed world. Living systems maintain their organization through interactions of their subsystems. This requires the use of energy; disorganization or death result when there is no energy, or when the living system does not use energy appropriately.

By the end of secondary school, scientifically literate students will understand that

- measurements can be graphically represented by the accurate and precise use of graphs, tables, and charts in the presentation of data;
- form and function in natural systems result from variation, adaptation, and natural selection; in the designed world, form and function result from design and engineering;
- living systems maintain their organization through interactions of matter, energy, and subsystems.

They will be able to

- use probability and statistics to make accurate inferences from data and events,
- trace the flow of transformations of matter and energy in natural and designed systems.

They will value

- measurement, form and function, and interaction as useful themes that help make connections in science.

B. Seeking Connections Between Science and Other Subject Areas

Students should search for ideas of science in areas other than science.

In every subject area, the scientific point of view can enrich students' perspectives. Students should search for ideas of science in areas other than science. For instance, they can study the influence science ideas have had on history. Many global issues, such as AIDS, overpopulation, and the greenhouse effect, require some knowledge of science in order to be fully understood.

The themes of systems, models, scale, constancy and change apply not only to science, but also to business, finance, education, law, government, politics, and other domains outside science and technology. These common themes are ways of thinking that connect scientific inquiry and scientific habits of mind with many disciplines.

Systems

The natural and designed world is too immense and complex to investigate or comprehend all at once. Thus, scientists and students learn to limit their investigations to portions of the world. The units of investigation are referred to as systems. A system is a group of related objects that form a whole. The objects may be either large or small, living or non-living, concrete or abstract.

One of the essential components of higher-order thinking is the ability to consider the whole in terms of its parts and, alternatively, to consider the parts in terms of how they relate to one another and to the whole. For example, people are accustomed to speaking about political systems, sewage systems, transportation systems, the respiratory system, and the solar system.

Students learn about systems so they can use this concept to understand various aspects of the world.

The concept of systems helps students learn about the world. Thinking and analyzing in terms of systems helps students keep track of objects, organisms, and interactions. Systems create manageable units for investigation and study, and they help us understand other concepts such as transformation and conservation of matter and energy.

Models

The usefulness of models lies in their ability to explain observations and concepts.

Physical, mathematical, and conceptual models are tools for learning about the things they are meant to resemble. Scientists and engineers use models to help them understand how things work. The usefulness of models lies in their ability to explain observations and concepts. Thus they help students develop understanding as well as abilities. Models provide a conceptual bridge between the concrete and abstract, and student understanding should proceed over the years from concrete models to mathematical models to conceptual models that correspond to real objects, systems, and events. How well a conceptual model works depends on people's ability to imagine that something they do not understand is in some ways like something they do understand. Imagery, imagination, metaphor, and analogy are as much a part of science as deductive logic.

Scale

Most variables in nature—size, distance, weight, temperature—differ immensely in magnitude. As they become more skillful in science, students should encounter ever larger ratios of upper and lower limits of these variables. But that is only the starting point for the idea of changes in scale. The larger idea is that the way in which things work may change with scale. For example, as something changes in size, its volume changes out of proportion to its area. So properties that depend on volume, such as mass and heat capacity, increase faster than properties that depend on area, such as bone strength and cooling surface.

Constancy and Change

Much of science and mathematics has to do with understanding the mechanism of change in systems.

Students should come to see that much of science and mathematics has to do with understanding the mechanism of change in natural, social, and technological systems. A lot of technology pertains to creating and controlling change. Constancy is also a subject of intense study in science. The simplest account of anything is that it does not change. Stability, conservation, equilibrium, steady state and symmetry are some types of constancy. Students need not memorizing the meanings of these terms; the important point is that they comprehend them.

Some change is cyclical: the direction of the change reverses at some point. Diurnal cycles, lunar cycles, seasonal cycles, and menstrual cycles are cyclical. Some change, however, is one-directional, for example, physical growth and intellectual development, puberty, and menopause.

The rate of change of a variable is of great interest to scientists. Understanding rate of change is more difficult than it might seem, because some variables change at a constant rate, while others change at an increasing or decreasing rate. Graphing rates of change provides a clear picture of the data in question. Thus graphs help scientists and students understand what they have observed. A student's goal should be to know how to read and interpret a graph of the behavior of any familiar variable against time and be able to tell a story about what is going on.

LOWER ELEMENTARY

During class discussions, projects, readings, and investigations, students should be given time to reflect on the value of thinking in terms of systems. They should be encouraged to apply the theme to diverse situations. For instance, they can describe the parts of simple and complex systems such as toys and bicycles. They can describe how parts relate to each other and the boundaries of the system as well as how it functions. These experiences should build a foundation for future study and application of the concept.

Young children understand physical models best, so teachers should use them to introduce modeling to students. Dolls, toy cars, boats and airplanes, and other everyday objects can stimulate discussions about how models are like and unlike real things. In the early grades, the term *model* should probably be used only to refer to physical models, but the notion of likeness is the central idea in using any kind of model.

Teachers should use physical models to introduce modeling to young children.

To understand how a variable changes with scale, students need to know the range of values for it and how to express the range in numbers that make sense and can be compared. Children should start by noticing extreme values of familiar variables—biggest, smallest, fastest, slowest—and how things may be different at those extremes. In the early grades they should be building structures and other things in their technology projects. Through such experiences they can begin to understand both the mathematical and engineering relationships of length, area, and volume. They can be challenged to measure things that are hard to measure because they are very small or very large, very light or very heavy. Terms about scale should be introduced only when students are well grounded in such direct experiences.

Whenever students study science, mathematics, or technology, the teacher should introduce discussion on the theme of change. Students should learn first to recognize change and describe it. Only after they have extensive experience with different kinds of change are they ready to start thinking about abstract patterns of change.

MIDDLE ELEMENTARY

The emphasis should be on a rich variety of experiences.

Middle-grade students are ready to explore some of the characteristics and dynamics of systems. The idea of simple systems extends to the idea of a subsystem, which is a system within a system, such as a student in a family, or a class in a school.

To become adept in the use of conceptual models, students need a foundation of hands-on experience with the materials, things, and processes around them. The curriculum emphasis, therefore, should be on creating a rich variety of experiences, rather than focusing on conceptual models themselves. Students need to acquire images and understanding from drawing, painting, sculpting, playing music, acting in plays, listening to and telling stories, reading, participating in games and sports, doing work, and living life.

Students' growing use of mathematics should be used extensively.

As students proceed to the upper grades, they should realize that measurement tools—thermometers, rulers, and balances—express precise scale qualities of systems. When they do science, this group of students should apply their growing understanding of mathematics. They should search for relationships, such as ratios, and apply elementary statistics. They should investigate the relationship of size to complexity and apply the concept of scale to understanding physical and biological phenomena. Students should understand and apply the notion that systems work differently and have different structures as they become more complex.

Middle elementary students should recognize patterns of change in the natural and designed world.

As students progress from elementary to middle school, they will develop a more sophisticated understanding of change, which will include such features as measuring and quantifying change, identifying the different qualities of change, perceiving different scales of change, and recognizing different patterns of change in the natural and designed world.

UPPER ELEMENTARY/MIDDLE SCHOOL

Students at this level can investigate the interactions and interdependence between systems.

Students at this level should be able to identify the boundaries, components, flow of resources, and feedback within systems. Also, they should understand the differences between open and closed systems. They can investigate the interactions and interdependence between systems and can investigate the fact that output from one system can be input for another.

Upper elementary and middle school students should be able to create and use models in many contexts, including computer simulations.

In the upper grades, students have enough academic knowledge and hands-on experience to deal with models more explicitly. They can examine physical models for the effects of scale on area, volume, and length. Students are ready for mathematical modeling, which epitomizes the nature and power of models and creates a context for connecting knowledge from different domains. The teacher's main goal should be to get students to create and use models in many contexts, rather than recite generalizations about them.

Students can use computer simulations as an aid to understanding conceptual models.

Students can use computers to develop and apply conceptual models. They can change variables with simulations and extend simulations for long periods of time. Students also should be able to make connections to the conceptual models expressed in other standards.

The study of scale lends itself to computer simulation in which the user can change scales at will.

As students become more familiar with very large and very small numbers, ratios, and powers of ten, extremes of range and changes in scale become more meaningful. In the upper elementary the use of ratios can now be explicit and comparisons of powers of ten extended. The teacher can introduce the idea that things necessarily work differently on different scales. Students can run computer simulations to study the effects of changes in scale on systems. For example, cooling rates of different-sized samples of water, strength of different-sized constructions from the same material, flight characteristics of different-sized model airplanes, all demonstrate the effect of scale.

Cycles of change can be extended in scales of time, space, and material.

The teacher can extend the idea of cyclical change to scales of time, space, and material. Students at the middle-school level are intrigued with biological systems, particularly their own. They should understand the limits to the capacity of systems to change and still maintain their identity.

By the end of grade 8, scientifically literate students will understand that

- a system is a group of related and interacting objects that form a whole; systems create manageable units for investigation and study;
- open and closed systems have different properties and transformations;
- imagery, imagination, metaphor, and analogy are as much a part of science as deductive logic is;
- the way in which things work may change with changes in scale;
- the concept of constancy includes stability, conservation, equilibrium, steady state, and symmetry;

- some change is cyclical; some is unidirectional.

They will be able to

- describe the parts of systems and how they function and relate to one another,
- identify systems and subsystems, including their boundaries, components, functions, flow of resources, feedback, and interactions;
- recognize, describe, and measure change,
- create and use models in different contexts,
- use computers to develop and apply conceptual models, investigate effects of changes in scale on systems, and run simulations of change and systems.

They will value

- thinking in terms of systems and applying systems in diverse situations,
- connections between science and other subject areas that help individuals gain knowledge.

SECONDARY

Secondary students should be able to apply their understanding of systems to scientific investigations, mathematics, technology, government, and society.

High school students should be learning to do systems analysis—the application of systems concepts and language to analyze problems in science, mathematics, technology, government, and social systems. They should compute, do investigations, and project outcomes using the computer. They should be able to compare the outcomes predicted for models they have designed with measurements of actual phenomena.

As students use models to help clarify their understanding of systems, they should realize that mathematical models can express functions in systems or relationships among systems and subsystems. For example, the density of objects is expressed as D=M/V. This model means that the density of an object is a function of its mass per unit of volume. Knowing the formula of density is not important; the significance of the mathematical model lies in understanding its power to explain density as it may be applied to understand real situations such as ocean currents or atmospheric circulation.

By secondary school students should have the background, experience, and sophistication to begin to grasp very large scales such as distances in the solar system, the number of stars in the universe, or the age of Earth. Similarly, very small scales necessary to compare structures at the microscopic or atomic level should be more readily grasped.

Secondary school students should have the background to begin to grasp very large and very small scales.

In grades 9–12, the theme of conservation should be clearly evident in science investigations. Students should realize that physical, life, and Earth systems exist in time and space. Because these systems interact, they change over time. Their rates of change differ widely, and their patterns of change exhibit great variety. Although matter and energy may be transformed during changes in systems, the sum of matter and energy is conserved.

The theme of conservation is clearly evident in science investigations.

By the end of secondary school, scientifically literate students will understand that

- systems analysis can be usefully applied in science investigations and in many other situations;
- mathematical models help clarify understanding of systems and express functions and relationships in systems and subsystems;
- applying the concept of scale to the universe or to the atomic level helps us understand the world around us;
- rates of change vary widely, and patterns of change exhibit great variety,
- the sum of matter and energy in transformations is conserved.

They will be able to

- use systems analysis to analyze a variety of situations,
- use computers to compute, simulate systems, and analyze models,
- apply concepts of systems, models, scale, constancy and change in science and other subject areas.

They will value

- systems, models, scale, constancy and change as useful themes that help make connections in science and other subject areas.

NATURE OF TECHNOLOGY

Scientifically literate students understand the nature of technology and its relationship to science and culture. They are prepared to make informed decisions about technological issues.

Technology is the application of knowledge to develop materials and systems that help people meet their needs and fulfill their desires. We use technology to make the world over to our design. It extends our ability to change the world—to cut, shape, or put together materials; to move from one place to another; to reach further with our hands, voices, and senses.

Technology is an integral part of every culture.

In the past, new technologies applied accumulated practical knowledge. Although this approach still yields valuable products, most new technologies today evolve from an understanding of complex scientific principles. Today's technologies are being developed to meet increasingly complex needs. They are more complex, and so are the processes involved in creating them, from research, design, and crafts, to finance, manufacturing, and marketing.

Pacific islanders developed sailing canoes, a form of technology, because they needed to fish and travel on the oceans. In turn, the experience of sailing, discovering new islands, and encountering other peoples changed their cultures.

Technology is an integral part of every culture. It both shapes and reflects a culture's values. Pacific islanders developed sailing canoes, a form of technology, because they needed to fish and travel on the seas. In turn, the experience of sailing, discovering new islands, and encountering other peoples changed their cultures.

Pacific children live in a world of rapid technological change.

Pacific children live in a world of rapid technological change. The effects of new technologies are often unpredictable and complex They may include unexpected benefits, unexpected losses, and unexpected risks. Because new technologies affect all aspects of life—health, employment, leisure, and personal and political decision making—anticipating their effects is as important as developing them. For these reasons, understanding technology is a crucial component of scientific literacy.

Technology education must be strengthened to enable island citizens to decide wisely about using technology, while maintaining the fragile island environments and unique cultures.

Progress in science and technology has given humankind the capacity to change the world on a grand scale. This is reflected in a growing awareness of the often pronounced effects of technological development on everyday life and culture in the Pacific islands. In a region where few people are prepared for such change, education plays a key role in preparing young people for decisions they will have to make as adults about their lives, careers, and environment—decisions that increasingly depend on a clear understanding of science and technology. Students must understand the influences of technology on culture and the world. As adults, they must be able to decide wisely about using technology to help develop the Pacific region, while maintaining its fragile island environments and unique cultures. Education about technology must be strengthened to prepare students to meet these challenges.

Scientific literacy means understanding these related concepts:

A. **Technology and Science.** Science and technology use many of the same processes. They are interdependent, with advances in one usually contributing to advances in the other.

B. **Design and Systems.** Engineers design and develop technological systems, which are limited by trade-offs, side effects and other constraints.

C. **Issues in Technology.** The decision to develop, use, or limit the use of a particular technology depends on the expected benefits, costs, anticipated risk, and cultural values.

A. Technology and Science

People have always produced technology; they have invented tools and techniques to improve their environment as they saw fit. This process is closely related to science. Technology proposes solutions to problems of human adaptation; science proposes answers to questions about the world. They are interdependent, for advances in one usually contribute to advances in the other.

Young children have already used a great deal of technology by the time they enter school. The school experience should build on this foundation.

For students to understand the nature of technology and the relationship between technology and science, they must do design and technology projects so they can solve a wide range of real-life problems while applying science knowledge and skills. After they have used tools and practical knowledge to solve problems, they can learn their underlying concepts.

LOWER ELEMENTARY

Technology is part of everyone's daily life. Young children have already used a great deal of it by the time they enter school. They have ridden in cars and canoes, used tools for fishing or gardening, helped cook, and listened to the radio. Children are natural explorers and inventors. They like to make things. Even before entering school most children have used things they found lying around to invent toys for themselves.

The school experience should build on this foundation, giving students many opportunities to use tools, examine the properties of materials, and design and build things. Activities should focus on problems and needs in the classroom, around the school and at home that interest children and that can be addressed safely. The task in these school years is to channel the students' inventive energies and increase their purposeful use of tools in appropriate design projects.

MIDDLE ELEMENTARY

During the middle elementary years, students should design more sophisticated projects and improve their skills in measurement, calculation and communication. In developing their projects, students should consider alternative ways of doing something and compare the advantages and disadvantages of each option.

Students should be given opportunities to use tools such as hand lenses, telescopes, microscopes, cameras, and tape recorders to observe phenomena and record what they see. Learning how to measure with tools connects science with technology and helps students develop confidence and skill using tools in their personal lives.

Students in the middle elementary years can begin to identify both new and old technologies and the contributions they make to society.

People tend to think of technology as something new. Students in the middle elementary years can begin to identify both new and old technologies that meet people's food, shelter, communication, and health maintenance needs.

UPPER ELEMENTARY/MIDDLE SCHOOL

Students can now develop a broader view of technology, and how it is both like and unlike science. Science primarily tries to explain something, and technology tries to make something happen or work. The relationship between science and technology can be further developed by having students consider instances such as space exploration, where scientific knowledge has made it possible to develop technology that has, in turn, led to further advances in science.

Technological advances, especially information systems, have changed cultural practices in almost all Pacific island societies. Until recently, people passed knowledge from generation to generation through apprenticeships and other person-to-person contact. Today knowledge is often passed on through books,

As upper elementary and middle school students begin to consider possible occupations, they should be introduced to the range of careers in technology and science.

videos, and other media. Advances in communication and transportation technologies have increased contact with and influences from the outside world.

As students begin to consider possible careers, they should be introduced to the range of opportunities in technology and science, including architecture, engineering, and industrial design. By reading, doing projects, going on field trips, and interviewing people in these fields, students will begin to perceive the great variety of occupations in technology and science and the preparation each one requires.

By the end of grade 8, scientifically literate students will understand that

- science needs technology for the vital instruments and equipment it develops. These inventions perform scientific tasks such as measuring, computing, communicating information, collecting and storing data, and collecting and treating samples.;

- people used to acquire technology by learning accumulated information on the job. Today's knowledge base for technology is found in libraries of print and electronic resources and is often taught in the classroom;

- architects, engineers, and others who design and create technology use scientific knowledge to solve practical problems. However they usually must consider human values and limitations.

They will be able to

- use measurement devices and other tools to solve problems,

- use tools to design and carry out project.

They will value

- local technology—and the underlying science—that has improved the quality of life on Pacific islands.

SECONDARY

In addition to participating in major design projects to deepen their understanding of technology, students now should be helped to develop a richer sense of the relationships linking technology and science. This can come from reflecting on project experiences and from studying the history of science and technology. For example, the Copernican revolution, genetic engineering, the industrial revolution, and the controversy over plate tectonics illustrate both the importance of technology to science and how closely they are related. The technologies that enabled Pacific islanders to navigate long distances played a major role in shaping Pacific cultures. Recent advances in computer technology, communication systems, and air transportation are also appropriate topics for investigation.

Secondary students should be helped to develop a richer sense of the relationships linking technology and science.

By the end of secondary school, scientifically literate students will understand that

- technological problems often create a demand for new scientific knowledge, and new technologies often spark scientific advances; they enable scientists to expand their research in new ways or to undertake entirely new lines of research;
- science, mathematics, creativity, logic, and originality are all needed to improve technology;
- technology affects society directly because it solves practical problems and serves human needs; it may also create additional problems and needs.

They will be able to

- use the necessary tools to design and carry out projects.

They will value

- Pacific island technologies that enabled islanders to survive in environments of limited resources,
- the impact of technology on Pacific island and other cultures; the need to understand the nature of technology in order to make informed decisions regarding its development and use.

B. Design and Systems

Engineers must consider a variety of factors when they design instruments, machines, and structures to accomplish specific tasks.

Engineering is the application of scientific knowledge, practical skills, creativity, and logic to advance technology. Engineers design instruments, machines, and structures to accomplish specific tasks. In doing so, they must consider not only the limitations of materials and knowledge, but also those imposed by time, money, law, and cultural values.

Students learn best about engineering and design by doing some. Through engineering projects, students learn how to analyze situations and gather relevant information, define problems, generate and evaluate creative ideas, develop their ideas into solutions, and assess and improve their solutions. To do these tasks well, they must develop drawing and modeling skills and hone their ability to record their analysis, suggestions, and results in clear language.

As students undertake more sophisticated projects, they will encounter many of the problems engineers face when designing technological systems: constraints, the need for trade-offs, feedback, side effects, and system failure. Students should discuss them in a variety of contexts.

There are many practical examples of engineering from everyday experience.

There are many practical examples of engineering from everyday experience. For example, a person designing and building a water catchment system for the family home is a practical engineer. This person's project is limited by the constraints of money and available materials. There are trade-offs: it must be decided whether to use a metal tank which is cheaper but rusts or a cement tank which is more expensive and will take longer to build. If the tank is not tightly covered or screened it will become a breeding ground for mosquitoes—a very undesirable side effect. If, during a heavy rain, water pours onto the ground instead of into the tank, feedback indicates system failure. The drain spout may be blocked, broken, or too small to handle the flow of water .

The concept of trade-off in technology is so important that it should be put into as many problem-solving contexts as possible.

These ideas can be introduced in simple form early in school and gradually become more prominent in the upper grades. The concept of trade-off in technology is so important that teachers should include it in as many problem-solving contexts as possible. Students should be explicit in their own proposals about what is being traded off for what. They should learn to expect the same of others who propose solutions to problems.

LOWER ELEMENTARY

Children should design and make things with simple tools and a variety of materials. They should identify a need or an opportunity of interest to them, then plan, design, make, test, and modify the design with appropriate help. After they gain experience working through one problem, they may find their next design project easier and feel more confident about trying it.

Young children should design and make things with simple tools and a variety of materials.

Constraints of safety, time, cost, school policy, space, availability of materials, and other realities will restrict student projects. Students must consider them while developing projects. Teachers can point out that adults also face constraints when they design things, and that the real challenge, for adults or children, is to develop solutions that give good results in spite of restrictions.

In the early grades, children may be inclined to go with their first design notion, lacking patience to test or revise it. Where possible, they should be encouraged to improve their initial ideas. It is important that they develop confidence in their ability to think up and carry out design projects.

MIDDLE ELEMENTARY

Students should become increasingly comfortable developing designs and analyzing the product: "Does it work?" "Could we make it work better?" "Could we have used better materials?" As students gain experience, they will need less direct guidance. They should realize early that both individual initiative and group work are valuable in spotting and ironing out design problems. They should also begin to enjoy challenges that require them to clarify a problem, generate criteria for an acceptable solution, suggest possible solutions, try one, and then either adjust it or start over with a newly proposed solution.

Students should become increasingly comfortable developing designs and analyzing the product.

As students undertake more extensive design projects, the teacher should emphasize that there are alternative design possibilities. One way for a teacher to help students to realize this is to have several groups design and execute solutions to the same problem, then discuss the advantages and disadvantages of each solution.

Middle elementary students should realize that there usually is not one best design for a product or process.

UPPER ELEMENTARY/MIDDLE SCHOOL

One idea to be developed in the middle grades is that complex systems require control mechanisms. Students should explore how controls work in such diverse systems as machines, athletic contests, politics, the human body, learning, and so forth. Students should try to invent control mechanisms (which need not be mechanical or electrical) that they can actually put into operation.

An idea to be developed in the upper elementary grades is that complex systems require control mechanisms.

The concept of side effects can be raised at this time. Case studies illustrate effectively the introduction of new technologies (antibiotics, automobiles, spray cans, pesticide sprays) that produced unexpected side effects. Students should also meet more interesting and challenging constraints as they work on design projects.

By the end of grade 8, scientifically literate students will understand that

- constraints usually must be considered during design. Some constraints, such as gravity or the properties of the materials to be used, are unavoidable. Others, such as social, political, economic, ethical, and aesthetic constraints, limit choices;

- all technologies produce effects other than those intended by the design; some may be predictable and some not. In either case, side effects may be unacceptable to some of the population and therefore lead to conflict between groups;

- most control systems have inputs, outputs, and feedback. The essence of control is comparing information about what is happening to what is desired, then adjusting the machine. Control systems sense information, process it, and change accordingly. In almost all modern machines, microprocessors serve as centers of performance control;

- systems fail because they were poorly designed, have faulty or poorly matched parts, or are used in ways that exceed the design capabilities. The most common way to prevent failure is to pretest parts and procedures.

They will be able to

- distinguish between science and engineering,

- demonstrate planning, drawing, and modeling skills in carrying out technology projects,

- cite examples of controls designed to regulate complex systems,

- identify examples of unintended side effects of technological systems,

- cite examples of Pacific island engineering of complex systems.

They will value

- examples of traditional Pacific island engineering that demonstrate low environmental impact on island ecosystems.

SECONDARY

Teachers should spend adequate time developing concepts introduced in earlier grades: resources (tools, materials, energy, information, people, capital, time), systems, control, and impacts. Students should move to higher levels of critical and creative thinking through more demanding design and technology work. They should practice developing and defining their ideas by drawing and using models both individually and in groups.

High school students are ready to study risk analysis and technology assessment.

High school students are ready to study risk analysis and technology assessment. They should become aware that designed systems are subject to failure but that the risk of failure can be reduced by a variety of means: over-design, redundancy, fail-safe designs, more research ahead of time, more controls, and so forth. They should also understand that these precautions add costs to a project and may cause it to be over budget.

Because no amount of precautions can reduce the risk of system failure to zero, the estimated risks of a proposed technology often must be compared to the risks of its alternatives. The choice is seldom between a high-risk option and a risk-free one, but comes down to trading off among actions, all of which involve some risk.

Surveys and interviews help students learn that comparing risks is difficult. How people perceive risk depends on how much they think they can control it (smoking cigarettes versus being struck by lightning), whether the risk is gradual or instantaneous (global warming versus a plane crash), and how it is expressed (the number of people affected versus the proportion affected).

By the end of secondary school, scientifically literate students will understand that

- in designing a device or process, an engineer should consider how it will be made, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs of these functions may introduce yet more constraints on the design;

- different people may value a given technology differently at different times;
- the more parts and connections a system has, the more ways it can go wrong. Complex systems usually contain components to detect, back up, bypass, or compensate for minor failures.

They will be able to

- use more sophisticated planning, drawing, and modeling skills to design and carry out projects,
- design control systems for their projects,
- work cooperatively to identify constraints, analyze risk analysis, and anticipate environmental impact of new technologies.

They will value

- examples of traditional engineering that enable Pacific islanders to adapt the environment to meet their needs,
- anticipating the positive and negative impacts of technologies before they are introduced into island ecosystems,
- career opportunities in engineering.

C. Issues in Technology

The decision to use technology always demands a trade-off. When the first canoe enabled Pacific islanders to go beyond the reef, they had to decide Does the possibility of better fishing outweigh the increased risk of danger? Should we do it?

It is critical that people understand the potential impact of a technology and be able and willing to decide whether to develop and use it.

Today, people around the world face similar decisions. Advances in science and technology touch us all, and it is critical that people understand the potential impact of a technology and be able and willing to decide whether to develop and use it both in their personal lives and in their communities and countries.

Technology itself is neither innately good nor bad. Technologies have benefits, limitations, and risks. Students need to know and care enough about it to question the use or curtailment of a particular technology and to anticipate the impact of each decision.

LOWER ELEMENTARY

These students are too young to understand the vast implications of technology, but they are ready to see that solving one problem can lead to another. The teacher can develop this concept by applying it to students' design projects. The question How will your project affect others? starts them thinking along these lines and helps them begin to realize the importance of considering the consequences of an action before doing it.

Lower elementary students should begin to realize the importance of considering the consequences of an action before doing it.

MIDDLE ELEMENTARY

Technology is an integral part of culture. Like language, it is evolutionary and dynamic, it developed over many years and continues to change with the introduction of new ideas and knowledge. In their middle elementary years, students can begin to examine Pacific island technologies and how they have shaped the lives of people past and present.

Students should understand that technological advances, especially in health care, transportation, and communication, create new opportunities for Pacific islanders, but the technologies may have undesirable side effects, and the opportunities may be available only to a few.

In their middle elementary years, students can begin to examine Pacific island technologies and how they have shaped the lives of people past and present.

UPPER ELEMENTARY/MIDDLE SCHOOL

Students in at this grade level should continue to enlarge their understanding of the influence of technology on society. They should appreciate that the development and use of technology has led to great achievement and, in some cases, wrought great damage. Although technology itself is neither good nor bad, its use and its effects, both expected and unexpected, can benefit people and the environment or harm them.

Case studies are appropriate for this age group. Examining current developments and case studies of experiences with technology helps students construct scenarios for the future of the islands and their peoples.

Upper elementary and middle schools students can benefit from considering case studies of experiences with technology.

By the end of grade 8, scientifically literate students will understand that

- our ability to shape the future results from our ability to generate new knowledge, develop new technologies, and communicate ideas with others;

- people have used technology throughout history to perform impressive feats;

- science and technology cannot always solve a problem;

- using a technology may produce undesired immediate or long-term effects;

- cultural priorities and values influence what aspects of technology are developed and how they are used.

They will be able to

- cite examples of appropriate and inappropriate technologies in the Pacific islands.

They will value

- their technological heritage, which enabled their culture to survive and grow in the unique environment of the Pacific islands,

- the need to carefully consider all foreseeable implications of a technology before developing and using it.

SECONDARY

The rapid growth of information and the ever-increasing pace of technological development have produced tremendous advances in the capacity to meet human needs and satisfy human desires. Unprecedented opportunities exist to improve the quality of life, however, these are balanced by a corresponding responsibility to weigh trade-offs and risks. Society must respond to both the promise and the threat of technological change, whether by adopting new technologies or curtailing the use of existing ones.

Rapid technological change in Pacific island communities may speed the pace of social change there.

Technology and culture are inextricably linked, each responding to and shaping the other. All societies change as a result of innovations in technology. But in Pacific island communities today, rapid technological change may speed the pace of social change there. The effects of new technologies can be felt as changes in social structures, as a different job market and new required job skills, and as changes in environments and ecosystems. Rapid change can be dislocating. Decisions about the kinds of technology to use and how to use them are important to a community and should be informed by a clear understanding of the trade-offs in a decision.

As young citizens about to enter the work force and the decision making process, secondary students must recognize their responsibilities and be able to address technological issues in an informed manner.

As young citizens about to enter the work force and the decision-making process, secondary school students must be prepared to address technological issues in an informed manner. Case studies about the Pacific and other regions help students understand the costs, benefits, (both economic and cultural) risks, and alternatives of adopting, rejecting, or curtailing the use of a technology. They also should be made aware of how the work force is changing, what skills they will probably need to be gainfully employed, and, in light of the rapid pace of change, the need to be life-long learners.

By the end of secondary school, scientifically literate students will understand that

- social and economic factors, such as cultural values, personal values, financial resources, local and national regulations, and economic competition, strongly influence which technologies will be developed and used;

- the decision to change technologies should be based on analysis of the risks, alternatives, and the social, economic, and environmental costs and benefits of the decision;

- many of our technologies can exert an impact on other species and on environmental quality;

- rapid technological change in the Pacific islands has improved the quality of life, but it has also created new problems and threatens traditional social structures and cultural practices;

- to enter the work force, individuals must have the technological skills in demand. Demand for workplace skills changes, however, as new technologies are introduced therefore people must also be prepared to learn new skills throughout their work lives.

They will be able to

- gather information to make informed judgments about technological development and change and communicate their opinions in an appropriate manner,
- function as life-long learners.

They will value

- their cultural and environmental heritage when participating in the decision-making process,
- other points of view about technological developments and consider them when deciding their position.

TECHNOLOGY AND SOCIETY: THE DESIGNED WORLD

The scientifically literate student understands that the world we live in (social, cultural, economic and ecological systems) has been shaped and controlled by humans developing, using, and restricting technology.

Technology enhances the capacity of humans to meet their needs by developing tools and changing the environment. Much of the world we inhabit has been designed, shaped, and controlled by using technology. These changes may benefit us, but they are not without risk. Thus both positive and negative impacts of a technology must be carefully considered and possible alternatives evaluated before deciding to develop and use the technology. While society determines which technologies to pursue, technology exerts a profound impact on human society.

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Recent technological advances have exerted a great impact around the world. This is especially true in the Pacific islands, where technologies of food production, transportation, communication, health care, and energy utilization have changed during the last few decades. Pacific islanders now travel across the region and around the world for work and pleasure. At home they are linked to the rest of the world through satellite-based communication, radio, television, and video tapes. Improved health care has increased life expectancy. Many island homes are now equipped with electricity and labor-saving appliances such as refrigerators, microwave ovens, and washing machines. People eat fish from the nearby ocean and rice from thousands of miles away. But as with technological change everywhere, Pacific islanders have made trade-offs. The political, social, and economic systems in the islands have changed greatly and are still under pressure. Population growth and changing lifestyles threaten ecological systems that have supported life on the islands for thousands of years.

Recent technological advances have exerted a great impact on the Pacific islands.

A discussion of technology should consider not only recent advances, but also the rich technological systems that Pacific island societies developed to ensure their survival in a unique environment. Pacific cultures contain a wealth of knowledge, skills, and designed systems that can and should inform decisions about development and the introduction of new technologies.

It is important to consider both recent technological advances and the rich technological systems that Pacific island societies developed to ensure their survival in a unique environment.

These crucial decisions will affect the lives of current and future generations in the island communities.

Scientifically literate students will be prepared to make sound personal decisions involving technology and participate in the public debate about technological development and change. They will understand these related concepts:

A. **Food Production and Distribution.** Food production, preservation, and distribution is essential to human existence. Changes in eating habits and agricultural and fishing practices throughout the Pacific affect many aspects of island life.

B. **Materials and Manufacturing.** The processing and use of materials is closely tied to technology. Manufacturing uses technology and as technology changes, the range of products that can be produced also changes.

C. **Use and Management of Energy Resources.** Students should understand the importance of energy resources to our daily lives. They should understand, study, and evaluate energy use in light of the available useful energy resources.

D. **Communication and Information Processing.** Technology has played an important role in collecting, processing, storing, and retrieving information. The spread of communication technologies influences people's behavior, affects their attitudes toward others, and changes social and cultural practices.

E. **Health Technology.** Health technology includes good health practices and the relationship between health technology and the health of the population.

A. Food Production and Distribution

The agricultural system is a complex network involving the production, preservation, packaging, and transportation of food. Food production evolved in the Pacific as a central feature of culture. Farming and fishing were so important that nearly all social relationships were tied in one way or another to gardening or fishing. The traditional cropping system of shifting cultivation provided nutrition, promoted rural economic stability, and preserved culture. Today most Pacific islanders still raise subsistence, local market, and export crops in family units using local technology.

New developments in technology have had a great impact on agriculture and fishing in the Pacific islands. More efficient machinery, fertilizers, modern fishing vessels have increased the production and harvesting of food. Transportation, refrigeration and chemical preservation technologies have improved food distribution. Technology has also improved food processing and packaging to retain their nutritional values.

New developments in technology have had a great impact on agriculture and fishing, in the Pacific islands.

These innovations have contributed to social, cultural, economic, and ecological changes in the region, causing major concern about the risks of many of the recently introduced technologies (pollution, over-harvesting).

Most Pacific islands have limited land resources for agriculture. Regulation and wise use of the food-producing resources, land and sea, are essential. It is imperative that students be acquainted with the basics of agriculture, know and care about how to improve agriculture, know what resources are required, and be involved in making wise decisions about acceptable impacts of technology on society and the environment.

It is imperative that students be involved in making wise decisions about acceptable impacts of technology on society and the environment.

Students should appreciate the value of traditional agricultural practices and their impact on island environments. This knowledge along with an understanding of advanced technologies should help lead to improved, sustainable food production in the islands.

LOWER ELEMENTARY

Most primary school children in the region eat foods from a variety of sources. They should be able to trace the food on the table to its local source—the ocean, the plantation, or the store—and recognize how it came to be on the table. They should learn which foods are produced by local farmers and fishermen.

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Students should understand that many local plants are edible and provide nutrients for the development of their bodies. They should realize that people raise these plants from seeds or cuttings and that they need soil, water, sunlight, and care to thrive.

Students who lack direct experience with food production can take a field trip to a farm or invite local farmers to speak to their class about food production.

MIDDLE ELEMENTARY

Middle elementary students should continue their study of food products from the local environment.

Middle elementary students should continue their study of food products from the local environment. Topics to cover include traditional and modern storage, transportation, preservation, processing, and packaging. Where possible, students should visit farms, markets, and processing plants.

Students can build on their earlier experiences by tracking the growth and development of plants from germination through harvesting or the production of new seeds. They can work on designed experiments to test the effects of water, light, and fertilizer on growth and development.

Many of the foods eaten by Pacific islanders come from other parts of the world. Students in these grades can begin to trace these foods to their sources. They can visit stores that sell imported foods and go see cargo vessels that transport food to and from the island. They can use a globe or map to locate the places where these foods are produced, then study about the different environments in which the food crops grow. This exercise provides an excellent opportunity to develop connections between the science and social studies curricula.

UPPER ELEMENTARY/MIDDLE SCHOOL

In middle school, students can examine how changes in technology, economy, demography, and politics affect agriculture.

In middle school, students can examine how changes in technology, economy, demography, and politics affect agriculture. Students' discussions can center on recent changes in agricultural and fishing practices in their area. They should also be exposed to farming practices in other places. They are ready to explore examples of social change made possible by advances in food production technology, and conversely, of technological advance prompted by social change.

Students should continue to garden and undertake investigations that let them monitor and control many of the variables that contribute to plant growth and development.

They should understand that food production and distribution systems are designed to provide people with the food nutrition necessary for developing and maintaining healthy bodies. Upper elementary and middle school students should begin exploring the nutritional benefits of the foods available to them. They should recognize that many of the foods available locally are healthier than imported foods .

By the end of grade 8 scientifically literate students will understand that

- plants need warmth, light, water, and protection from harmful weeds and pests to thrive;

- products of technology, such as better machinery and improved farming techniques, have improved the efficiency of the food production and distribution systems; they facilitate planting and harvesting, keep food fresh with packaging and cooling, and move it long distances to market;
- both time-tested and new methods are used for preserving food;

- nutritional value is an important dietary concern. We now have available a wide variety of foods from many places, but many local crops have high nutritional value and should remain a part of the diet;

- climate and soil determine the kinds of crops that can grow in a particular area; irrigation and fertilizer can help them grow better and faster.

They will be able to

- describe human nutritional needs and choose foods that results in good personal nutrition;

- describe local food production and distribution technologies and the complex interactions of these technologies with economics, health and nutrition, resource depletion, and environmental impact.

The will value

- the importance of producing a variety of foods locally and the nutritional value of traditional foods,

- social changes resulting from new food production and distribution systems.

Secondary students' understanding of agricultural technology can be increased by drawing upon their understanding of the underlying science.

SECONDARY

Secondary school students should use systems concepts to study how agricultural processes—production, preservation, and transportation—are related to each other and to communications technologies, government regulations, subsidies, and world markets. They should discuss social side effects and trade-offs of agricultural strategies in both local and world contexts. They will gain a deeper understanding of agriculture as applied science by studying the interaction of crops with their environments, the inheritance of traits, mutations and genetic engineering, and natural selection.

By the end of secondary school, scientifically literate students will understand that

- new varieties of farm plants and animals have been engineered by manipulating their genetic instructions to produce new characteristics;

- choosing an agricultural technology may require trade-offs between increased production and environmental harm and between efficient production and social values;

- agriculture and the food industry offer career opportunities essential to the cultural, economic, and social well-being of Pacific islanders.

They will be able to

- compare local food production and distribution technologies with those in other places;

- identify some of the complex interactions of these technologies with economics, health and nutrition, politics, and their impact on cultures;

- describe some of the positive and negative impacts of modern food production and distribution technologies, including environmental changes and resource depletion.

They will value

- social and environmental improvements resulting from modern food production and distribution technologies.

B. MATERIALS AND MANUFACTURING

Humans have taken materials from their surroundings and processed them into a useful form from the earliest times. The processing and use of materials is very closely tied to technology. Manufacturing relies on technology, and as technology changes, the range of products that can be produced also changes. Often the product of one manufacturing system is used for the raw material or tool in another.

People from small, remote islands in the Pacific Ocean developed a variety of technologies to transform materials into useful tools and products.

Manufacturing is usually associated with large urban areas, but this is not always the case. People from small, remote islands in the Pacific Ocean developed a variety of technologies to transform materials into useful tools and products.

New technologies are being developed so quickly that the life spans of many products, jobs, and even industries have become very short. Workers are expected to learn skills for many new jobs over a lifetime. The nature of available jobs is also changing. The growing use of advanced manufacturing technologies is reducing the demand for direct labor, and increasing demand for workers skilled in process engineering, general office work, information processing, quality control, and maintenance.

Students should learn about the manufacturing process by studying and manipulating many kinds of materials.

To understand manufacturing, students must understand the relationship between the properties of materials and their uses. They should study and manipulate many kinds of materials so they learn about the physical and chemical properties of materials as well as about manufacturing.

Students can start to understanding the manufacturing process by studying manufacturing activities in their immediate surroundings. Sewing clothes, build shelves and furniture from wood, making roofs, baskets, and mats from plant leaves and bark are examples of using available materials and their properties to manufacture useful products.

LOWER ELEMENTARY

Lower elementary students should get many opportunities to work with different materials, identify their properties, and figure out their suitability for different purposes.

Young children can begin to understand the relationship between the properties of a material and its uses. They should get many opportunities to work with different materials, identify their properties and figure out their suitability for different purposes.

Lower elementary children should be able to identify simple or common tools and cooking utensils at home and suggest their special purposes. They should be encouraged to manipulate common materials. Have them watch and, when safe, assist adults who are making things.

They should also learn that many products can be recycled by participating in school- or community-based recycling programs.

Many interesting activities enable middle elementary children to experience how people process materials.

MIDDLE ELEMENTARY

Cooking can help young people develop concepts about the effects of combining ingredients and treating mixtures to change their properties. By producing common products from plant leaves and fibers, cutting and carving traditional tools and cooking utensils students can discover properties of various materials and experience how people transform materials into useful objects.

Teachers can channel students' enthusiasm for making things into assembly-line activities that require teamwork and produce multiple products.

Teachers can channel students' enthusiasm for making things into assembly-line activities that require teamwork and produce multiple products. Students can develop and use a series of simple workstations to reassemble tools, make sandwiches, or fold paper into objects. They should consider how to improve the uniformity, quantity, and quality and reduce the costs of manufacturing products.

Once students have a sense of the complete cycle, they can understand how recycling conserves energy and natural resources.

UPPER ELEMENTARY/MIDDLE SCHOOL

Recycling activities take on added value when students learn about a material's origins and history. Students at this level can trace the production cycle of common materials such as paper, lumber, aluminum, glass, petroleum, and plastics. Their investigations should begin with the natural formation of raw materials, then examine the techniques used to gather them, process them into workable materials, transform them into industrial and consumer products, and dispose of the products when they are no longer useful. Students should identify points in the production and disposal cycle where used materials can be collected, sorted, and reprocessed into usable materials. Once students have a sense of the complete cycle, they can understand how recycling conserves energy and natural resources. They can then reflect on how their own consumption choices influences what products are made and how they are packaged.

By the end of grade 8, scientifically literate students will understand that

- some kinds of materials are better than others for making things. The choice of materials for a job depends on their properties and on how they interact with other materials;

- naturally occurring materials, such as wood, clay, cotton, and animal skins may be processed or combined with other materials to change their properties;

- Pacific islanders developed a variety of ways to process resources and manufacture products to meet their needs,

- through science and technology, a wide variety of materials that do not appear in nature have become available;

- manufacturing usually involves a series of steps, such as designing a product; obtaining and preparing raw materials, processing the materials mechanically or chemically, and assembling, testing, inspecting and packaging. The sequence of these steps is often important;

- although many things are still made by hand in some parts of the world, many others are now produced using automated machines. These machines require human supervision;

- current technology supports mass production which reduces manufacturing costs, produces uniform products, and creates new synthetic materials that can reduce the depletion of some natural resources;

- automation has changed the nature of work in most fields, including manufacturing. Workers need better learning skills and more flexibility to take on new and rapidly changing jobs;

- discarded products contribute to the problem of waste disposal. Sometimes they can be used to make new products, but not all materials can be easily recycled.

They will be able to

- relate the properties of materials to their uses in manufacturing;

- identify and describe examples of local manufacturing processes and the materials and resources required to carry them out;

- demonstrate how materials were used to make the inventions and devices they use for their science and technology investigations;

- identify and describe some of the environmental, economic, energy, and social impacts of manufacturing.

They will value

- traditional manufacturing processes and their relationship to cultures,

- the environmental consequences of resource use for manufacturing,

- the importance of recycling materials used in manufacturing.

SECONDARY

Chemistry, physics, biology, and geology provide many clear examples of the relationship between science and technology.

With the continued development of the Pacific there has been a tendency to rely more and more on nonrenewable energy resources to maintain and improve life styles.

The study and design of materials involves several disciplines and issues. Secondary school students should explore how scientific knowledge fuels technological advances and how technology creates new scientific knowledge. Chemistry, physics, biology, and geology provide many clear examples of the relationship between science and technology.

As students understand how atoms are configured in molecules and crystals, they can begin to see the connections to properties of materials. This understanding naturally leads to laboratory tests that measure a material's physical properties. Such tests can be included in investigations that require students to select and process materials in order to achieve the optimum balance between properties available and properties needed.

By the end of secondary school, scientifically literate students will understand that

- new tools and techniques based on modern scientific knowledge have changed manufacturing processes, as have electronic controls that make operations faster and more consistent;

- waste management includes considerations of quantity, safety, degradability, and cost. It requires social and technological innovations because waste-disposal problems are political and economic issues as well as technical and environmental problems;

- scientific research identifies new materials and new uses of known materials.

They will be able to

- relate the atomic and molecular structure of substances to the properties that make them useful in manufacturing;
- cite examples of new products made possible by the creation of new materials by technology;
- describe some of the complex relationships between science and technology as they relate to manufacturing.

They will value

- traditional manufacturing processes and their relationship to cultures,
- the potential for employment in manufacturing,
- the environmental and social impacts of new manufacturing products,
- recycling materials and finding new uses for manufacturing waste products.

C. Energy Resources: Use and Management

People have used energy resources to improve their quality of life since they first learned to control fire. Dependence on energy, especially its nonrenewable forms, has increased with progress in technology. Pacific islanders traditionally used wood and sunlight as sources of energy. Much of the recent development in the Pacific islands has depended upon the availability of usable energy resources, most of which are imported. The introduction of new technology has created a demand for imported petroleum products.

As with all other forms of technology, the use of the various energy resources has benefits and costs. Balancing the trade-offs is part of the decision-making process. Fossil fuels, currently a major energy source, are expected to be depleted in the near future, and are certain to become too costly. Nuclear power poses unresolved waste-disposal difficulties along with the ominous health, social, cultural, and ecological implications of accidents. Wood and coal are available in large supply but their use adds greatly to the air pollutants thought to produce the greenhouse effect. Solar energy is renewable and nonpolluting but current technology produces a low net energy yield. Hydroelectric energy technology shows potential use for only a few Pacific islands. Small-scale windmill projects may be viable as an alternative energy source.

LOWER ELEMENTARY

Students at this level need only become aware that energy is important in their everyday lives.

Students at this level need only become aware that energy is important in their everyday lives and that many aspects of their existence depend upon the use of energy resources. They can associate sources of energy with their uses: electricity gives people light and cooks food; batteries power flashlights and radios; petroleum fuels outboard motors and cars; and moving air moves sailboats. Toys that use batteries, solar energy, and wind can be used for classroom demonstrations.

The early elementary years are a good time for students to become safety conscious.

Safety is a concern for all. The early elementary years are a good time to introduce students to precautions for using energy safely.

MIDDLE ELEMENTARY

Middle elementary students are ready to begin identifying specific energy resources that influence their lives.

Middle elementary students are ready to begin identifying specific energy resources that influence their lives. Examples may include cooking over a fire, using wood as a fuel, or using petroleum products as a fuel for transportation. Students should associate the use of electricity with the energy used to generate it.

The emphasis here is on energy resources and the distinction between renewable and nonrenewable resources. Wood, a common fuel in many Pacific islands, should be recognized as a limited, but renewable resource. Trees must grow many years before they can be harvested, and their use must be managed. Students can learn about technology based on fossil fuels and realize that these are nonrenewable resources. Students should also develop concern about the availability of such resources in the future.

Middle elementary students are old enough to learn and care about energy conservation and what they can do at home to help.

Students can be introduced to some of the basic ecological or environmental effects of cutting forests for firewood, the use of the sun's energy as a resource, and the detrimental effects of dumping fossil fuel wastes. They should learn to care about energy conservation and what they can do at home to help.

UPPER ELEMENTARY/MIDDLE SCHOOL

People use energy for direct applications and to prepare and developing products they use. Students should distinguish these aspects of energy resource use and be able to trace them in common examples.

Using and allocating any resource involves trade-offs. Students at this grade level should learn about energy use issues and decisions. Teachers should emphasize relevant local situations. The copra industry provides an excellent example of deciding about the use of energy resources. Copra production once played a major role in all Pacific island economies and still exists on many of them. After harvesting, coconut must be dried. This drying process may be carried out through sun-drying, heating with the husks and shells of the harvested coconut, or heating by using wood or fossil fuel resources. Each of these methods requires choices about allocating energy resources and affecting the environment and economy.

The existence of choices and an awareness of the issues involved in deciding how energy resources will be used is appropriate for students in upper elementary and middle school.

By the end of grade 8, scientifically literate students will understand that

- energy sources are renewable or non-renewable. Non-renewable sources are present in finite amounts and their use must be carefully planned. Some energy sources cost less to use and cause less pollution than others;
- the sun is the main source of renewable energy for people and its energy can be used in various ways. Energy from the sun is available indefinitely;
- energy can change from one form to another, although in the process some energy is always converted to heat;
- different parts of the world have different amounts and kinds of energy resources available for use;
- different ways of obtaining, transforming, and distributing energy have different environmental consequences.

They be able to

- identify and trace energy flow in the manufacture and use of common products, such as processed foods, household appliances, and motor vehicles;

- identify alternative energy sources or behavioral changes to replace current energy use patterns.

They will value

- conserving energy by using efficient appliances and technology that relies on renewable energy sources,
- the social, economic, and environmental impacts of the increased use of many fuels,
- the choice to seek and use alternative sources of energy that are renewable and less harmful to the environment.

The issues surrounding energy resource utilization and allocation provide an excellent capstone topic of study for secondary school students.

SECONDARY

More in-depth studies of energy concepts like work, kinetic and potential energy, storage of energy, and thermo-dynamics and entropy, should be investigated at this time.

The use of local energy resources, the importation of fuels, the economic impact of fuel-dependent development on the regional economy and individual families, the environmental implications of using certain fuels, and the availability of alternatives should all be part of student discussion. They can propose policies for conserving and managing energy resources and send them to the appropriate public officials. Teachers should invite guest speakers from the state energy offices or agencies to enlighten students about current and future energy situations.

Students at this level should be capable of putting energy use issues into a global perspective, tracing energy use on a worldwide scale, and appreciating the implications of rapidly consuming nonrenewable resources.

By the end of secondary school, scientifically literate students will understand that

- all energy sources have advantages and disadvantages and society must consider trade-offs among them;
- industrialization increases demand for energy. this raises standards of living but also depletes the earth's energy resources more rapidly and increases the environmental risks associated with the use of fossil and nuclear fuels;

- as human society has developed, energy use has increased. Most current technology is based upon the consumption of limited nonrenewable resources;

- energy issues, such as sources, use, distribution, conversion, cost, and depletion, are critically important to human society. Research indicates that some sources of energy are very limited. Work is underway to make usable energy from renewable sources more efficient;

- Pacific island communities have grown increasingly dependent on external energy resources to meet increased demand resulting from using new technologies. The economic and social cost of this dependence must be understood and alternatives investigated.

They will be able to

- collect information and data about the appropriate use of energy resources, develop a position on the issue, and communicate it to others;

- identify alternatives to current energy practices, stating the positive and negative effects of both the current and alternative practice.

They will value

- technologies based on renewable energy resources because they cause less negative impact on the environment.

D. Communication and Information Processing

Recent advances in technology have expanded the means and speed of communication. The volume of information that can be communicated has also increased. The spread of communication technologies brings social and cultural changes, affects people's attitudes toward others, and influences behavior. This is most evident in the island societies of the Pacific where vast ocean distances have kept people relatively isolated. Most island societies now actively exchange information with people in all parts of the world.

The spread of communication technologies brings social and cultural changes.

Technology not only transmits information, it also collects, stores, and retrieves it. Students should learn through experience and discussion that writing, drawing, photographing, talking into a tape recorder, and entering letters and numbers into computers are all ways of capturing and saving information. Information may be incorporated in dances, songs, chants, and stories. It may be engraved as symbols on a piece of wood or in the intricate tattoos found in many cultures.

Students should be familiar with communications through spoken language, songs and dances, symbols, physical mobility, and written material.

Students should be familiar with traditional, written, and electronic communication. Although telephones, tape players, compact disks, television, and communication satellites are becoming commonplace, students also should be familiar with communications through spoken language, songs and dances, symbols, physical mobility, and written material. In fact, the introduction of written language and books to the Pacific islands in the last century was the first "communication revolution."

The volume of information to be processed has increased dramatically in recent years. In many societies, information is a valuable resource and information processing is a major activity.

The volume of information that people must process has increased dramatically in recent years. In many societies today, information is a valuable resource and information processing is a major activity. Many businesses and jobs are based on information processing. Students should become comfortable with a variety of means of storing and retrieving information, including computers. They should also be aware of the impact of the information explosion on societies, especially their own.

LOWER ELEMENTARY

Lower elementary students should understand the need to have common meanings for sounds, signs, symbols, gestures, etc., so that they can be understood by others.

Even before mastering the alphabet, young children realize that shapes, symbols, and colors have special meanings (red means danger, green means go, arrows mean direction, a smile mean someone is pleased, a frown that they are unhappy,). Students should understand that we have common meanings for sounds, signs, symbols, and gestures so we can communicate with each other.

Young people are fascinated by sending messages different ways, for example with sign language, road signs, recycling symbols, and company logos. In the early elementary years, children should realize that information can be sent and received in many ways. People use devices, such as telephones and radios, to send and received messages quickly and clearly. Students can discuss the advantages and disadvantages of the communication methods with which they are familiar. The Pacific cultures have an especially rich variety of ways of communicating. They sing, dance, tattoo, carv· ·tems, make art, and use body gestures Island peoples communicated with each other for thousands of years without telephones and without written languages.

Children are often required to keep folders, notebooks, journals, or portfolios to organize and store their work so it can be reviewed at a later date. These are personal information storage and retrieval systems. Young children can design and use simple strategies for storing and retrieving information that is recoraed in the form of words and pictures.

Children's folders, notebooks, journals, and portfolios are personal information storage and retrieval systems.

MIDDLE ELEMENTARY

People have always tried to communicate with one another. Signed and spoken language were early inventions. Early forms of recorded messages were markings on wood or stone. People have since invented devices, such as paper and ink, engraved plastic disks, and magnetic tapes for recording information. These devices enable great amounts of information to be stored and retrieved and sent to other people or places. Communication technologies enable people to send and receive more information and do it faster, more reliably, and over longer distances.

Students can start to study the major communication systems of the past and present. They can learn how telephone and radio connect them to other parts of their island community and the rest of the world. They should gain experience writing and drawing and using audio tapes, videotapes, and computers, with reference books to assist them. They should be able to use these technologies to communicate information to classmates and students elsewhere. They should also use them to gather, organize, and present information in different formats. Written reports, pictorial records, audio or video tapes, and electronic files are possibilities.

Middle elementary students can start to study the major communication systems of the past and present.

UPPER ELEMENTARY/MIDDLE SCHOOL

At this level, students can understand communication systems as a series of linked black boxes connecting people in one location with people in another location. They can recognize that each black box in the chain accepts an input signal, processes that signal, and produces and sends a new signal. A microphone is a black box that converts sound into electricity, an amplifier is a black box that takes a weak signal and produces a stronger signal, and a speaker converts electricity into sound. Building on their experiences with electricity, students can understand that these devices must be connected with wire to work. Students need to experiment with simple devices, such as microphones, speakers, and amplifiers, before they can think about more sophisticated

Middle school students should experiment with simple communication devices and understand how communication systems link people in one location with people in another.

devices such as video cameras, cathode-ray tubes, stereo systems, and satellites.

In addition to written records, students should use electronic devices for retrieving, processing and storing information. These include audio tapes, video tapes, and computers. Upper elementary and middle school students should be able to use a variety of software programs to help them process and store data.

By the end of grade 8, scientifically literate students will understand that

- communication is an important human activity which depends upon a group of people giving the same meaning to sounds and symbols;

- there are many means of communication and new methods are always being developed;

- people can err in coding, transmitting, or decoding information, therefore, they need some means of checking for accuracy. Repeating the message is a frequently used method;

- information can be carried by many media, including sound, light, and objects. The ability to code information as electric currents in wires, electromagnetic waves in space, and light in glass fibers has made communication millions of times faster than by mail or sound;

- most computers use digital codes containing only two symbols, O and 1, to perform all operations. Continuous signals (analog) must be transformed into digital codes before they can be processed by a computer;

- one of the values of computers is that they can, on command, reorganize information in many ways, thereby enabling people to make more and better uses of the information;

- an increasing number of people work at jobs that involve processing or distributing information. Because computers can do these tasks faster and more reliably than people, they have become standard tools both in the workplace and at home.

They will be able to

- identify and describe the advantages and disadvantages of different types of communication;
- describe the contribution of science and technology in creating global communications;
- create simple communication systems and devices,
- describe some of the complex parts and interactions in a communication system,
- demonstrate skill in using global communication technologies.

They will value

- traditional Pacific island communication systems designed to pass knowledge from one generation to the next,
- the impact of global communication systems on island life and cultures.

SECONDARY

Students need to experience firsthand how technology helps people communicate more information to more people in less time, with greater accuracy, and fewer misunderstandings. They can begin to understand how some common communication devices transform patterns of sound or light into patterns of electricity and transmit electrical patterns across a variety of linkages and how receivers process incoming signals and convert patterns of electricity back into patterns of sound and light.

Secondary students need to experience, firsthand, how technology helps people communicate to more people faster and more reliably.

Students should use information processing devices, such as computers, to collect and analyze data from experiments, to simulate a variety of biological and physical phenomena, to access and organize information from databases, and to use programmable systems to control electronic and mechanical devices. They should also have experience using computer models. This is a good time for students to think about organisms as systems in which information is shared in genes in a code that can be interpreted by biochemical processes.

Secondary students should use information processing devices, such as computers, to collect and analyze data, to simulate a variety phenomena, to access and organize information, and to use systems to control electric and mechanical devices.

By the end of secondary school scientifically literate students will understand that

- almost any information can be transformed into electrical signals. A weak electrical signal can be used to shape a stronger one, which can control other signals of light, sound, mechanical devices, or radio waves;

- the quality of communication is determined by the strength of the signal in relation to the noise that tends to obscure it. Communication errors can be reduced by boosting and focusing signals, shielding the signal form internal and external noise, and repeating information, but all of these increase costs;

- a variety of communication systems now criss-cross the globe allowing more extensive and faster communication;

- computer modeling explores the logical consequences of a set of instructions and a set of data. The instructions and data input of a computer model try to represent the real world so the computer can show what would actually happen. In this way, computers assist people in making decisions by simulating the consequences of different possible decisions;

- as technologies that provide privacy in communication improve, so do those for invading privacy.

They will be able to

- demonstrate skill in using computers to access information and to communicate with others in the Pacific and the world;

- identify and describe the impact of new communication systems in their lives and on Pacific island cultures;

- describe some of the complex parts and interactions in a communication system.

They will value

- the impact of global communication systems in providing access to information;

- the potential threat to privacy posed by some technologies.

E. Health Technology

Health technology is the result of years of investigating how the human body functions, how to keep it in good condition, and how to protect it from disease. Health technology includes good health practices and the relationship between technology and the health of the population. Students should learn how the body works, what causes diseases, how they are transmitted, and how the body protects itself from diseases.

Health technology includes understanding good health practices and the relationship between health technology and the health of the population.

Students should know that technology plays a critical role technology in shaping and maintaining individual and population health. They should realize that while technologies like dialysis machines, life-support systems, and organ transplant surgery improve and prolong human life, advances in basic health care have made the greatest strides in improving health. Vaccines, antibiotics, good personal hygiene, and eating nutritious diets have made all people healthier.

Modern waste disposal systems, sanitary food handling, refrigeration, and medical imaging are other important technological advances that have made us healthier and lengthened life expectancies. Students should be aware that difficult and sensitive issues arise when deciding about the use of many modern medical technologies. Some of these are technical but many are ethical and involve social and cultural values.

LOWER ELEMENTARY

Young children know that germs can make them sick, even though they may not know exactly what germs are. They should know when it's important to wash their hands, to be careful about what goes into their mouths, cover their mouths when they sneeze and cough, and avoid contact with someone who is contagiously sick. Children should also know that shots and oral vaccines can prevent certain diseases and that, if they do get sick, medicines can sometimes help them get better. This knowledge can be built upon to help students realize that science and technology contribute to good health.

Young children know that germs can make them sick, even though they may not know exactly what germs are.

MIDDLE ELEMENTARY

Students can collect information on their own health with simple devices such as a watch, a thermometer, and a stethoscope, and they can begin to get a sense of how such information varies. Students can even undertake projects such as designing aids for the disabled. If children visit a hospital, they can see examples of how

Middle elementary students can collect information on their own health and can begin to get a sense of how such information varies.

computers and monitoring instruments are important in various aspects of health care.

Students at this age should begin to relate their good health to good diet, good personal hygiene, and vaccinations they received as babies.

UPPER ELEMENTARY/MIDDLE SCHOOL

The history of medicine and public health contains numerous accounts that will fascinate middle school students.

Teachers should try to interest students in prevention, vaccination, and other public health measures.

Teachers can capitalize on students' interest in their changing bodies by having them measure their basic vital signs and other health-related characteristics. Using simple tools such as blood-pressure devices, thermometers, and stethoscopes, students can monitor their own health.

The history of medicine and public health contains numerous accounts likely to fascinate middle school students. They usually know about the marvels of modern treatments but are ignorant of preventative programs like sewer systems. Because the health of populations depends more on public health measures than on treatment, teachers should try to interest students in prevention, vaccination, and other public health measures.

By the end of grade 8, scientifically literate students will understand that

- sanitation measures such as the sewer systems, landfills, quarantines, and safe food handling are important in controlling the spread of disease-causing organisms. Improving sanitation to prevent disease has contributed more to saving human life than any advance in medical treatment;

- the ability to measure the level of substances in body fluids has enabled physicians to compare samples with normal levels, make sophisticated diagnoses, and monitor the effects of the treatments they prescribe;

- it is becoming increasingly possible to manufacture chemical substances such as insulin and hormones that are normally found in the body. They can be used by individuals whose bodies cannot produce the amounts required for good health.

They will be able to

- describe the impact of health technologies in the Pacific;
- identify health technologies they or their families use or have access to including vaccines, improved sanitation, antibiotics, and hospital services,
- use simple tools such as a watch, thermometer, and stethoscope to monitor their own health,
- describe some of the important functions of computers in monitoring health and diagnosing diseases.

They will value

- the availability and usefulness of health technologies in their own lives,
- the importance of maintaining and improving health technologies in the Pacific to improve the quality of life.

SECONDARY

Secondary students can understand the science behind the technology, such as genetics and molecular chemistry.

Students can now understand some of the science behind the technology. For example, genetics and molecular chemistry make possible genetic engineering and chemical synthesis of drugs. And physicists' knowledge of radioactivity and the behavior of waves in materials underlies various imaging techniques. Students can routinely use information technology to store, retrieve, and analyze physiological and health information. They should also examine and discuss issues of life support and access to affordable health care.

By the end of secondary school, scientifically literate students will understand that

- because of the large amount of information that computers can process, they play an increasingly larger role in medicine. They are used to analyze data, monitor diagnostic information about individuals, and track statistical information on the spread of disease;
- knowledge of genetics is opening whole new fields of health care. In diagnosis, mapping genetic instructions in cells

enables scientists to detect defective genes that may lead to poor health. In treatment, substances from genetically engineered organisms may reduce the cost and side effects of replacing missing body chemicals;

- knowledge of molecular structure and interactions aids in synthesizing new drugs and predicting their effects;

- biotechnology has contributed much to health improvement, but its cost and application are controversial social and ethical issues.

They will be able to

- describe some of the complex relationships between science, technology, and society in the context of improved health in the Pacific and the world;

- practice sound health habits and monitor their health using available technologies.

They will value

- the availability and utility of health technologies in their own lives,

- maintaining and improving health technologies for people in the Pacific and the world to improve the quality of life;

- career opportunities in health care and health technology.

MATTER: ITS STRUCTURE AND CHANGES

The scientifically literate student understands the structure of matter, the changes it undergoes, and the properties it exhibits as a result.

In order to understand how science describes the world, students must comprehend the nature of matter. They must know about the properties of materials and their combinations, changes of state, effects of temperature, and the behavior of large collections of pieces. The final stage of this understanding is the realization that these behaviors are linked and can be explained by the atomic and kinetic molecular theories.

In order to understand how science describes the world, students must comprehend the nature of matter.

Things in the physical world are made up of an array of materials that seem to differ greatly in shape, density, flexibility, texture, color, and so forth. In spite of initial appearances, everything is made up of a relatively small number of basic materials combined in various ways. When students realize these underlying similarities they can better appreciate their world and apply their new knowledge in technological applications.

As students study the atomic and kinetic molecular theories, they will be able to explain the physical and chemical properties of matter. They will be able to predict what can happen when matter interacts and describe how matter and energy are related. When studying these theories students should develop an understanding of how science operates to generate new knowledge, even about things too small to be seen. The history of science in this area provides us with many case studies of how we know what we think we know and how science contributes to that knowledge.

As students study the atomic and kinetic molecular theories, they will be able to explain the physical and chemical properties of matter.

The atomic and kinetic molecular theories powerfully explain many phenomena, but demand imagination. Therefore, although the groundwork must be developed earlier, the unifying idea of atoms should not be introduced until the upper elementary and middle school years then become more fully developed in secondary courses.

For years, science educators have wrestled with the appropriate use of the terms *mass* and *weight* when matter is discussed in the classroom. The terms have different meanings and should be used correctly. For students, however, the difference between the two is difficult to comprehend and is of little importance until late in the school experience. For these reasons, teachers should use the correct terms in instruction from the earliest grades but should not dwell on the distinction between them until upper elementary and middle school or early high school.

To understand the nature of matter, students should know these related concepts:

A. **The Properties of Matter.** Human senses, with the help of tools, allow us to determine the properties of materials. Understanding these properties enhances human abilities to use materials for a variety of purposes.

B. **Changes in Matter.** Matter can undergo a variety of changes—physical and chemical change, natural and controlled change. In these changes, the amount of matter and the number of atoms remain constant in ordinary situations.

C. **The Unifying Ideas: The Atomic and Kinetic Molecular Theories.** The atomic and kinetic molecular theories are powerful tools to explain many phenomena. These theories provide a framework in which the various behaviors of matter can be explained and predictions made.

A. The Properties of Matter.

Human senses, with the help of tools, allow us to determine the properties of materials. Changes of state, effects of temperature, behavior of large collections of pieces, and the construction of items from parts are key to understanding the properties of matter.

The atomic and kinetic molecular theories provide powerful models for explaining the structure of matter, but most students are not ready to understand the theories before adolescence.

The relationship between the properties of a material and the application of the material in human technology is also important. Too often questions, such as Why aren't cars made of cement? are not asked. Although these questions may seem silly, they engage students in thinking about the properties and applications of different types of matter.

The atomic and kinetic molecular theories provide powerful models for explaining the structure of matter and predicting its behavior. Because of this, bringing these theories into the earlier grades is a great temptation, but most students are not ready to understand atomic or molecular theory before adolescence. Students need to become familiar with the physical and chemical properties of many different kinds of materials through firsthand experience before they can be expected to consider the theories that explain them.

LOWER ELEMENTARY

Students should examine and use a wide variety of objects, categorizing them according to their various observable properties. Objects can be described by the materials they are made from (clay, wood, rock, cement, and so forth.) and by their physical properties (color, size, shape, weight, texture, and so forth.) Tools, such as magnifying glasses and magnets, aid the senses when students explore the properties of matter. Using hand lenses introduces students to the concept that tools have been developed to allow us to learn more than we could have using our senses alone.

Young students should examine and use a wide variety of objects, categorizing them according to their various observable properties.

The concept that materials are made out of pieces and that these pieces can be put together and taken apart to make new things is an important underlying idea that leads to the eventual understanding of theories related to matter. For this reason, students, need to begin to understand that things can be made from pieces and that the properties of the new object may be different from those of the original pieces. Wood and cement can become a house. A car comes apart into glass, plastic, metal, and other components whose properties are very different from the whole car.

MIDDLE ELEMENTARY

The study of materials should continue and become more systemic and quantitative. Students should begin to design and build objects that require different properties of materials.

Objects and materials can be described using more sophisticated properties, such as conduction of heat and electricity, buoyancy, solubility, and transparency. Students should also begin to use measurement and estimation of size, capacity, and mass to enrich their descriptions of objects. The use of tools, such as magnifying glasses and simple microscopes should continue, so that students will gain a realization that materials can be composed of parts that are too small to be seen without magnification.

During the middle elementary years, the concept of objects being made of parts can be extended to include investigations of the masses of these parts. These experiences should lead students to a basic understanding of the conservation of mass (although the formal terms and definition are not necessary at this stage). Students need to realize that no matter how parts of an object are assembled, the mass of the whole object is always the same as the sum of the masses of the parts. When a thing is taken apart, the sum of the masses of the parts is the same as the mass of the whole. Students only reach this understanding after a large number

During the middle elementary years, the concept of objects being made of parts can be extended to include investigations of the masses of these parts.

of hands-on experiences, in which the mass of objects is determined.

The introduction of the atomic and kinetic molecular theories, in upper elementary and middle school enhances the student's ability to describe matter.

UPPER ELEMENTARY/MIDDLE SCHOOL

Students develop a greater ability to describe and its properties. They are able to use an increasingly large variety of tools and characteristics to develop their descriptions. The introduction of the basic ideas of atomic and kinetic molecular theories, at this time, enhances students' ability to describe matter.

Students should develop a sound understanding of the relationship between the properties of a material and the uses of the material by humans, both currently and in the past.

By the end of grade 8, scientifically literate students will understand that

- objects and materials can be described and classified by using a variety of physical and chemical properties;

- some properties depend on the amount of material (such as mass and volume). Some properties (such as density, melting point, and boiling point) are independent of the amount of material;

- equal volumes of different substances usually have different masses.

They will be able to

- use tools for observing and measuring properties of matter,

- relate the properties of materials to products, structures, and substances useful in their lives.

They will value

- the wise use of material resources,

- the need to search for alternative materials either to replace those which are limited in quantity or whose properties are more suitable for the intended use.

SECONDARY

In high school, study of the properties of matter should continue in all science courses. In the Earth sciences, properties define differences in minerals, rock formations, changes of state, water and rock cycles and so on. In biology, properties of matter both define and limit the range of living things. Chemistry and physics constitute the study of matter, its properties, changes, and transformations with energy.

As students progress through their high school courses, they will use more sophisticated instruments, make more precise observations and measurements and develop an understanding of properties of matter-based atomic and kinetic molecular theories.

By the end of secondary school, scientifically literate students will understand that

- all matter is made up of atoms. The atoms of any element are alike but different from atoms of other elements;
- Equal volumes of different substances usually have different masses.

They will be able to

- describe the basic assumptions of the atomic theory,
- relate the properties of materials to their atomic structure.

The will value

- the usefulness of scientific models to explain physical and chemical properties of matter.

B. Changes in Matter.

Matter can undergo a variety of changes in form and properties but the amount of matter and the number of atoms remain constant in ordinary situations.

Understanding the processes of change in matter and attempting to control these changes has been part of human activity for thousands of years. The concept of causing and controlling change is key to many aspects of human life and technology. Food is cooked, cars are painted, wood is treated, sea walls are built, all as part of controlling change.

Understanding the processes of change in matter and attempting to control these changes has been part of human activity for thousands of years.

Although it is important to have a theoretical understanding of the principles that explain the behavior of matter, it is more important that elementary school students explore and experiment with common changes.

Students at the lower elementary level should begin their exploration of changes in matter by exploring common materials.

LOWER ELEMENTARY

Students at the lower elementary level should begin their exploration of changes in matter by exploring common materials. The effects of treatments such as mixing, heating, freezing, cutting, wetting, and bending provide a good introduction. As a result of these explorations students should realize that not all materials respond to treatment in the same way.

Students should look at the changes in matter that are commonplace in the everyday world. Some changes are fast and some are slow. Some changes in matter occur naturally and others are deliberately caused by people. Wood rots and iron rusts as part of natural processes. Metals are shaped by humans to make tools and food is cooked to change its properties.

MIDDLE ELEMENTARY

At this stage, students can begin to structure investigations to see how substances change, such as when pure substances are combined to form mixtures. Examples from the familiar environment of the home and the natural world provide an excellent basis to begin these explorations. Heat energy is a major cause of change. Heating and cooling cause changes in the properties of materials and many kinds of changes occur faster under hotter conditions.

Exploration of change, both in the classroom and the world around them, should lead students to realize that when a new material is made by combining two or more materials, it has properties that differ from the original materials. For that reason, many different substances can be made from a small number of basic materials

Upper elementary students should be familiar with characteristics of the different states of matter and the transitions between them.

UPPER ELEMENTARY/MIDDLE SCHOOL

Upper elementary and middle school students should be familiar with characteristics of the different states of matter, including gases, and the transitions between them. Most importantly, students should experience a great many examples of reactions between substances that produce new substances which are very different from the reactants.

By the end of grade 8, scientifically literate students will understand that

- matter exists in different states, each of which has different properties. Under the right conditions matter will change from one state to another;
- change in matter may form new materials and be difficult to reverse (chemical change) or may change the properties of the matter without forming new materials (physical change);
- changes in matter are part of all living and non-living systems;
- rates of change vary and can be influenced by temperature, dissolving in water, and the nature of the reactants;
- when matter interacts in a closed system, the total mass in the system remains the same. Mass is conserved.

They will be able to

- demonstrate changes in matter and the ability to control the change by using everyday materials,
- describe instances from their everyday lives where changes in matter are controlled, either to encourage or discourage change.

They will value

- the importance of changes in matter to new technologies, synthesizing new materials, and seeking ways to recycle used materials.

SECONDARY

Living systems, non living systems, and human technology all involve changes in matter. At the secondary level students should be able to recognize and understand the interrelationships among the various systems and the role that changes in matter play.

At the secondary level, students should be able to recognize and understand the interrelationships among the various systems and the role that changes in matter play.

By the end of secondary school, scientifically literate students will understand that

- changes in either pressure, temperature, or volume of a gas results in predictable changes in either or both of the other properties;
- living systems survive, in part, as a result of the transfer and transformation of matter;
- Earth's systems involve the effects of energy on matter to cause both physical and chemical changes;

They will be able to

- relate local technologies, including the utilization and preservation of materials, to either causing or controlling changes in matter.

They will value

- the human endeavor to develop technology to cause and control changes in matter in order to produce useful materials and improve the quality of life.

C. The Unifying Ideas: Atomic and Kinetic Molecular Theories

These theories provide a framework in which the various behaviors of matter can be explained and predicted.

The atomic and kinetic molecular theories are powerful tools to explain many phenomena. These theories provide a framework in which the various behaviors of matter can be explained and predicted. It is through these theories that earlier observations concerning the structure, properties, and changes of matter become unified.

UPPER ELEMENTARY/MIDDLE SCHOOL

With continued hands-on experience with matter, its properties, and its changes, middle school students can begin to absorb the basic ideas of the atomic and kinetic molecular theories.

With continued hands-on experience with matter, its properties, and its changes, upper elementary and middle school students can begin to understand the basic ideas of the atomic and kinetic molecular theories.

A meaningful grasp of the ideas addressed by these theories depends upon developing a number of other understandings and skills. Because most students will lack the necessary understandings until late in elementary school, it is probably not appropriate to begin addressing these issues until the upper grades. The more detailed study should be reserved for secondary school.

By the end of grade 8, scientifically literate students will understand that

- a model for the structure of matter can be created that consists of very small particles that become rearranged during a reaction, but do not change in number or mass during a reaction. Different substances are made up of different kinds of particles;
- the particulate model is useful in describing the structures and properties of solids, liquids, and gases;
- all substances are composed of different arrangements of atoms;
- there are groups of elements that have similar properties.

They will be able to

- describe matter as composed of small particles in motion and identify some of the properties resulting from this assumption.

They will value

- the usefulness of models to describe complex properties and events that cannot be directly observed.

SECONDARY

Understanding the general architecture of the atom and roles played by the main parts of the atom in determining the properties of materials now becomes relevant and critical for a greater depth of understanding to take place.

In high school the general architecture of the atom and its roles in determining the properties of materials becomes important for a greater depth of understanding to take place.

By the end of secondary school, the scientifically literate student will understand that

- atoms consist of a positively charged nucleus surrounded by one or more negatively charged electrons. The electric force between them holds atoms together. An atom's electron configuration determines how it can interact with other atoms;

- the nucleus is composed of protons and neutrons, each almost two thousand times heavier than an electron. The number of positive protons in the nucleus determines the number of electrons, their configuration, and the properties of an element;

- the nuclei of radioactive isotopes are unstable and spontaneously decay, emitting particles and/or wave-like radiation. A large group of identical nuclei decay at a predictable rate. This predictability of decay allows the use of radioactivity to estimate the age of many materials;

- when elements are ordered according to masses of their atoms, the same sequence of properties is repeated in the list;

- atoms often join in various combinations in distinct molecules or in repeating three-dimensional patterns. An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules;

- the rate of reaction among atoms and molecules depends on how often they encounter one another, which is affected by concentration, temperature, and pressure. Some atoms and molecules are highly effective in catalyzing the interaction of others;

- like most scientific ideas, the ideas about atoms and the nature of matter developed over a long period of time. Scientists continue to investigate atoms and have discovered even smaller parts that make up electrons, neutrons, and protons.

They will be able to

- relate observed properties and changes in matter to the behavior of molecules and atoms as described in the atomic and kinetic molecular theories.

They will care about and value

- the nature and growth of science as shown in the historical development of the current theories on the properties of matter,

- the ongoing refinement of these theories as additional data is collected.

ENERGY

The scientifically literate student understands energy—its sources, uses, transformations from one form to another, and its conservation under ordinary conditions.

The physical universe is a collection of systems that interact through energy and its transformation. Energy manifests itself in a variety of forms (light, sound, wave, wind, heat, electromagnetic, and so forth.), all of which have been described after many years of observation and experimentation. All these forms can be, and often are, transformed from one type to another.

Because energy is part of all natural processes, involving both the physical and living surroundings, and because of its role in powering human technology, an understanding of energy is a cornerstone of scientific literacy.

Because energy is part of all natural processes, involving both the physical and living surroundings, and because of its role in powering human technology, an understanding of energy is a cornerstone of scientific literacy.

Energy is an abstract but fundamental concept in science. The forms of energy are well known and the effects of energy are readily evident, but energy itself is difficult to conceptualize. For this reason students will be able to talk about and experiment with energy before they will be able to define it. An exact definition of energy is unnecessary until late in the school experience.

The term *energy* is used in both the traditional physics sense and in the everyday sense of energy resources used by human societies. *Conservation* is used only in connection with the principle that within a system the total amount of energy remains constant under ordinary conditions. *Energy resource management* is used when discussing the preservation and thoughtful use of available energy sources by human societies.

Scientific literacy includes an understanding of the following related concepts:

A. **The Characteristics and Forms of Energy.** Energy is the ability to do work. It manifests itself in a variety of forms and displays a variety of characteristics.

B. **Energy Transformations and Conservation.** The transfer and transformation of energy is a critical part of all living, physical, and human systems. During these transformations, energy is reduced in one place but increased in others by exactly the same amount. A significant portion of the energy produced, however, may be in a form that is not useful.

A. The Characteristics and Forms of Energy

Energy manifests itself in a different forms, each of which has distinct characteristics. Heat, electricity, sound, chemical energy (including strong and weak nuclear interactions), light (and other forms of electromagnetic radiation), gravitational potential energy, and kinetic energy are the principal forms with which students should become familiar.

Chemical, gravitational potential, and kinetic energy are specifically dealt with in other standards. Heat, light, electricity, and sound are emphasized in this standard.

LOWER ELEMENTARY

It is not necessary to introduce energy as a scientific concept at this stage. Students should have many different experiences with the different forms of energy that they encounter on a daily basis. What makes it work? is a good question to begin the discussion on energy. Cars need gas; toys and radios need batteries; televisions and refrigerators need electricity; solar water heaters and calculators need light; windmills and sailboats need wind, and so forth.

If the major forms of energy are identified for students, young children will enjoy the challenge of "finding" the energy in their lives and identifying its effects—helpful and harmful.

As the major forms of energy (light, heat, sound, electricity, water waves, and so forth) are identified, children of this age will enjoy the challenge of "finding" the energy in their lives and identifying its effects, both helpful and harmful. The sun should be recognized as a major energy source.

The interaction of the senses with light, sound, and heat is also important at this stage. Beginning with an exploration of sounds they can make themselves, children can create sounds using an assortment of "instruments" and come to the realization that different sounds can be created by causing air to vibrate. Light enables us to see. Light sources, including the sun, produce light which is reflected by other objects, allowing us to see them. Objects absorb heat energy which makes them feel hot. Those objects having less heat energy feel cold. The sun is a source of heat, as well as light, and objects in direct sunlight become warmer than those left in shady areas.

MIDDLE ELEMENTARY

By the middle elementary grades, students are able to begin manipulating energy in its various forms to determine its characteristics. The relationship between the forms of energy and materials provides for meaningful and interesting explorations. Some types of materials let energy to pass through them and others do not. There are conductors and insulators, things that are transparent and opaque. A material that is a good conductor of one form of energy may be a poor conductor of another.

By the middle elementary grades, students are able to begin manipulating energy in its various forms to determine its characteristics.

Light energy exhibits interesting properties, including reflection and refraction, that can be studied through simple activities. The study of light can also be connected to study of the eye, vision, and related physiology.

The exploration of sound, begun in the early elementary years can continue with a more detailed study of how various sounds are produced, how humans perceive sound, and how sound can be both helpful and harmful to human life.

Heat is a form of energy that is particularly interesting to students of this age. Heat energy affects matter, causing it to expand (in most cases) and, if enough heat is supplied or removed, to change the state. Energy, including heat, can be transferred. When warmer objects are placed with cooler ones, the warmer one loses heat energy and the cooler one gains until they are at the same temperature. Temperature is an indirect measure of the heat energy present and can be a very difficult and confusing idea for students, unless the concept is based upon a great deal of hands-on practice.

Electricity, as a common form of energy (whether from current electricity or batteries) is a worthwhile topic on which to base an exploration of society's use of and dependence on energy to maintain present-day life styles.

UPPER ELEMENTARY/MIDDLE SCHOOL

The study of energy in the upper elementary and middle school years should reinforce the concepts introduced in middle elementary school, with the addition of more in- depth study. At this stage, students can begin to measure angles of incident and reflected light, calculate the electrical energy used by appliances, graph changes in heat energy (temperature) over time, and so forth.

The study of energy in the upper elementary school years should reinforce the concepts introduced in middle elementary school, with the addition of more in depth study.

By the end of grade 8, scientifically literate students will understand that

- energy is found in a variety of forms including heat, light, sound, electrical, and mechanical. Two of the most useful forms of energy are electrical and magnetic;
- energy can be stored physically and chemically. Batteries, food, wood, and gasoline store energy chemically. Stretched rubber bands, compressed springs, suspended objects store energy physically;
- the sun is the major source of energy for events on Earth's surface;
- every human action requires energy;

They will be able to

- identify and describe different forms of energy,
- measure heat energy involved in reactions with matter,
- describe some of the uses of energy in mechanical and living systems.

They will value

- the importance of energy to their lives and for all living things,
- the increasing knowledge humans have developed to control energy and convert it for technological purposes,
- the environmental impacts of increasing energy use by humans.

The forms of energy and their properties should be revisited in the secondary years to improve student understanding of the concepts.

SECONDARY

Study of forms of energy and their properties should be revisited in the secondary years to improve student understanding of the concepts. The application of mathematics to these investigations is a useful tool but should only be used where it contributes to greater understanding.

By the end of secondary school scientifically literate students will understand that

- energy is the ability to do work;
- energy exists in a variety of forms that can be divided into kinetic energy, which is the energy of motion, and potential energy, which depends on relative position. The total energy of the universe is constant. It can only be converted from one form to another and/or moved from one place to another;
- mass is a form of energy, and like all others can be converted into other forms;
- heat energy in a material consists of the motion of its atoms and molecules. Heat energy will spread itself out evenly, spreading by radiation and conduction into cooler places.

They will be able to

- identify and describe properties and classifications of energy and its ability to do work;
- describe the importance of energy physical and living systems.

They will value

- the impact that understanding energy through science has had on technology and cultures,
- the potential dangers of energy conversion and use by humans.

B. Energy Transformations and Conservation

Most of what goes on in the universe involves one form of energy being transformed into another.

Most of what goes on in the universe—the explosion of stars, the operation of machines and computers, the growth and development of the human body—involves one form of energy being transformed into another. When energy changes from one form to another, the total amount of energy present remains unchanged but part, sometimes a large part, of the resulting energy will be in unusable form. Heat energy is a very common "waste product" of energy transformations.

Students should begin understanding energy transformations and conservation by observing these changes in their immediate surroundings, initiating and controlling energy transformations, eventually realizing that energy resource management is extremely important to human societies.

Explore the energy transformations that are part of the lower elementary student's everyday environment. Food as an energy source for people and other animals and sunlight for plants warrant exploration.

LOWER ELEMENTARY

The question, What makes it work? can be extended to What did the energy make it do? to begin building the concept of energy changes. The battery made the toy move, the battery or electricity lets the radio produce sound, the wind made the sail boat move, and so forth. It is far too early to introduce the concept of conservation of energy but young children can see that energy changes form and that one form of energy is used to produce another (For example, the batteries in a toy or radio are eventually "used up" when the toy moves or the radio produces sound).

Special care should be taken to explore the energy transformations that are part of the student's everyday environment. Food as an energy source for people and other animals and sunlight as an energy source for plants warrants exploration. Details of the processes involved are not necessary at this time.

The study of energy transformation in the middle elementary students' immediate environment helps them grasp the importance of energy in all aspects of life.

MIDDLE ELEMENTARY

The transformations of mechanical and electrical energy are commonplace and relatively easy to study. The mechanical energy of machines is a common experience and opens the door to exploring the development of tools that assist society in designing a world more suitable to people. The study of electricity through simple circuits designed by students and through the production, distribution, and use of electricity by the community provides insight into this form of energy and the importance it has gained in human societies

Energy transformations in the natural setting should also be examined. Wind, erosion, landslides, and ocean waves are all examples of energy transformations.

By upper elementary and middle school, students can begin to look seriously at energy transformations by tracing energy through various systems.

UPPER ELEMENTARY/MIDDLE SCHOOL

At this level, students can begin to look seriously at energy transformations by tracing energy through various systems. With examples that involve several different forms of energy, students should be able to trace where energy comes from and where it goes next. Heat, light, motion of objects, chemical, elastic energy can all be studied in this way. The study of systems in terms of energy can and should be expanded to include living and Earth systems.

It is important that students understand that energy is not used up, but simply transformed. Food, gasoline, and batteries are used up, but the energy they once contained is present in a new form. Through a variety of experiences, students should reach the understanding that, in normal situations, energy cannot be created or destroyed—it is simply transformed. Students also need to realize that no process is one hundred percent efficient and that, although energy is conserved, useful and waste energy is produced in the process of change. These energy transformations involve either work being done, heat being produced, or both.

Through a variety of experiences, students should reach the understanding that, in normal situations, energy cannot be created or destroyed—it is simply transformed.

By the end of grade 8, scientifically literate students will understand that

- energy cannot be created or destroyed but can be changed from one form to another;
- most of what occurs in the universe, from exploding stars and waves on the ocean to the growth and motion of people, involves some form of energy being transformed into another;
- all energy transformations have undesirable side effects. Some energy is always transformed into unusable forms and in many cases, such as nuclear power and burning fossil fuels, there are unwanted by-products;
- within human communities and in the natural world, are numerous chains of energy transformation;
- energy conversions are never one hundred percent efficient. When energy is transferred from one object to another or is transformed from one form to another, work and/or heat are involved. Some energy is lost as heat, making it unavailable for useful work.

They will be able to

- demonstrate converting one form of energy into another,
- measure the heat produced in energy transformations,
- use kinetic molecular theory to describe a model of heat,
- trace energy flow through actual or simulated ecosystems.

They will value

- their increasing ability to use science to describe and understand nature.

SECONDARY

The concepts of energy transformation developed in the earlier grades can be extended for secondary students now.

The concepts of energy transformation developed in the earlier grades can now be extended to include nuclear energy and energy in living systems, and to a limited extent, mathematical skills can be applied to the study of energy transformation.

By the end of secondary school, scientifically literate students will understand that

- the transfer and transformation of energy is a critical part of all living, natural, and human-made systems. Earth systems, chemical changes, and biological processes require and/or release energy;

- whenever the amount of energy in one place or form diminishes, the amount in other places or forms increases by the same quantity, although at least some of the energy will be in an unusable form;

- transformations of energy usually produce some energy in the form of heat. Although the total energy remains constant, the heat spreads itself out evenly and is often not usable;

- human technology has been applied in numerous ways to transform energy into forms that are easy to move from one place to another, easy to store, or easy to use, depending on the requirements involved;

- energy is released whenever the nuclei of very heavy atoms, such as uranium, split into smaller ones, or when very light nuclei combine to form heavier ones. The energy released in these transformations is much greater than the energy released during a chemical change.

They will be able to

- measure work and heat resulting from energy transformations,

- calculate the efficiency of energy transfer in sample systems,

- describe possible ways or uses of technology to increase efficiency of energy transfer,
- trace the energy transformations within physical and biological systems.

They will value

- the environmental impact of the by-products produced by certain energy transformations.

MOTION AND FORCE

The scientifically literate student understands that the movement of matter can be explained or described in terms of application of forces; that position and motion of objects are judged relative to a frame of reference; that all objects exert force; that forces have both magnitude and direction; and that change in motion or momentum are caused by forces.

An understanding of motion, like matter and energy, is essential to understanding the physical world.

The mathematics of equation solving should not be a barrier to understanding the important science concepts.

Nothing in the universe is at rest. An understanding of motion is an essential part of understanding the physical. Motion covers a wide range of topics, from the movement of objects to vibrations and the behavior of waves.

Understanding the motion of objects does not demand the use of equations. For purposes of scientific literacy, a qualitative understanding is sufficient. Equations may clarify relationships for mathematically adept students, but for many, such abstractions may obscure rather than clarify. For example, almost all students can grasp that the effect of a force on an object's motion will be greater if the force is greater, but learning $a=F/m$ is apparently more difficult.

Newton's Laws of Motion are simple to state and sometimes teachers mistake the ability of students to recite the three laws correctly as evidence that they understand them. However, most research indicates that students typically have trouble relating formal ideas of motion and force to their personal view of how the world works.

These seem to be the basic obstacles:

1. One problem is the ancient perception that sustained motion requires sustained force. The contrary notion that it takes force to change an object's motion, that something in motion will move in a straight line forever without slowing down unless a force acts on it, runs counter to what we see happening with our eyes. Most ordinary demonstrations about force and motion are inaccurate because of overlooked forces and usually do not help to reinforce a scientific understanding of motion.

2. Limitations in describing motion may keep students from learning about the effect of forces. Students tend to think in

terms of motion or no motion, so the first task may be to help students divide the category of motion into steady motion, speeding up, slowing down. For example, falling objects should be described as falling faster and faster rather than just falling down. Students then would understand why coconuts land with such an impact. The basic idea expressed in Newton's Second Law of Motion is not difficult to grasp, but vocabulary may be in the way if students have to struggle over the meaning of force and acceleration.

3. Like inertia, the action-equals-reaction principle is opposite to what people think. To say that a book presses down on the table is sensible enough, but then to say that the table pushes back up with exactly the same force and that force disappears the instant you pick up the book seems false on the face of it.

What can be done? Students should have lots of experience to shape their intuition about motion and forces long before encountering laws. Especially helpful are experimentation and discussion of what happens as surfaces become more elastic or more free of friction.

Understanding motion and force means students know about these related concepts:

A. Motion. Different kinds of motion of objects on Earth and in the universe explain everyday events and can be used to predict future events.

B. Forces of Nature. Gravitational and electromagnetic forces give matter some of its properties and result in the motions of and interactions between objects.

A. Motion

Linear and vibrational motion treated only descriptively bring no special problems other than the occasional confusion caused by the word *speed* being used in the English language for both frequency and velocity. Does a guitar string move quickly (back and forth a thousand times per second) or slowly (only 15 miles per hour or so)? Studies of vibration may serve to introduce ideas of frequency and amplitude because there are so many examples of vibrating systems that students can experience directly. They easily see vibrations as a common way for some things to move and see frequency as a measure of the motion.

Wave motion, however, presents a greater challenge. Wave motion is familiar to children through their experiences with water. Surface waves on water provide the standard image of what waves are. Ropes and springs can also be used to show some properties of waves. Even without formal schooling, young people learn that many other kinds of waves exist: radio waves, x rays, radar, microwaves, sound waves, ultraviolet radiation, and more. But they still might not know what these things are or how they relate to one another, what they have to do with motion, or in what sense they are all waves.

LOWER ELEMENTARY

From the beginning, students should view, describe, and discuss all kinds of moving things: themselves, insects, birds, boats, oceans, sand on the beach, stars. They hould keep notes, draw pictures of objects or animals in motion, and raise questions for discussion. Do they move in a straight line? Is their motion fast? Or slow? How can you tell? How many ways does a growing plant move? Students should gain varied experiences in getting things to move or not to move, and changing the direction and speed of things in motion.

Lower elementary students should view, describe, and discuss all kinds of moving things: themselves, insects, birds, boats, oceans, stars.

Students should be introduced to vibrations as phenomena rather than theory. They can feel the vibrations of drums, bells, strings, their own voices. They can feel the vibrations on the instruments as they hear the sounds. These experiences are important for their own sake and need no elaboration.

Students should be introduced to vibrations they can feel like the vibrations of drums, bells, strings, their own voices.

Through such experiences students will find that things move with different kinds of motion, such as straight line, zigzag, round and round, back and forth, fast and slow. They will also know that to change how something is moving you must give it a push or a pull and that things that make sound vibrate.

MIDDLE ELEMENTARY

Students should continue describing motion. As they do more experiments, they can be more quantitative. Determining the speed of fast things and slow things can be a challenge that students readily respond to. They can work out for themselves some of the general relationships between force and change of motion. They can internalize the notion of force as a push or pull of one thing on another. Students should further study vibrations in relationship to how fast something vibrates and what sounds occur.

Middle elementary students can work out for themselves some of the general relationships between force and change of motion.

As students expand their experiences with motion they will see that something that is moving may move steadily or change direction and that force has an effect on both speed and direction of moving objects.

The force-motion relationship can be developed more fully in the upper elementary grades.

The presence of friction should be part of their study. The more experiences students have in seeing the effect of reducing friction, the easier it may be for them to imagine the friction-equals-zero case.

UPPER ELEMENTARY/MIDDLE SCHOOL

The force-motion relationship can be developed more fully now. The difficult idea of inertia can be introduced. Students have no trouble understanding that an object at rest stays that way unless acted upon by a force—they see it every day. The difficult notion is that an object in motion will continue in motion endlessly unless acted upon by a force. Telling students to disregard what they see is of little use. Common sense will prevail. The more experiences students have in seeing the effect of reducing friction, the easier it may be for them to imagine the friction-equals-zero case.

Students can now examine some of the properties of waves by using water tables, ropes, and strings. They can also begin to learn about the electromagnetic spectrum, including the assertion that it consists of wave-like actions. Wavelength should be the property receiving the most attention, but only minimal calculations.

By the end of grade 8, scientifically literate students will understand that

- Vibrations in materials set up wave-like disturbances that spread away from the source. Sound and earthquake waves are examples. These and other waves move at different speeds in different materials.

- In the absence of retarding forces such as friction, an object will keep its direction of motion and its speed. Whenever an object is seen to speed up, slow down, or change direction, an unbalanced force is acting upon it.

- Light from the sun is made up of a mixture of many colors of light, even though to the eye light looks almost white. Things that give off or reflect light have a different mix of colors.

- Something can be "seen" when light waves are emitted or reflected by it. Light waves enter the eye just as something can be heard when sound waves from it enter the ear.

- Human eyes respond to a narrow range of wavelengths of electromagnetic radiation (visible light). Differences of wavelength within that range are what allows our perception of differences in color.

They will be able to

- describe the origin of sound in vibrations of musical instruments,
- identify different kinds of motion and the effect of force on direction and speed,
- describe the apparent color of objects as a result of reflection and absorption of different colors of light.

They value

- their ability to describe complex events by applying simple laws of motion,
- their ability to understand and control motion in their environment.

SECONDARY

At this level, students should learn about relative motion, action-reaction principles, wave behavior, interaction of waves with matter, and the Doppler effect, now used in weather observation to determine the movement of typhoons and hurricanes and in astronomy to measure the red shift of distant galaxies. Relative motion is fun to investigate. Students will find it interesting to figure out their speeds in different frames of reference. Many activities and some excellent films illustrate these relationships. Learning the concept is also important for the role it plays in understanding the Copernican revolution and simple relativity.

Students will find it interesting to figure out their speeds in different frames of reference.

At this level it is also time to show the power of mathematics. Students can move from a qualitative understanding of force-motion relationships to one of quantitative understanding (the change in motion is directly proportional to the amount of force and inversely proportional to the mass). Experimentally, they can show that the change in motion increases with greater force and decreases with increasing mass.

Secondary school students can move from a qualitative understanding of force-motion relationships to one of quantitative understanding.

The interactions between matter and energy of various wavelengths can lead to a discussion of how properties and uses are interrelated.

The effect of wavelength on how waves interact with matter can be developed. Students can investigate the blueness of the sky and the redness of sunsets that result from light of different wavelengths or the color of grass resulting from its absorbing light of both shorter and longer wavelengths while reflecting green. This scattering of wavelengths of light enable Pacific islanders to predict the weather.

Electromagnetic waves have different effects on the human body. Some pass through the body with little effect, some can be injurious to the skin, and some are absorbed in different amounts by internal organs. Some are even used to cook food.

By the end of secondary school, scientifically literate students will understand that

- the change in motion of an object is directly proportional to the applied force and inversely proportional to the mass;
- all motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion;
- whenever one thing exerts a force on another, an equal amount of force is exerted back on it;
- accelerating electrical charges produce electro-magnetic waves, radio waves, microwaves, radiant heat, visible light, ultraviolet radiation, x rays, and gamma rays. Wavelengths vary from radio waves (longer) to gamma rays (the shortest). In empty space, all electromagnetic waves move at the speed of light;
- the observed wavelength depends upon the relative motion of the source and the observer. If either is moving toward the other, the observed wavelength is shorter. If either is moving away, the wavelength is longer. This is what we use to determine the direction and speed of typhoons and hurricanes. Because the light seen from almost all distant galaxies has longer wavelengths than comparable light here on Earth, astronomers believe that the whole universe is expanding;
- waves can superimpose on one another, bend around corners, reflect off surfaces, be absorbed by materials they enter, and change direction when entering a new material. All these effects vary with wavelength. The energy of waves (like any

other form of energy) can be changed into other forms of energy;

They will be able to

- apply their knowledge of motion and electromagnetic forces to constructing simple motors and radios,
- describe relative motion from different frames of reference,
- identify applications of the principles of motion in their lives,

They will value

- the technologies that result from understanding motion in medicine, food preparation and preservation, weather prediction, astronomy, and other areas,
- their ability to predict events based on understanding motion of objects,

B. Forces of Nature

In helping students broaden their understanding of the fundamental forces of nature, teachers should emphasize gravitational and electromagnetic forces.

For the early school years, force may be treated as the cause of motion, and an explanation of force itself may be postponed. But the force between a bat and a ball has an entirely different origin than that between Earth and the moon. In helping students broaden their understanding of the fundamental forces of nature, teachers should emphasize gravitational and electromagnetic forces.

Students should developing the general idea of universal gravitation and how weak it is compared to other kinds of forces. Gravity becomes appreciable only when very large accumulations of matter are considered such as the entire Earth. To students, gravitational forces seem strong compared to the trivial electrical forces on dry hair charged by combing. But through investigation and discussion they can begin to understand quite the opposite. The whole Earth is required to pull the hair down, while only a small amount of charge is needed to force it up against gravity.

Electrical and magnetic forces and the relationship between them should be dealt with qualitatively. Fields can be introduced, but only descriptively. Most important is that students get a sense of electric and magnetic fields (as well as of gravity) and of some simple relationships between magnets and electric currents. The priority should be on what conditions produce magnetic fields and what conditions induce an electric current.

LOWER ELEMENTARY

The focus should be on motion and encouraging lower elementary children to observe when and how things seem to move or not to move.

At the lower elementary level the focus should be on motion and encouraging children to observe when and how things seem to move or not to move. They can see that things fall to the ground if not held up. They should observe motion everywhere, making lists of different kinds of motion and what things move that way. Children may use magnets to get things to move without touching them and thereby learn that forces can act at a distance with no perceivable substance between them.

It is sufficient at this level for students to know that things near the earth fall to the ground unless something holds them up, and that some things like magnets can make things move without being touched.

MIDDLE ELEMENTARY

The main notion to convey to middle elementary students is that forces can act at a distance.

The main notion to convey here is that forces can act at a distance. Students should carry out investigations to become familiar with the pushes and pulls of magnets and static electricity. The term *gravity* may interfere with students' understanding because it is often used as an empty label for the common (and ancient) notion of "natural motion" toward the earth. The important point is that the earth pulls on objects.

Students at this level can be expected to know that Earth's gravity pulls objects toward it without touching them. Magnets exert similar forces on objects. Without touching them, materials that have been electrically charged can pull on other materials.

UPPER ELEMENTARY/ MIDDLE SCHOOL

Middle school students should construct devices to observe the magnetic effects of current and the electric effect of moving magnets.

Up to this point, gravity has been seen as something happening near Earth's surface. This can be generalized to all matter everywhere in the universe. Some demonstrations in the laboratory or on film or videotape of gravitational force between objects may be essential to break through the primary notion that things just naturally fall. Students should construct devices to observe the magnetic effects of current and the electric effect of moving magnets. At first, the devices can be simple electromagnets. Later, more complex devices, such as motors can be introduced and constructed.

By the end of grade 8, scientifically literate students will understand that

- every object exerts gravitational force on every other object. The force depends upon how much mass the objects have and on how far apart they are. The force is difficult to detect unless at least one of the objects has a lot of mass;
- the sun's gravitational pull holds the earth and the other planets in their orbits, just as the planets' gravitational pull keep their moons in orbit around them;
- electric currents and magnets can exert a force on one another.

They will be able to

- describe the effects of gravity on motion of objects,
- identify everyday applications of electric and magnetic forces.

They will value

- their increasing ability to understand and describe events in their world.

SECONDARY

At this level students should learn how well the principle of universal gravitation explains the structure of the universe and much that occurs on Earth. The principle will become familiar and important to the Pacific people from many examples such as star formation, tides, comet orbits, and so forth. The most important fact is that the earth's gravity does extend beyond its atmosphere to a great distance into space.

Secondary students should learn how well the principle of universal gravitation explains the structure of the universe and much that occurs on Earth.

Study of the nature of electric and magnetic forces should be integrated with the study of the atom. What is likely to surprise many students is how much more powerful electromagnetic forces are than gravitational forces, which are negligible on the atomic scale. As students come to understand the action-reaction principle, they will expect forces to be mutual.

Study of the nature of electric and magnetic forces should be integrated with the study of the atom during secondary school.

By the end of secondary school scientifically literate students will understand that

- gravitational force is an attraction between masses. The strength of the force is proportional to the masses and weakens rapidly with increasing distance between them;

- electromagnetic forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. At the atomic level, electric forces between oppositely charged electrons and protons hold atoms and molecules together and thus are involved in all chemical reactions. On a larger scale, these forces hold solid and liquid materials together and act between objects when they are in contact, as in sticking or sliding friction;

- there are two kinds of charges—positive and negative. Like charges repel one another. Opposite charges attract one another. In materials, there are almost exactly equal proportions of positive and negative charges, making the materials as a whole, electrically neutral. Negative charges associated with electrons are far more mobile in materials than positive charges. A very small excess or deficit of negative charges in a material produces noticeable electrical forces;

- different kinds of materials respond differently to electrical forces. In conducting materials, such as metals, electrical charges move easily; whereas in insulating materials, such as glass, they can move hardly at all. At very low temperature, some materials become superconductors and offer no resistance to the flow of current. In between these extremes, are semi-conductive materials;

- magnetic forces are very closely related to electric forces and can be thought of as different aspects of a single electromagnetic force. Moving electrical charges produce magnetic forces. Moving magnets produce electric forces;

- the forces that hold the nucleus of an atom together are stronger than electromagnetic forces. That is why such great amounts of energy are released from nuclear reactions in the sun and other stars.

They will be able to

- describe and identify different kinds of forces along the electromagnetic spectrum,
- identify applications of gravitational and electromagnetic forces in their lives.

They will value

- the potential and hazards of controlling usable energy from gravitational, electromagnetic, and nuclear forces.

THE PLANET EARTH: OCEANS AND LAND

Scientifically literate students understand the motions of the earth and how these motions are related to natural phenomena on Earth's surface. They also understand and appreciate the processes that shape the surface of the earth and the relationship of the earth's surface to the living environment.

The motion of the earth and its relationship to the moon and sun cause climate, the seasons, the weather, and the characteristic motion of the seas. The very face of the earth, has been molded by processes that occur within the earth itself. And all living things are ultimately shaped by forces that reach from the deep center of the earth to the outer limits of its atmosphere.

These are very big concepts about great, powerful processes in the physical world. It is important that students grasp them because they relate human and other forms of life to the physical environment in very concrete terms. By understanding how Earth interacts with other objects in space, they develop an appreciation of the natural forces and processes that affect all life and phenomena on the planet.

By understanding how Earth interacts with other objects in space, students develop an appreciation of the natural forces and processes that affect all life and phenomena on the planet.

Students should begin their study of these processes by observing and questioning what is "near" them. Later they can be introduced to other environments and events that are "far" from them. They may ask questions such as Why do hurricanes and typhoons occur during certain times of the year? Why does the ocean move toward then away from shore? How does the moon reflect this movement? Why do Pacific islands differ in structure and form? How do Pacific islands differ from continents? In what ways do plants and animals differ in different ocean and land environments? How do living creatures survive great changes in their environments or on the earth's surface?

Natural forces are not the only ones that shape the earth's surface. The fragile ocean and land ecosystems of the Pacific islands have been greatly modified by human activity, especially modernization. If the earth warms and the sea level rises, what will become of our low-lying atolls? When trees are unearthed to make way for roads and buildings, what happens during heavy seasonal rains? What becomes of the topsoil no longer secured by plant roots? And how does soil erosion affect water resources and coral reefs? Most importantly, how can scientifically literate students address the harmful effects of human activity?

Scientifically literate students will understand how human existence is influenced not only by the physical environment but also by the ways people use the earth's natural resources.

The scientifically literate student understands how human existence is conditioned not only by the physical environment but also by the ways people use the earth's natural resources. They recognize too, how human activity affects the physical and living environment. Scientifically literate students understand these related concepts:

A. **Motions of the Earth.** The earth's revolution around the sun, the tilt of its axis, its rotation on its axis, and the moon's orbit around the sun cause climates, seasons, weather, and characteristics of the ocean.

B. **Processes that Shape the Surface of the Earth.** Forces within the earth continually change its surface, forming ocean basins, island formations, and vast continents. Human activities also affect the surface of Earth.

C. **Relationship of the Earth's Surface to the Living Environment.** The non-living environment of water and land shapes ecosystems. Living organisms are conditioned by rainfall, temperature, topography, mineral concentrations, and solar radiation.

A. Motions of the Earth

Seasons, weather, tides, waves, and currents are phenomena familiar to students. A scientifically literate student, however, will know how they occur and change.

Understanding how the earth is heated at different times of the year will help students grasp how the Pacific differs from other places on Earth.

Seasons change because the earth revolves around the sun on a tilted axis. Understanding how the earth is heated at different times of the year will help students grasp how the Pacific differs from other places on Earth. They will be able to comprehend why a continental climate has hot summers and cold winters, and their tropical climate has rainy, windy, and dry seasons.

Solar energy heats Earth's air, land, and oceans. When large masses of air are heated (or cooled), they move, causing winds, fronts, and air pressure systems, in other words, weather conditions. Moisture in the air produces humidity and clouds. A scientifically literate student should understand how air and water behave when heated and cooled.

Waves are pulses of energy that move through the ocean. The most common source of energy for waves is the wind blowing across the surface of the ocean. Waves are also set in motion by earthquakes and the gravitational pull of the moon.

Currents are a less visible motion of the seas. They move below the surface of the water in response to wind patterns and differences in water dens ·y. Density is determined by the salinity and temperature of the water, which change at varying depths. For example, denser water will move under a less dense, or less salty, body of water. Pacific islanders have traditionally used currents to navigate long distances on the ocean. A scientifically literate student should understand how different types of water behave and cause currents.

Tides are the regular rise and fall of ocean water caused by the gravitational attraction between the earth, moon, and sun. The ocean "swells" on two sides of the earth—the side facing toward and the side facing away from the moon. This swelling causes ocean water to rise near shores, making a high tide. The positions of the earth and the moon relative to the sun also change the height of tides. For example, some tides are higher than other high tides, and some low tides are lower than normal low tides. Traditional knowledge of the skies and the seas has long enabled Pacific islanders to predict the tides and adjust their fishing techniques accordingly.

LOWER ELEMENTARY

Lower elementary students should begin their study of planet Earth by exploring the concept of time. Activities such as noting the sunrise and sunset, moonrise and moonset each day; recording the beginning and end of each week, month, and year, and the events and activities that occur within them help students develop an idea of schedule.

In general, young students should be able to describe the natural phenomena around them.

In general, students at this level should be able to describe the natural phenomena around them. They should describe the weather, noting if it is sunny, rainy, cloudy, or windy. They can begin categorizing cloud types and wind direction and types of rainfall.

Students should begin observing the moon, noting how it changes, and developing an awareness of the relationship between moon phases and tides.

Students of this age are able to recognize simple connections such as different kinds of clouds dropping different kinds of rain. They can begin to relate the tides to the phases of the moon. They should also begin to build an understanding of cycles in nature. This idea can be developed by having them observe the moon, noting its shape and placement in the sky, and watching how they change. They should start to recognize the time of year when rains begin or cease, when typhoons typically form, when certain fruits or fish are in season. They are also able to begin learning direction in terms of North, South, East, and West.

Lower elementary students should be introduced to. concepts of hot and cold and some factors that cause these conditions. These concepts can be clarified through investigations with water and how water and objects in water behave under different circumstances such as hot and cold, floating and sinking

MIDDLE ELEMENTARY

Students should continue describing the natural phenomena around them using words and pictures, emphasizing similarities and differences.

Students should continue to develop their abilities to describe the natural phenomena around them using words and pictures. They are ready to learn the local and scientific names for moon phases and different kinds of clouds. They should investigating the weather using simple instruments such as wind vanes, anemometers. thermometers. rain gauges, and applying the Beaufort scale. The water cycle can be introduced at this level as well as properties of air and water.

In the middle elementary grades students should begin using models to conceptualize the movement of the moon around the earth, the earth around the sun, and the earth's tilt. They should understand the differences between moonrise and moonset, sunrise and sunset. They should be able to answer the questions How much later did the moon rise tonight than last night? and How much later did the sun rise in January than September?

UPPER ELEMENTARY/MIDDLE SCHOOL

Upper elementary and middle school students can begin to understand the concepts and causes of the motion of the earth and its relationship to weather patterns, climate, tides, and currents.

At this level, students should continue to develop their observations of natural phenomena in their surroundings and begin to relate it to phenomena in other parts of the world and on a global scale. They are ready to begin exploring the concepts and causes of the motion of the earth and its relationship to weather patterns, climate, tides, and currents.

Investigations of weather should include recording data and graphing it and learning to identify similarities and differences among storms. Students are able to build on their studies of Pacific environments and apply these concepts to study how weather in different areas of the world affects their island. They should apply their understanding of water currents and the effects of heating and cooling the air around their islands to an exploration of these phenomena on a global scale. They can compare waves and currents to global wind patterns and jet streams. They can study the effects of changes in global air and water temperatures on the earth's environments. Variations in temperature, seasons, and climate around the world can be clarified by introducing them in conjunction with latitudes, longitudes, and how the earth is heated differently in different areas. Students should be introduced to the theories of global warming and the greenhouse effect and discuss their implications for the Pacific islands.

By the end of grade 8, scientifically literate students will understand that

- seasons differ around the world because of location and the tilt of the earth's axis;
- tides are caused by the relative motions of the earth and the moon;
- the earth's rotation causes ocean currents and winds;
- the earth's rotation, the properties of water, and the differential heating of land, air, and water combine to cause weather phenomena, including cloud types, wind direction, the water cycle, and different forms of precipitation.

They will be able to

- show and explain how the earth moves around the sun and the moon around the earth;
- estimate wind speed using the Beaufort Scale;
- make and use simple weather instruments such as a wind vane, anemometer, and rain gauge;
- relate local cultural knowledge about moon phases and tides and describe how they influence island life.

They will value

- their ability to understand and predict weather phenomena,
- traditional weather knowledge and applications.

Weather and climate can be taught in greater depth at the secondary level and should include changes that affect the earth's environment.

SECONDARY

Weather and climate can be taught in greater depth at the secondary level. These students are able to relate descriptions and categories to the physical processes they describe. Students should know the different kinds of fronts (cold, warm, occluded, and stationary) and how they behave; the different kinds of storms (rain, snow, thunder, cyclone, anticyclone, hurricane or typhoon, and tornadoes); planetary winds (polar and prevailing); climatic zones (polar, temperate, and tropical); the structure of the atmosphere (troposphere, stratosphere, ionosphere, exosphere); and the different land biomes and animals and plants that inhabit them.

Further emphasis should be placed on global warming phenomena and the absorption of heat by carbon dioxide. Students should relate this concept to other factors that can change climate, such as plate tectonics, changes in the sun's energy output, variations in the position of the earth relative to the sun, the temporary ocean current *El Nino,* and their effects on climate around the world.

Secondary students are ready to apply mathematics to their investigations of weather. For example, they should understand the concept of air pressure and how to calculate it.

By the end of secondary school scientifically literate students will understand that

- the transfer of energy at the boundaries between the atmosphere, the land masses, and the ocean creates different temperatures and densities in both the ocean and atmosphere;

- weather and climate involve the transfer of energy in and out of the atmosphere;

- the action of gravitational force on masses of different densities causes them to rise or fall, resulting in movements influenced by the rotation of the earth. These forces and motions produce winds and ocean currents.

They will be able to

- explain the formation of weather fronts and how they behave,

- identify and describe global wind patterns.

They will value

- how global changes in weather and climate affect life in the Pacific,
- their responsibilities as global citizens.

B. Processes that Shape the Surface of the Earth

Scientifically literate students should have an understanding and appreciation of the natural and mechanical processes that shape the surface of the earth.

Scientifically literate students should understand and appreciate the natural and mechanical processes that shape the surface of the earth. These include plate tectonics, earthquakes, volcanoes, floods, typhoons and hurricanes, cyclones, tidal waves, ocean currents, weathering and erosion, and human activities.

Students should know about the structure and formation of the earth's crust and the mantle. They should understand that the constant motion of the mantle causes stress on the crust which breaks, tilts, and/or folds crustal rocks. The downward force of the crust constantly balances the upward force of the mantle. This is called *isostasy*.

Students should be able to describe earthquakes and volcanoes—two of the most spectacular motions of the earth's crust. The most common cause of earthquakes is faulting. Motions of earthquakes can create giant ocean tidal waves or *tsunamis*, which can travel 700 to 800 kilometers per hour and reach 20 meters in height as they approach coastlines. Such huge masses of water can inflict great damage and cause loss of life. Scientists estimate that several thousand earthquakes move the surface of the earth each year, producing major changes in Earth's surface features. About twenty earthquakes each year cause in catastrophic changes. Earthquake waves, called seismic waves, are measured on the Richter scale.

Volcanic formation and eruptions are the basis of land formation. Most volcanic activity (and earthquakes) occurs along the Pacific "Ring of Fire." Volcanic eruptions have created the different types of Pacific islands, atolls and reefs, as well as the continents.

Because of their size, location, and recent formation, Pacific islands are highly susceptible to damage from natural forces including typhoons, hurricanes, tidal waves, weathering, and erosion. Students should deepen their understanding of how their islands were formed and changed by these forces so they develop a sense of caring and stewardship about them.

Students should begin learning about the concept of change. They should observe their environment and see how things change and what causes them to change.

LOWER ELEMENTARY

These students are ready to begin learning about the concept of change. They are able to observe their environment for evidence of change, and can explore how things change and what causes them to change. It is important for young students to become aware that they can cause positive change in their surroundings, for example, by planting trees or flowers to enhance the appearance of a locale.

In the middle elementary grades students should start learning how their islands and reefs are formed and how they can be changed.

MIDDLE ELEMENTARY

Students should become increasingly familiar with the features of their island environments. They should be encouraged to observe them and discuss how they could be changed by both natural and human activities. Students might construct models of islands from sand and observe how these models can be changed, reshaped, or destroyed by moving water, wind, and other forces. They also should start learning how their own islands and reefs were formed and what forces could change them.

Upper elementary students can begin to understand the concepts and causes of volcanoes, earthquakes, waves and currents, floods, and how these change the shape of the earth's crust.

UPPER ELEMENTARY/MIDDLE SCHOOL

At this level, students can begin to understand the concepts and causes of volcanoes, earthquakes, waves and currents, and floods, and how these events and processes change the shape of the earth's crust. Examining how these forces affect their own and other Pacific islands will help them relate the concepts to the shaping and reshaping of the continents.

By the end of grade 8, scientifically literate students will understand that

- land forms on Earth's surface are made by earthquakes, volcanoes, folding, and faulting;
- land forms are worn down and shaped by gravity, water, wind, weather, erosion, and living things;
- rock is composed of different combinations of minerals, and different rock types (sedimentary, igneous, and metamorphic) are formed by processes in the earth's crust;
- Pacific islands and reefs are formed by natural rock formation processes and living organisms.

They will be able to

- describe the formation of their Pacific environment,
- identify human impacts on local and regional environments.

They will value

- the relationship and importance of plants to land surfaces, especially in protecting the soil,
- their responsibility to protect and preserve the fragile ocean and land environments of the Pacific.

SECONDARY

Concepts introduced in the elementary years should be developed further at the secondary level. Students should broaden their understanding of natural processes that shape the earth's surface by studying plate tectonics. In- depth study of island and continental formation should be emphasized. Investigations should be designed to foster a deeper sense of understanding about and caring for their islands, to prepare students to take their place as adult citizens.

Secondary students should further their study of natural processes shaping the earth's surface by including the study of plate tectonics.

By the end of secondary school scientifically literate students will understand that

- the formation, weathering, sedimentation, and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same although its form changes;
- the slow movement of material within the earth is caused by heat flowing out from the deep interior and the action of gravitational forces on regions of different density;
- the solid crust of earth, including both the continents and ocean basins, consists of separate plates that ride on its fluid mantle.

They will be able to

- identify and describe changes in their own environment and in the Pacific region,

- identify and describe global changes that affect Pacific island life.

They will value

- their island ecosystems as they prepare to take their place as adult citizens.

C. Relationship of the Earth's Surface to the Living Environment

Organisms interact with each other and with the non-living environment to form dynamic ecosystems. Ecosystems can be as small as a drop of water or as large as the Pacific Ocean.

Organisms do not interact on a passive environmental stage. They interact with each other and with the non-living environment to form ecosystems, dynamic systems shaped by the actions of the organisms that inhabit them and by the natural forces of rainfall, temperature, topography, mineral concentrations, and solar radiation. Ecosystems are found in all kinds of environments because organisms live virtually everywhere. They are found in fresh water and oceans, in forests and deserts and grasslands, in tundras, and on mountains.

Ecosystems can be as small as a drop of water or as large as the Pacific Ocean. Each organism in an ecosystem fills a role as a producer, consumer, scavenger, or decomposer. The competitive and cooperative relationships among them balance living things and resources in an ecosystem.

The particular place inhabited by a plant or animal species is its habitat. An organism's habitat provides the food, shelter, and other resources it needs to survive. Land habitats differ greatly from ocean habitats, partly because of differences in the structure of the earth's surface.

Pacific island ecosystems are predominantly ocean ecosystems. The land area of island nations is vastly exceeded by the magnitude of their ocean resources. But land and sea are inextricably related. Wave action shapes the land and the resulting form at water's edge becomes part of a land-sea ecosystem. Water evaporated from the ocean rises to the clouds and falls as rain to nourish life on land. There are many interactions between land and sea, and they help sustain life on Earth. These systems are delicate and balanced but unstable. If students understand these characteristics of their island environments, they may be more likely to use these resources wisely.

LOWER ELEMENTARY

A useful way for students to begin their study of the relationship between living things and Earth's surface is by classifying plants and animals, living things and non-living things. This prepares them to compare similarities and differences within and across categories. Students should be introduced to the concept of habitats and their importance in ecosystems. They can observe where organisms live, what they need for survival, and how these differ from the needs of other organisms.

In lower elementary, students are able to observe and discuss animal movement, body structures, and food intake (for both land and sea creatures). Students should also begin to describe simple food chains.

Lower elementary students should begin classifying plants and animals, living things and non-living things.

MIDDLE ELEMENTARY

In middle elementary grades, students should continue to classify, categorize, and compare plants, animals and their habitats. They should further develop their understanding of the food chain by considering the role of the sun in plant growth and by elaborating the different roles played by producers, consumers [primary and secondary] and decomposers within an ecosystem or habitat. They should be able to illustrate food chains and food webs, predator-prey relationships, and describe how animals and plants meet their needs. These topics can open the door to discussing the idea of dependence within an ecosystem and what things may disrupt the balance of relationships within them.

Now students can grasp the connection between body structures and habitats: a fish uses gills to get oxygen from water; a bird uses wings to move through the air. These concepts can be reinforced by having them describe and discuss adaptations organisms have evolved to meet basic needs, protect themselves, compete, or cooperate. Investigations should help students see how plants have adapted to different environments (shoreline plants have tougher leaves than inland plants) and how they use the environment to reproduce (seed dispersal).

Students should further develop their understanding of the food chain by considering the role of the sun in plant growth and by examining the different roles played by producers, consumers, and decomposers.

UPPER ELEMENTARY/MIDDLE SCHOOL

In the upper elementary grades, students should describe and discuss interactions among organisms and between living and non-living things. This concept can be introduced by expanding their understanding of cycles and the ecosystem that they formed in the lower and middle elementary grades. Organisms also depend on the non-living parts of an ecosystem (air, sun, water, other environmental factors). Cycles are important to the interaction of

In the upper elementary grades, students should describe and discuss Interactions among organisms and between living and non-living things.

plants and animals (water, oxygen-carbon dioxide, matter). Energy in an ecosystem flows through food chains and food webs.

Natural phenomena and human activities often change habitats. Students should be able to describe how activities on land may affect the ocean environments and vice versa. They should be able to offer examples of positive and negative interactions. Plants and animals often can adapt to changing habitats. Students should understand how their structures enable them to adapt for survival.

By the end of grade 8, scientifically literate students will understand that

- living things are adapted to their environment and changes in the environment will affect the organisms that inhabit it;
- people adapt their way of living to their physical environment; this is reflected in culture;
- human activities can protect and preserve or damage the earth's surface and its ecosystems.

They will be able to

- identify habitats in different environments,
- diagram a familiar ecosystem,
- identify and describe effects of environmental change on living things,
- identify and describe effects of changes caused by living things on the environment.

They will value

- the impact of their activities and those of others on local, regional, and global environments.

Students should understand the interactions of biotic and abiotic factors in both ocean and land environments.

SECONDARY

High school students should have a firm grasp of the complexity of the relationships between the earth's surface and the living environment. They should understand the interactions of biotic and abiotic factors in both ocean and land environments at a systems level. Their comprehension should include how human activities intervene in natural systems and how natural changes in land surfaces and oceans affect living things. They should be able to apply these concepts to discuss the ocean as an economic resource for Pacific island states.

Students should be aware of different organisms and their habitats around the world. Their investigations should enable them to compare and contrast life forms on land and in the ocean; describe how tide and seasons affect ecosystems; identify differences in living things in three regions of the ocean: sunlit surface, mid waters, dark ocean depths. Students should know the various factors (climate, location, an so forth) that shape habitats so that plants and animals live under a variety of conditions.

Emphasis should be placed on oceans as an economic resource for Pacific island states.

By the end of secondary school scientifically literate students will understand that

- earth's surface has been changed by both humans and nature;
- organisms change over time as they interact with the non-living environment. Darwin's theory of change induced by variation, adaptation, and natural selection helps explain changes in ecosystems and differences in species.

They will be able to

- predict how changes on Earth's surface will affect local ecosystems,
- identify and describe local examples of how living things affect the non-living environment and vice versa.

They will value

- their responsibilities as citizens of the Pacific and the world.

THE UNIVERSE

The scientifically literate student understands the composition and structure of the universe, the motion of objects in it, including the earth, and the underlying scientific principles.

The scientific effort to understand the universe is part of an ongoing quest to find our place in the cosmic scheme.

The scientific effort to understand the universe is part of an ongoing quest to find our place in the cosmic scheme. The development of our knowledge of the universe is surely not complete, but we have made great progress. Given the vast distances in the universe and the array of objects, some too large to comprehend and some too small to see, it is a tribute to human intelligence that we have made as much progress as we have in understanding it. An important component of scientific literacy, therefore, is having a sense of human existence in time and space and an understanding of current scientific thinking about the composition and order of the universe.

The people of the Pacific region have used their understanding of the stars, the sun, the moon, and the planets to assist them in many areas of their lives.

The location of the earth in the cosmos is of particular importance to us as the inhabitants of the planet. The phenomena of the seasons and the phases of the moon are directly related to Earth's position and motion in the solar system. People have tried to understand these relationships for millennia. They have studied the stars, the sun, the moon, and the planets and used their observations to assist them in planning their lives, planting crops, predicting weather patterns, fishing, and navigating the seas. This was especially true of the peoples in the Pacific region.

In order for students to gain a scientific understanding of these occurrences it is important that they understand the geometry of lighting and "seeing," that they model and act out sun-Earth-moon relationships, and that they have direct experience with shadows, reflection, and warming effects at different angles.

An integrated picture of the earth has many components and is developed over a number of years. Those components directly related to the earth within the solar system are dealt with in this standard category. Other aspects are dealt with in other categories..

Students will have a sense of human existence in a context of time and space if they know about these related concepts:

A. **The Composition of the Universe.** The universe consists of a vast area containing a great number and variety of objects. Many ideas about the origin and nature of the universe have developed throughout human history.

B. **Order in the Universe.** The universe and the objects in it appear to operate according to a number of established principles which have been realized over time. Pacific Island cultures applied their understanding of the universe to aid their daily lives.

A. The Composition of the Universe

The universe is vast and contains a great number and variety of objects. The closest of these objects to Earth are the sun, moon and other planets.

Almost every culture, including those in the Pacific region, has developed a concept of the nature and origin of the universe based upon observations made over a long period of time, their needs, and their unique view of human existence.

Almost every culture, including those in the Pacific region, has developed a concept of the nature and origin of the universe based upon their needs, their view of human existence, and observations of nature made over long periods of time.

Human interest in the origin of the universe continues today. Our current understanding, still incomplete, is based upon a long history of scientific observation and the analysis of the large amounts of data gathered with the aid of ever-advancing technology.

LOWER ELEMENTARY

The beginning experiences of children with the universe should be entirely based on observation and the resulting descriptions.

When children first investigate the universe, they should simply observe the skies and describe what they see. Get them to notice the skies at various times during the day and during the year.

Nighttime observations should lead students to realize that the stars are too numerous to count, they are scattered unevenly, and they have different brightness or color. Daytime observations should help them understand that the sun is a star which can be seen only in the daytime and that, like the moon and stars, it appears to move slowly across the sky from east to west. Moon sightings during the day may be an interesting and unexpected event

Because all peoples have been fascinated by the skies, they figure in the folklore and traditions of most cultures. For children, exploring this part of their heritage often establishes an interesting and meaningful connection.

MIDDLE ELEMENTARY

Students should begin to develop an inventory of the variety of things in the universe and to group and classify them according to their nature. This inventory should be based on direct observations, aided whenever possible by the use of telescopes or binoculars, and supported by photographs and data collected from other sources.

Once students have observed the stars, moon, and planets, classes can use photographs of planets and their moons and collections of stars to study their variety of size, appearance, and motion. Students can construct diagrams of the solar system using a variety of scales. Working alone and in small groups, they should also make physical models and explain what they show. Teachers should point out that the current model of the solar system cannot be assembled by observation alone and that the models we often see show the solar system as it would appear to someone looking toward the system from deep in space. Films, computer simulations, a planetarium, and observations using a telescope will help students understand this idea.

Once students have conducted their own observations of the stars, moon, and planets, middle elementary classes can use photographs of planets and their moons and collections of stars to study their variety of size, appearance, and motion.

Students must develop some ideas about light and sight before they can understand astronomical phenomena. It is particularly important that they realize that large light sources that are far away appear smaller than similar sources that are closer. This helps them understand that stars are like the sun, some are larger than the sun (and some are smaller) but they are so far away that they look like points of light.

There is no particular educational value in memorizing the names of stars or moons, or in counting them, although some students enjoy doing so. Nor should students invest much time trying to get the scale of distances firmly in mind.

Because they lived on islands, most Pacific people knew how to sail. Many of the cultures developed navigational systems based upon their observations of the skies. An understanding and appreciation of this aspect of the students' cultural background is an important part of scientific literacy and can appropriately be introduced at this level.

Most Pacific Islanders took an interest in sailing and developed navigational systems based upon their observations of the skies. An understanding and appreciation of this aspect of the students' cultural background is an important part of scientific literacy.

UPPER ELEMENTARY/MIDDLE SCHOOL

Students at this level should add more detail to their picture of the universe, paying attention to matters of scale. Using astronomical tools, such as star finders, binoculars, telescopes, and computer simulations will develop their ability to conceptualize it. Devising and building models of size and distance are effective

Students in upper elementary and middle school should add more detail to their picture of the universe and should support their understanding using a variety of astronomical tools.

activities for this grade level. Everyone should experience trying to fashion a physical model of the solar system.

By the end of grade 8, scientifically literate students will understand that

- we live on a relatively small planet, the third from the sun, in a system of planets revolving around the sun;
- nine planets move around the sun in nearly circular orbits of varying sizes. Most of these planets are orbited by moons and even flat rings of rock. Although Earth has only one moon, it is orbited by many artificial satellites, some in stable orbits and others in less stable orbits;
- earth is the only planet in the solar system that appears able to support life. The compositions and conditions of the other planets (and all of the moons) differ greatly from Earth's;
- the universe contains billions of galaxies. Each galaxy contains billions of stars. To the naked eye, even the closest of these galaxies is no more than a dim, fuzzy spot of light;
- the sun is a medium-sized star located near the edge of our galaxy and is many times closer than any other star. Light from the sun takes several minutes to reach Earth, but light from the next nearest star requires several years to reach us.

They will be able to

- describe their observations of the movements of sun, moon, planets, and constellations,
- identify some of the instruments scientists have used to observe and measure motion in the universe,
- create models of the solar system showing the relative positions of planets and their satellites.

They will value

- the importance of models to represent explanations of events that are too large to be observed directly,

- traditional cultural explanations by Pacific islanders of the composition of the universe.

SECONDARY

Mathematical models and computer simulations are used to study evidence from a variety of sources in order to form a scientific account of the universe. Space probes, many kinds of telescopes, and an array of other sources have all contributed data to this effort.

By the end of secondary school scientifically literate students will understand that

- the stars differ from each other in size, temperature, and age, but appear to be made up of the same elements that are found on Earth and behave according to the same physical principles;

- an assortment of telescopes has aided astronomers in the discovery of a wide variety of fascinating objects in the universe;

- because objects in the solar system are relatively close to us and space probes are recent developments, astronomers understand our solar system better than any other part of the universe These objects can be studied and classified in terms of what they are made of and how they were formed;

- current evidence suggests that the universe is more than ten billion years old. The current theory is that its entire contents expanded from a hot, dense, chaotic mass. Stars condensed because of gravity.

They will be able to

- measure the location and movements of the sun, moon, planets, and constellations,

- describe the role of technology in understanding the structure of the universe,

- describe how explanations of the structure and movements in the universe have changed over time.

They will value

- models to represent explanations of events that are too large to be observed directly,
- the role of technology in changing explanations of science,
- how scientific explanations change over time.

B. Order in the Universe

As a result of centuries of observation, Pacific Islanders developed a detailed understanding of order in the universe and used that knowledge to guide various aspects of their lives.

The universe and the objects in it seem to operate according to established principles such as the universal law of gravitation and Kepler's laws. As part of the universe, the solar system is also subject to these principles. In particular, the motion of the earth and moon within the solar system produces natural phenomena on Earth that affect human life.

Pacific islanders developed over the centuries, a detailed understanding of order in the universe that guided various aspects of their lives. Navigation, farming, weather prediction, fishing, hunting, calendars, and other facets of island life were affected by how people interpreted the skies.

The early elementary years are the time for students to develop an awareness of natural cycles, such as changes that are caused by the movement of heavenly bodies.

LOWER ELEMENTARY

In the early elementary years, students are able to develop an awareness of natural cycles, such as day and night, sunrise and sunset, tides, and seasonal changes, that are caused by the movement of heavenly bodies. Observing the moon and noting how it changes is an appropriate investigation for this grade level. The lunar cycle is important to the students' understanding of a number of phenomena. Students can records their observations and develop graphical representations of them, so that the cyclic nature becomes apparent. Cause and effect relationships are beyond the ability of most students and should be avoided.

Relating investigations to students' daily lives will reinforce the lessons. For example, they can be reminded of activities in their lives that are affected by changes in the skies. Because fishing activities are so closely tied to the moon, this is likely to be an important connection that can be easily made.

MIDDLE ELEMENTARY

During the middle elementary years, students should learn to differentiate planets from stars and moons. As part of this process there should be a realization that star patterns stay the same as the stars move across the sky and that the planets change their positions relative to these patterns. Historically, people have named some of the star patterns, developed stories about them, and used them for purposes such as navigation. The names, stories, and uses varied from one culture to another. The observation that different stars can be seen in different seasons has been applied in an assortment of ways by a variety of peoples.

During the middle elementary years, students should learn to differentiate planets from stars and moons.

Like all planets, the earth is nearly spherical in shape. Its rotation on its axis once every 24 hours causes day and night and makes it seem as if the sun, moon, planets, and stars are orbiting the earth each day. At this stage, students should learn the earth's relationship to the sun, moon, and other planets. They should also experience and understand reflection and the formation of shadows.

Students should develop an understanding of the earth's relationship to the sun, moon, and other planets.

Although most of the islands in the Pacific are tropical, they have seasonal changes (times of sunrise and sunset and seasonal crops) that can be related to the revolution of the earth around the sun.

UPPER ELEMENTARY/MIDDLE SCHOOL

Students can now consolidate their knowledge of the earth as a planet with a few details and getting a firmer grasp of the geometry involved in explaining the seasons, phases of the moon, and tides. They can investigate these concepts by acting out and modeling the sun-Earth-moon relationships. They should also be given opportunities to experience the behavior of light on surfaces (shadows, reflection, and the warming effects of different angles). Understanding the phenomena of moon phases and seasonal changes requires a grasp of a combination of concepts about the earth and lunar motions, and the properties of light.

Upper elementary students can consolidate their prior knowledge of the earth as a planet by adding more details and getting a firmer grasp of the geometry involved in explaining the seasons, phases of the moon, and tides.

By the end of grade 8, scientifically literate students will understand that

- the sun gravitational pull of the sun holds Earth and other planets in their orbits, just as the gravitational pull of the planets keeps their moons in orbit around them;

- because Earth turns on an axis that is tilted relative to the plane of its motion around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in heating causes seasons and weather patterns;

- the moon orbits Earth once every 28 days. Changes in position relative to the sun result in the observed phases of the moon;
- study and observation of the skies has given people knowledge of the universe that they have applied to predict weather patterns, plant crops, fish, and navigate.

They will be able to

- describe phenomena including tides, seasons, and lunar phases, by using or describing suitable models of the solar system and the motion of objects within it.

They will value

- explanations of the motions in the universe developed by their own and other Pacific cultures as a result of extensive observation of the skies.

During the high school years concepts from chemistry, physics, and astronomy come together as a unified picture of Earth's place in the solar system and universe.

SECONDARY

During the high school years the pieces join to form a unified picture of Earth's place in the solar system and universe. Concepts from chemistry, physics, and astronomy combine to explain the motion of the earth, other planets, and moons within the solar system. The Copernican revolution, along with the work of Kepler and others, provides an excellent example of mathematics, technology, observation, and experimentation working together to build theories and models that radically changed humankind's view of self and world.

By the end of secondary school, scientifically literate students will understand that

- symmetry and regularity in the behavior of objects within the solar system and universe appear usually to be effects of gravitational force. The behavior of objects within the solar system can be described using Newton's law of gravitational force and Kepler's laws;

- seasons, tides, day and night, moon phases, eclipses and other phenomena all result from the combined effect of motions of sun, Earth and moon;

- our understanding of the relative positions and motions of objects within the solar system are the result of centuries of observation and study, aided by ever improving technology. The development of this understanding had significant social impact.

THE LIVING ENVIRONMENT

The scientifically literate student understands the diversity and unity of living things; their similarities and differences, habitats, behaviors, interactions, and interdependence. Especially important is understanding concepts of evolution, heredity, cell structure and functions, body structure and functions, and life cycles.

People are naturally curious about other living things. They seek answers to many questions about them. In particular, they try to develop concepts, principles, and theories that better explain living environment.

Living organisms are made of the same components as all other matter, experience the same transformations of energy, and move using the same forces. The principles and laws of the physical setting apply to living things as well as to stars, raindrops, and television sets. But living organisms also have characteristics that are best explained by other principles.

All species are part of complex ecosystems involving themselves, other species, and their physical surroundings. Ecosystems exist in relative equilibrium, but they are subject to change by natural events. Human activity is capable of severely and often permanently disrupting this equilibrium. Continued existence of life on Earth depends upon the nature of the new equilibria that are established.

Species exist as part of complex systems involving themselves, other species, and their physical surroundings.

Understanding the living environment means students know about these related concepts:

A. Diversity of Life. Life on Earth exhibits great diversity. Life forms are classified based on similarities and differences among them.

B. Heredity. Instructions for developing living organisms are passed from parents to offspring in thousands of discrete genes, each of which is a segment of a molecule of DNA.

C. Cells. The cell is the building block of all living organisms. Many of the basic functions of organisms take place at the cellular level.

D. **Interdependence of Life.** Species interact directly or indirectly with a multitude of others to form an ecosystem. Ecosystems can be relatively stable, but changes in them caused by natural and human activities affect all members of the system and eventually other ecosystems.

E. **Flow of Matter and Energy.** Organisms are linked to one another and their surroundings by the exchange of energy and matter.

F. **Evolution.** Life forms change over time through natural processes that involve variation, adaptation, inheritance of characteristics, and natural selection. Significant changes in life forms may give rise to new species.

G. **Stewardship.** Humans have responsibilities of stewardship of the environment. As citizens they must learn to ask important questions about the immediate and long-range impacts of their decisions on the environment.

A. Diversity of Life

Millions of types of organisms inhabit the earth—some similar to each other, some very different. Biologists classify organisms into groups and subgroups on the basis of similarities and differences in their structures and behavior.

Children have a natural sense of wonder toward the diversity and complexity of life. Their curiosity can be dampened, however, by premature explanations about abstract concepts.

Educators should build on students' interest in living things while moving them gradually toward a deeper understanding.

The challenge for educators, therefore, is to build on students' interest in living things while moving them gradually toward a deeper understanding.

Botanists, zoologists, geologists, surveyors, explorers, amateur collectors, and even fortune-hunters have learned to understand the living environment first through observation, then classification, then theory. This is a useful model for students to follow in learning about the environment.

LOWER ELEMENTARY

All students must have the opportunity to observe a variety of plants and animals in the classroom, on the school grounds, at home, and elsewhere in their daily lives. But to be meaningful, observation should be purposeful, prompted by the desire to answer questions about how organisms live, grow, develop, or care for their young.

Some students may enjoy displaying the living things they find with drawings, photographs, or specimens. Teachers should encourage them to ask questions they can answers by examining plants and animals (using hand lenses when needed) and then checking their observations and answers with one another.

Some children's literature gives plants and animals attributes they do not have. This is not a concern. It is more important that young children learn a love of reading. They can learn to distinguish between stories that portray plants and animals the way they really are and those that do not. Questions about real or imaginary characteristics of plants or animals described in books should lead students to reference works, which are other sources of information they must start learning to use.

Some children's literature gives plants and animals attributes they do not have. This is not a concern. It is more important that young children learn a love of reading.

MIDDLE ELEMENTARY

Students in the middle elementary grades should continue to learn about the variety of living organisms, both familiar and exotic. As they gain experience, they become adept at identifying similarities and differences among organisms. Although the emphasis should still be on external features, observations should be refined. Hand lenses, introduced earlier, should now be routinely used by students. Microscopes should be introduced, not to study cell structure, but to begin exploring the world of organisms that cannot be seen by the unaided eye. A wealth of films exist to supplement direct observation.

As students become familiar with the characteristics of organisms, they should be asked to invent schemes for classifying them (without using the Linnean classification system). Their criteria can be expected to vary according to their uses, gross anatomy, behavior patterns, habitats, and other features. The aim is to have them realize that there are many ways to classify things. The value of any classification system depends on its usefulness. A scheme is useful if it either aids decisions on some matter, or deepens understanding of the relatedness of organisms. Classification schemes will, of course, vary with purposes (pets/non pets, edible/non edibles).

As students become more familiar with the characteristics of organisms, they should be asked to invent schemes for classifying them.

Science at the upper elementary level should provide students with opportunities to enrich their growing knowledge of the diversity of life on the planet and to connect it to what they are learning in other subject areas, especially in geography.

UPPER ELEMENTARY/MIDDLE SCHOOL

Science at this level should provide students with opportunities to enrich their growing knowledge of the diversity of life on the planet and to begin to connect that knowledge to what they are learning in other subject areas, especially in geography. Whenever students study a particular region in the world, they should learn about the plants and animals found there and how they are like or unlike those found elsewhere. Tracing simple food webs in varied environments can contribute to a better understanding of the interdependence of organisms (including humans) and their environment.

Students should begin to turn their attention from external anatomy to internal structures and functions. Patterns of development such as complete and incomplete metamorphosis may be introduced in to further illustrate similarities and differences among organisms. Also, they should begin to move from their invented classification systems to those used in biology. Classification systems are not part of nature. Rather, they are frameworks created by humans to describe and make sense of the variety of organisms and to frame research questions. A provocative exercise is to have students try to differentiate between similar organisms that are alike in many ways, for example, between cats and small dogs.

By the end of grade 8, scientifically literate students will understand that

- one of the most general distinctions among organisms is between plants which use sunlight to make their own food, and animals which consume energy-rich foods. Some kinds of organisms, many of them microscopic, cannot be neatly classified as either plants or animals;

- animals and plants have a great variety of body plans and internal structures that contribute to their being able to survive;

- similarities among organisms are found in internal anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more important than behavior or general appearance;

- for sexually reproducing organisms, a species comprises all organisms that can mate with one another to produce fertile offspring;

- all organisms, including humans, are part of and depend on two main interconnected global food webs One includes microscopic ocean plants, the animals that feed on them, and finally the animals that feed on those animals. The other web includes land plants, the animals that feed on them, and so forth.

They will be able to

- classify plants and animals into groups based on similarities and differences,

- identify ocean and land food chains and food webs.

The will value

- respecting and taking responsibility for all living things,

- interdependence of all living things including humans.

SECONDARY

Two aims dominate at this level. One is to advance student understanding of why diversity within and among species is important. The other is to take the study of diversity and unity to the molecular level; that it is possible to infer relatedness among organisms from DNA or protein sequences. An investigation of the DNA-fingerprinting controversy may provide an interesting way to approach the question of the nature and validity of molecular evidence.

High school students should understand why diversity within and among species is important. They should take the study of diversity and unity to the molecular level.

By the end of secondary school scientifically literate students will understand that

- the variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions; a great diversity of species increases the chance that at least some living things will survive in the face of large changes in the environment;

- the degree of kinship between organisms or species can be estimated from the similarities of their DNA sequences, which often closely match their classification based on anatomical features.

They will be able to

- describe why biodiversity is important to life on Earth,
- identify the impact of human activities on plants and animals in local ecosystems.

They will value

- human responsibilities to protect and preserve biodiversity.

B. Heredity

Building an observational base for heredity ought to be the first undertaking in the lower grades.

Building an observational base for heredity ought to be the first undertaking in the lower grades. The organisms young children usually recognize are themselves, their classmates, and their pets. Here is the place to start studying heredity. It is important to be cautious about having children compare their own physical appearance to that of their siblings, parents and grandparents. It is also important to be cautious having children compare the different ethnic groups within the classroom. Such comparisons must be handled delicately so that no one gets embarrassed. Direct observations of generational similarities and differences of some plants and animals are essential.

Learning the genetic explanation for how traits are passed from generation to generation can begin in the middle years and continue into high school.

Learning the genetic explanation for how traits are passed from generation to generation can begin in the middle years and continue into high school. But it is essential for students to know about molecules before DNA. The interaction between heredity and environment in determining plant and animal behavior will interest students. Examples of actual cases can help them grasp the complex interactions of genetics and environment.

LOWER ELEMENTARY

Students should observe how offspring of familiar animals compare to one another and to their parents. Students know that organisms produce their own kind (dogs produce puppies, cats produce kittens, roses bear roses, etc.).

With increasing experience and observations, students will realize that there is variation among individuals in a population. Not all puppies or kittens are alike. These experiences provide the basis for later explanations of heredity.

With increasing experience and observations, students will realize that there is variation among individuals in a population.

MIDDLE ELEMENTARY

Students should move from describing individuals to identifying some traits and classifying organisms by those traits. Students can begin to keep a list of local plants and animals. They will also be able to recognize variations among members of a population whose members are alike. Students may use the simple or dissecting microscopes for observations.

Students can make family trees and choose one or two visible traits within their families as an introduction to inherited traits. From these cumulative experiences, students will begin to see that there must be a mechanism for traits to be passed from one generation to another.

In middle elementary school, students will begin to see that there must be a mechanism for traits to be passed from one generation to another.

UPPER ELEMENTARY/MIDDLE SCHOOL

At this level, students can begin the study of genetic traits—what offspring inherit from parents. This topic can be handled as a natural part of the study of human reproduction. Students should examine examples of lineages for which breeding has been used to emphasize or suppress certain features of organisms. They should be able to prepare more complex pedigrees.

By upper elementary school, students can begin the study of genetic traits—what offspring inherit from parents.

By the end of grade 8, scientifically literate students will understand that

- offspring are very much, but not exactly, like their parents and like one another; there is variation among individuals within a population;

- some likenesses between children and parents, such as eye color in humans, flower color in plants, are inherited. Other traits such as table manners or building skills are learned and not inherited;

- in some organisms all the inherited characteristics come from a single parent. In organisms that have sexes, typically half of the characteristics come from each parent;

- new varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits;

- for offspring to resemble their parents, there must be a reliable way to transfer information from one generation to the next;

- in sexual reproduction, a single specialized cell from a female merges with a specialized cell from a male. As the fertilized egg, carrying genetic information from each parent, multiplies to form the complete organism with about a trillion cells, the same genetic information is copied in each cell.

They will be able to

- identify the variations among individuals of one kind within a population,

- list some likenesses between children and parents, such as eye color in human beings, or fruit or flower in plants, are inherited,

- describe technology's role in selective breeding of certain organisms.

The will care about and value

- the ability of humans to selectively breed plants and animals for production of desirable traits.

Knowing the functions of DNA will make it possible to explain the differences and similarities among organisms of the same species, explain hereditary diseases, and the evolution of new species.

SECONDARY

DNA provides for both the continuity of traits from one generation to the next and the variation that in time can lead to differences within a species and to entirely new species. Knowing the functions of DNA will make it possible for students to explain the differences and similarities among organisms of the same species, hereditary diseases, and the evolution of new species. The students will be aware of the possibilities for scientists to manipulate genes and thereby creating new combinations of traits and new varieties of organisms.

By the end of secondary school scientifically literate students will understand that

- the information passed from parents to offspring is coded in DNA molecules;

- genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment;

- gene mutations can be caused by such things as radiation and chemicals. When they occur in sex cells, the mutation can be passed on to offspring. If they occur in other cells, they can be passed on to descendant cells only;

- gene mutation in a cell can result in uncontrolled cell division, called cancer. Exposure of cells to certain chemicals and radiation increases mutations and the chances of cancer;

- the sorting and recombining of genes in sexual reproduction results in a great variety of possible gene combinations in the offspring of any two parents.

They will be able to

- describe local examples of heredity,

- describe the result of human reproduction and importance of traits.

They will value

- the importance of biotechnology and genetic engineering,

- the ethical and moral issues of bioengineering.

C. Cells

Students should have extensive experiences with plants and animals before being introduced to the idea of cells. The familiar description and depiction of cells in blood sometimes lead students to think that organisms contain cells rather than that they are made up of cells. Imagining the large number of cells is a problem for young students—often beyond their comprehension.

Students should have extensive experiences with plants and animals before being introduced to the idea of cells.

Students even at upper elementary level may have difficulty with the idea that cells are the basic units of life.

Students even at upper elementary level may have difficulty with the idea that cells are the basic units of life. Neither familiarity with functions of regular-sized organisms nor observation of single-celled organisms will reveal much about the chemical activity going on inside cells. For most students, the story should be kept simple. The way to approach the idea of these small microscopic units is to start with the needs of organisms.

Information transfer and energy transformation are functions of nearly all cells. The molecular aspects of these processes should wait until students have observed the transformation of energy in a variety of physical systems and have examined more generally the requirements for the transfer of information. Information transfer may mean communications among cells within an organism or passing genetic codes from a cell to its descendants.

LOWER ELEMENTARY

Emphasis should be on young students observing a variety of familiar animals and plants and considering processes they all need to stay alive.

Emphasis should be on observing a variety of familiar animals and plants and considering things and processes they all need to stay alive, such as getting food and getting rid of waste. Students should use hand lenses to make things appear three-to-ten times bigger and more detailed. They should be encouraged to wonder what they might see if even more powerful lenses were used.

MIDDLE ELEMENTARY

Experiences should expand to include the observation of microscopic organisms using magnification in middle elementary school.

Experiences should expand to include the observation of microscopic organisms using a scale of magnification of 30 to 100 power with simple dissecting scopes and microscopes Watching organisms is always informative. But students can also view films of living cells growing and dividing, taking in substances, and changing direction when they run into things. Some of the living things they observe may be single cells, others multi-cellular. Some students may reason that because tiny cells are alive, they probably have the same needs as other, larger organisms.

UPPER ELEMENTARY/MIDDLE SCHOOL

Once students have a "magnification sense," they can gradually concentrate on cells and cell structures.

Once students have a "magnification sense," they can gradually concentrate on cells and cell structures. Students at this level are most interested in the human body, so they can begin with as many different body cells as possible—skin, bone, muscle, nerve—and then move on to examining cells of other animals and plants. Through this kind of activity students can discover that cells are the fundamental building blocks of their own bodies and other living things as well.

By the end of grade 8, scientifically literate students will understand that

- all living things are composed of cells. Some living things consist of a single cell; some are made of a collection of cells that play different roles;
- cells continually divide to make more cells for growth and repair. Various organs and tissues function to serve the needs of cells for food, air, and waste removal;
- many of the functions of organisms such as extracting energy from food and getting rid of waste are carried out within cells.

They will be able to

- use hand lenses and microscopes to obser 'e the detail of cells,
- identify cells as the basic building block of organisms.

The will value

- the life functions of all living things including getting energy, growth and repair, and waste removal. These functions must be carried on by all cells, plants and animals, and humans.

SECONDARY

With greater sophistication and better instruments, students can now begin to view the cell as a system itself and as part of larger systems; sometimes as part of a multi-cellular organism, always part of an ecosystem. The cell membrane serves as a boundary separating the cell from its environment. The membrane contains the proteins it makes, equipment to make them, and stockpiles of fuel to continue its functions. Students should become aware of the variety of functions cells serve in an organism and how needed materials and information get to and from cells. It may help to think of an organism as a community of cells, each of which has some common tasks and some special jobs.

With greater sophistication and better instruments, secondary students can now begin to view the cell as a system itself and as part of larger systems.

The idea that protein molecules assembled by cells conduct the work that goes on inside and outside the cells in an organism can be learned without going into the biochemistry of cells. It is sufficient for students to know that molecules involved are different configurations of a relatively few kinds of amino acids, and that the different shapes of the molecules influence what they can do.

Students should acquire a general picture of the functions of the cell and know that the cell has specialized parts that perform these functions.

Students should acquire a general picture of the functions of the cell and know that the cell has specialized parts that perform these functions. This can be accomplished without many technical terms. Emphasis on vocabulary can impede understanding.

Discussion of what needs to be done in the cell is much more important than memorizing and naming the parts that do it.

Discussion of what needs to be done in the cell is much more important than memorizing and naming the parts that do it. For example, students should know that cells have certain parts that oxidize sugar to release energy and parts to stitch protein chains together according to instructions; but they don't need to remember that one type of part is a mitochondrion and the other is a ribosome.

By the end of secondary school scientifically literate students will understand that

- every cell is surrounded by a membrane that controls what can enter and leave the cell;
- within the cell are specialized parts for transport of materials, energy capture and release, protein building, waste disposal, information feedback, and movement;
- a living cell is composed of a small number of chemical elements—mainly carbon, hydrogen, oxygen, phosphorus, and sulfur. Carbon, because of its small size and structure, can join to other carbon atoms in chains and rings to form large and complex molecules;
- the work of the cell is carried out by the many different types of molecules it assembles, mostly proteins. Protein molecules are long, usually folded chains made from twenty different kinds of amino acid molecules. The function of each protein molecule depends on its specific sequence of amino acids and the shape of the chain of its parts;
- complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities such as growth and reproduction;
- the genetic information in DNA molecules that provides instructions for assembling protein molecules is found in cells;

- most cells function best within a narrow range of temperature and acidity.

They will be able to

- identify the cell as the basic unit of life and describe some of its functions,
- identify some of the health risks of cell damage and how such risks can be avoided.

They will value

- the importance of health and safety practices to maintaining good personal well being,
- tall life on Earth, from single-celled organisms to complex organisms !ike humans.

D. Interdependence of Life

The general notion that species depend on one another and on the environment for survival can easily be grasped by students. But their awareness and experiences must be supported by knowing the kinds of relationships that exist among organisms, the kinds of physical conditions that organisms must cope with, the kinds of environments or habitats created by the interaction of organisms with one another and their physical surroundings, and the complexity of such systems. Students should become acquainted with and knowledgeable about the ecosystems around them and others.

LOWER ELEMENTARY

Students should investigate the habitats of many different kinds of local plants and animals such as trees, weeds, aquatic plants, insects, worms, fish and some of the ways in which animals depend on plants and on each other for good, shelter and nesting. Investigating the environment where they live (home, school, neighbor, village) facilitates inquiry, observation, description and exploration.

Young students should investigate the habitats of many different kinds of local plants and animals and some of the ways in which animals depend on the plants and on each other for food.

MIDDLE ELEMENTARY

For middle elementary students, knowledge and studies of organisms within an environment should start and build on relationships they can directly observe.

Students should explore how various organisms satisfy their needs in the environments in which they are typically found. They can examine the life needs of different organisms and consider how the conditions in particular habitats can limit the survival of living things. Their knowledge and studies of organisms within an environment should start and build on relationships they can directly observe. Through field trips, outdoor exploration or nature walks, beach, cave, or tide pool excursions, students should see a great diversity of life in different habitats, and that changes in one organism's habitat are sometimes beneficial and sometimes harmful.

UPPER ELEMENTARY/MIDDLE SCHOOL

Upper elementary and middle school students should be guided from specific examples of the interdependence of organisms to a more systematic view of the kinds of interactions that take place among organisms.

Students' knowledge, skills and appreciation of the environment is built on continuous studies of organisms and interactions with the environment. However, they should be guided from specific examples of the interdependence of organisms to a more systematic view of the kinds of interactions that take place among organisms. Researching and understanding consequences of "how and why" of environmental relationships, ecosystems, and their complexities, is critically important in the growing knowledge of the students.

By the end of grade 8, scientifically literate students will understand that

- in all environments—freshwater, marine, forest/ jungle, grassland, mountain and others—organisms with similar needs may compete with one another for resources including food, space, water, air and shelter. In any particular environment, the growth and survival of organisms depend on the conditions. Some kinds of plants and animals survive well, some survival less well, and some cannot survive at all;

- organisms may interact with one another in several ways. They may be in a producer-consumer, predator-prey, or parasite-host relationship, or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other.

They will be able to

- identify examples of interdependence among organisms,
- describe food chains and food webs in ocean and land environments.

The will value

- the unique organisms, environments, and ecosystems in the Pacific.

SECONDARY

For secondary students, scientific knowledge, skills, habits of mind, and attitudes come together as they study ecosystems. The concept of an ecosystem should bring coherence to the complex array of relationships among organisms and environments that students have encountered. Students growing understanding of systems in general can suggest and reinforce characteristics of ecosystems—interdependence of parts, feedback, inputs and outputs. Stability and change in ecosystems can be considered in terms of variables such as population size, number and kinds of species and productivity. This is a time for extended investigations, experimentation and refined inquiry.

The concept of an ecosystem should bring unity to the complex array of relationships among organisms and environments that students have encountered.

By the end of secondary schools scientifically literate students will understand that

- ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors. A damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one;
- like many complex systems, ecosystems tend to have cyclic fluctuations around a state of relative equilibrium. In the long run, however, ecosystems always change when climate changes or when one ore more new species appear as a result of migration or local evolution;
- human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

They will be able to

- identify and describe local ecosystems.
- identify and describe the impact of human activities on changing local ecosystems.

They will value

- the interdependence of all organisms in local and global systems,
- the impact of human activities at local and global levels (global warming and greenhouse effect),
- that all human actions have impacts on other living things.

E. Flow of Matter and Energy

Organisms are linked to one another and to their physical setting by the transfer of matter and energy.

Organisms are linked to one another and to their physical setting by the transfer of matter and energy. This fundamental concept brings together insights from the physical and biological sciences. But energy transfer in biological systems is less obvious than in physical systems. Fire heats water, falling water makes electricity. But energy stored in molecular configurations is difficult to show even with models.

The cycling of matter and flow of energy can be found at many levels of biological organization, from molecules to ecosystems. The study of food webs can start in the elementary grades with the transfer of matter, be added to in the middle grades with the flow of energy through organisms, and then integrated in high school as students gain knowledge of energy storage in molecular configurations develops.

Children should begin to be aware of the basic parts of the food chain.

LOWER ELEMENTARY

At this level, children should begin to be aware of the basic parts of the food chain: plants need sunlight to grow, some animals eat plants, and other animals eat both plants and animals.

An awareness of recycling, both in nature and in human societies, may play a helpful role in the development of children's thinking. Familiarity with decomposition and recycling of materials fosters the notion that matter continues to exist even though it changes from one form to another.

MIDDLE ELEMENTARY

At this level students should begin to notice that substances may change form but they never appear out of nowhere and never just disappear. Questions should encourage students to consider where substances come from and where they go and to be puzzled when they cannot account for the origin or fate of a substance.

Students at this level should identify the basic parts of the food web. They will be able to trace the decreasing amount of energy from chain to chain. Energy is necessary for life. It is neither created nor destroyed

Middle elementary students should begin to notice that substances may change form and move from place to place, but they never appear out of nowhere and never just disappear.

UPPER ELEMENTARY/MIDDLE SCHOOL

Students' attention should be drawn to the transfer of energy that occurs as one organism eats another. In scientific usage, food refers only to those substances, such as carbohydrates, proteins and fats from which organisms derive the energy they need to grow and operate and the material of which they are made. It's important to emphasize that the sugars that plants make out of water and carbon dioxide in the presence of sunlight and chlorophyll are their only source of energy.

By upper elementary and middle school, students' attention should be drawn to the transfer of energy that occurs as one organism eats another.

By the end of grade 8, scientifically literate students will understand that

- all stored food energy comes originally from sunlight;
- all organisms need energy to stay alive and grow;
- food provides the energy and the building material for all organisms. Plants use the energy from light to make sugars from carbon dioxide and water. Organisms, including plants, then break down the plant structures to produce materials and release the energy they need to survive;
- plants and animals both need to take in water, and animals need to take in food. In addition, plants need light;
- almost all kinds of animals' food can be traced back to plants;
- over the whole earth, organisms are growing, dying and decaying and new organisms are being produced by the old ones;

- matter is transferred between organisms and between organisms and their physical environment repeatedly in cycles. Even though the form and location of matter change, its amount remains constant.

They will be able to

- identify the numerous materials that can be recycled and used again,
- identify sources and flows of energy in food chains and food webs,
- differentiate between producers, consumers, and decomposers,
- identify causes of pollution in local environments due to temporary accumulation of unrecycled matter.

They will value

- conserving energy and matter at their homes or within their community,
- the role that plants play in their environment,
- the important role of decomposition in recycling matter.

SECONDARY

Secondary students should observe and measure heat generated by consumers and decomposers.

Energy can be accounted for by thinking of it as being stored in molecular structures during photosynthesis and released during oxidation or respiration. Students should observe and measure heat generated by consumers and decomposers.

Discussion at this level should center on the difficulty of predicting the impact of human intervention with ecosystems. Investigating local examples of such human impact is essential. Students should be knowledgeable about issues such as the use of fossil fuels and why humans should pay considerable attention to the recycling of matter and energy.

By the end of secondary school scientifically literate students will understand that

- matter is cycled and energy flows through biological systems in the processes of photosynthesis, respiration, and decomposition;

- the chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going;

- the success of an ecosystem is dependent on recycling the residue of dead organic materials. It is also dependent on human activities and technology;

- some environmental conditions allow land and marine organisms to grow faster than decomposers can recycle them back to the environment. Layers of energy rich organic materials have been gradually turned into coal beds and oil pools by pressure from the overlying earth. Burning these fuels allows energy to go back to the environment as heat plus large amounts of carbon dioxide.

They will be able to

- identify the limiting factors of life in any environment as the availability of energy, water, oxygen and minerals,

- identify the various processes and their functions to utilize energy within an organism; photosynthesis, respiration, and decomposition.

They will value

- that human activities and technology can change the flow of matter and energy and reduce the fertility of the land,

- the greenhouse effect and global warming as with their possible effects on the sea level rise of the Pacific islands.

F. Evolution of Life

Before natural selection is proposed as a mechanism for evolution, students must recognize the diversity and apparent relatedness of species.

Students take years to acquire sufficient knowledge of living organisms and the fossil record.

It is important to distinguish between *evolution* and *natural selection*. Evolution embraces the history of change of natural things over time and the study of patterns and processes that shape those histories. Patterns and processes in evolution may be astrophysical, geological, biological, biochemical, or cultural/societal. These are well substantiated and generally accepted as fact by scientists. Natural selection is the proposed mechanism for those historical changes in life forms over time.

Students should be familiar with the evidence of evolution so that they will have an informed basis for judging different explanations. This familiarity depends on knowledge from the life and physical sciences; knowledge of phenomena occurring at several different levels of biological organization and over long time spans; and of how fossils form and how their ages are determined.

Before natural selection is proposed as a mechanism for evolution, students must recognize the diversity and apparent relatedness of species. Students take years to acquire sufficient knowledge of living organisms and the fossil record. To appreciate how natural selection can account for evolution, students have to understand the important distinction between the selection of an individual with a certain trait and the changing proportions of that trait in populations. Their being able to grasp this distinction requires some understanding of the mathematics of proportions and opportunities for them to reflect on the individual versus population distinction in other contexts.

Controversy is an important aspect of the scientific process. Students should realize that although virtually all scientists accept the general concept of evolution of species, scientists do have different opinions on how fast and by what mechanisms evolution proceeds. A separate issue altogether is how life itself began.

LOWER ELEMENTARY

Even as young students make observations of organisms in their own experiments, they can extend their experiences with other experiences, such as stories, books, and films.

Students should begin to build a knowledge base about biological diversity by observing lots of plants and animals. Student curiosity about fossils, the first people, even dinosaurs can be used as examples to consider life forms that no longer exist. This distinction between extinct creatures and those that still live elsewhere will not be clear for some time. Even as students make direct observations of organisms, they can extend their experiences stories, books, and films. Students should understand that different plants and animals have features that help them survive in different kinds of places and that some kinds of organisms that once lived on Earth have disappeared.

MIDDLE ELEMENTARY

Students can begin to look for ways in which organisms in one habitat differ from those in another and consider how helpful those differences might be for survival. The focus should be on the consequences of different features of organisms for their survival and reproduction. Evidence for the similarity within diversity of existing organisms can draw upon students' expanding knowledge of anatomical similarities and differences.

Middle elementary students can begin to look for ways in which organisms in one habitat differ from those in another and consider how helpful those differences might be for survival.

UPPER ELEMENTARY/MIDDLE SCHOOL

During these years several lines of evidence can be further developed. The fossil evidence can be expanded beyond extinction and survival to the notion of evolutionary history. Breeding experiments can illustrate the inheritability of traits and the effects of selection. It was familiarity with selective breeding that stimulated Darwin's thinking that differences between successive generations can naturally accumulate.

During the upper elementary years the fossil evidence can be expanded beyond to the notion of evolutionary history. Breeding experiments can illustrate the inheritability of traits and the effects of selection.

By the end of grade 8 scientifically literate students will understand that

- individuals of the same kind differ in their characteristics and sometimes the differences give individuals an advantage in surviving and reproducing;

- small differences between parents and offspring can accumulate (for example, through selective breeding) in successive generations so that descendants are very different from their ancestors;

- sometimes individual organisms with certain traits may be more likely than others to survive and have offspring. In such cases changes in environmental conditions can affect the survival of individual organisms and entire species;

- many thousands of layers of sedimentary rock provide evidence for the long history of the earth and for the long history of changing life forms whose fossil remains are found in the rocks. More recently deposited rock layers tend to contain fossils resembling existing species;

- the basic idea of biological evolution is that the earth's present-day life forms had common ancestors reaching back to the simplest one cell organisms about 4 billion years ago. During the first 2 billion years, only single-cell microorganisms existed, but once cells with nuclei developed about 1 billion years ago, increasingly complex multi-cellular organisms evolved.

They will be able to

- identify examples of selective breeding from local organisms,
- describe the advantages of biodiversity to survival of life on Earth.

They will value

- all forms of life in their environment,
- evolution and natural selection as powerful ideas to explain change in life forms on Earth over time.

SECONDARY

Knowing what evolutionary change is and how it played out over geological time, secondary students can now turn to better understanding its mechanism.

Knowing what evolutionary change is and how it played out over geological time, students can now turn to better understanding its mechanism. They need to shift from thinking in terms of selection of individuals with a desirable trait to proportions of a trait in populations. Familiarity with artificial selection, coming from studies of plant and animal breeding and their own experiments, can be applied to natural systems, in which selection occurs because of environmental conditions.

Understanding radioactivity makes it possible for students to understand dating techniques used to determine the age of fossils and to appreciate the immense passage of time that has elapsed for changes to accumulate. Knowledge of DNA contributes to the evidence for life having evolved from common ancestors and provides a plausible mechanism for the origin of new traits.

History should not be overlooked. Learning about Darwin and what led him to the concept of evolution illustrates the interacting roles of evidence and theory in scientific inquiry. The concept of evolution provides a framework for organizing new as well as old biological knowledge into a coherent picture of life forms.

By the end of secondary school scientifically literate students will understand that

- molecular evidence supports the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another;
- natural selection provides the mechanism for evolution. Natural selection leads to organisms that are well suited for survival in particular environments. Chance alone can result in persistence of some inheritable characteristics having no survival or reproductive advantage or disadvantage for an organism;
- inheritable characteristics can be observed at molecular and whole-organism levels—in structure, chemistry, or behavior. These characteristics strongly influence what capabilities an organism will have and how it will react;
- evolution builds on what already exists, so the more variety there is, the more there can be in the future. Thus, the importance of biodiversity.

They will be able to

- describe the major mechanisms of change over time in life forms including variation, natural selection, and inheritance of characteristics,
- identify examples of organisms uniquely adapted to their environment,
- describe the impact of Darwin's theory of evolution on science and society.

They will value

- scientific explanations for biodiversity and the change in life forms over time.

G. Stewardship

The children of the Pacific must be taught to appreciate their environment.

The idea of being part of a system, and taking steps to maintain the ecosystem should be instilled in students.

The children of the Pacific must be taught to appreciate what they currently have available (life and a beautiful, active environment). The idea of owning something in a system, belonging to the system, and taking steps to maintain the ecosystem should be instilled in them. This will lead not only to caring about themselves, but to caring for the ecosystem as a whole. Students should develop educational skills to share with their peers, influence the elderly to keep the environment clean for cultural reasons, sacred reasons, health reasons and ecosystem survival reasons.

Young children should be guided to care for plants, animals and their environment.

LOWER ELEMENTARY

Young children should be guided to care for plants, animals and their environment. Concrete experiences of "caring" can be related to all their surroundings—the air we breathe, the water we drink, the places we enjoy (beach, park, home, school), and the plants and animals that surround us. All students of the Pacific should learn in the lower elementary level about conservation, preservation and recycling. Understanding and appreciating the value of their environment is critical to life. Ways of protecting the environment are interwoven with issues and concerns about pollution (land, air, water) and ways of recycling and reusing materials around them.

MIDDLE ELEMENTARY

Students will progressively build more knowledge and appreciation about their environment and its resources and understand why good management and conservation practice (energy, recycling, reuse) are necessary.

Traditional management of resources should be introduced to the middle elementary schools. Discuss examples of the usage of natural resources and how wastes are disposed.

Students should build more knowledge and appreciation about their environment and understand why good management and conservation practices are necessary.

Discussions on the habitats, health and happiness of Pacific islanders are dependent upon the environment and its conservation. Students should be encouraged to value what surrounds them (fish, wildlife, resources) in order to conserve, protect, and manage the islands' resources on a sustainable basis. Sustainable means that we use our resources carefully so that future generations of Pacific people will still have enough to provide for their basic needs of food, water, fuel, shelter, and clothing and so that as economic development of our islands increases, our islands will still maintain the important aspects of our unique island ways of life.

UPPER ELEMENTARY/MIDDLE SCHOOL

Students should identify the local environmental issues and discuss approaches to solving some them. What are the causes of water and land pollution? What is the effect of pollution on the ecosystem? How do deforestation and soil erosion affect the land and ocean environments? Is waste dumping being monitored? How? The deterioration of the traditional Pacific's agricultural methods contributed a lot to plant and animal extinction, the loss of its traditional food systems and the increase of health problems.

By middle school, students should identify the local environmental issues and discuss approaches to solving some of the current problems.

Students may role-play being future leaders on how to preserve and restore the Pacific environments. They should consider the use of technology, set rules for citizens to be responsible, and contact other Pacific islands for input on solutions for immediate major environmental problems. This level should reflect a "caring" behavior towards their environment.

By the end of grade 8, scientifically literate students will understand that

- habitats, health, and happiness of people depend upon the environment. People are responsible for the conservation, protection, and management of natural resources.

They will be able to

- investigate environmental problems and issues such as water and land pollution, deforestation and soil erosion, plant and animal extinctions (endangered species), deterioration of Pacific agricultural and food systems, and waste dumping,
- work with others to design possible ways to sensitively address existing environmental problems and issues,
- investigate and implement traditional practices in one major area of stewardship (farming, waste disposal, recycling, food preparation, etc.).

They will value

- preserving, respecting and restoring our environment,
- their own and other Pacific island traditional ways of living, working, and developing in harmony with living things, land and ocean environments.

High school students will have diverse perspectives on the influence and long range effects of environmental protection and management which can lead to useful discussions of concerning issues and problems.

SECONDARY

As a group of well-versed students with sufficient background on environmental issues and problems, high school students will have diverse perspectives on influence and long-range effects of environmental protection and management. Discussions on the cost not only economically but ecologically of nuclear pollution should be undertaken. Listing the health hazards involved with the improper disposal of domestic, industrial, and solid waste can develop sensitivity to and potential future action on such issues. Careful consideration of the economic influences of developing marine resources versus the time span to replenish them is also important.

The children of the Pacific must reevaluate the ways of their ancestors. Long before modern technology, our ancestors had technologies that used natural materials from the land that were then returned to the land. Technologies to explore the land and sea were environmentally safe. These traditional ways are rapidly vanishing.

By the end of secondary school, scientifically literate students will understand that

- good management and environmental protection will result in long-range preservation and success in a given community;
- the ancestors of Pacific islanders had systems for managing the natural resources that provided for the maintenance and balance of nature;
- human greed leads to the destruction of a variety of ecosystems, and organisms.

They will be able to

- investigate traditional ways of distributing land and marine resources among community members,

- illustrate to members of the community the health hazards, the costly solutions, and the ecological damage involved in the improper disposal of matter,
- educate local leaders on the impact of population growth.

They will value

- restoring the traditional ways of treating the environment and its various factors with respect and care,
- maintaining rain forests, coastal zones, and wildlife,
- the image of the Pacific as "Paradise of the planet."

THE HUMAN ORGANISM

The scientifically literate student understands that, as similar as we humans are in many ways to other species, we are unique in our ability to use language and thought.

To understand ourselves and others is a basic human need. By understanding ourselves and our abilities, we can respect and care for ourselves and our Pacific island cultures, and help bring people together with shared knowledge that will enable us to sustain ourselves and thrive in an ever-changing world.

By understanding ourselves and our abilities, we can respect and care for ourselves and our Pacific island cultures.

By understanding how people learn, we ourselves may be able to learn more effectively and appreciate the difficulties some face. Knowing about the limitations of human learning can help people anticipate problems (theirs and others) and continue to seek better answers to emerging questions.

It is increasingly important for young people to understand the steps they can take to maintain good physical, mental, and emotional health. The effects of substance abuse, poor nutrition and hygiene, and other behaviors that lead to poor health and the spread of disease are part of science education.

Today, many Pacific island young people experience great difficulty coping with the stresses of constant change. This is demonstrated in the rising number of youth suicides. We must use science education to help students deal with the complexity of our human existence and to prepare them to thrive during rapidly changing times.

We must use science education to help students deal with the complexity of our human existence and to prepare them to thrive during rapidly changing times.

Understanding the human organism means students will know about these related concepts:

A. **Human Development.** Humans go through stages of growth and development, from conception to old age and death, that continue in a cyclical fashion over generations.

B. **Basic functions.** The human body can be described as a collection of systems (organs, tissues, cells).

C. **Learning.** Humans have a unique ability to invent ideas and learn behaviors that can be transmitted from one generation to the next, creating culture.

D. **Physical and Mental Health.** The body needs care and nurturing to maintain good physical health. The ability to cope with one's circumstances depends upon sound mental and emotional health.

A. Human Development

Conception, growth and development, and finally aging and death make up the human life cycle. Birth and death fascinate people of all ages. Perhaps no other topic brings children closer to a sense of connectedness to people of all cultures and all times. Technologies that let us interfere with this cycle raise controversial ethical questions that can lead to conflict between groups with different values and priorities.

Although individuals look and behave differently, differences are minor when compared to the similarities.

Although individuals look and behave differently, these differences are minor when compared to the similarities among human beings. People in the same family, same ethnic group, and even people from diverse ethnic groups are more alike than different.

The physiological similarities make it possible for people from anywhere in the world to donate blood and organs. Furthermore, as great as cultural differences seem to be, all peoples have demonstrated the ability to develop language, technology, and arts, which distinguish human beings from other species.

LOWER ELEMENTARY

Young children should be finding out about themselves. They should be encouraged to wonder, observe, and discuss themselves and people around them.

In early childhood, children should be finding out about themselves and animals, developing ideas about how people and other animals live, grow, feed, move, and use their senses. They should concentrate on external features. Although many may be able to identify some major internal organs and have some idea of their functions, these systems should not be emphasized at this time.

Young children's curiosity can motivate them to explore their human identity. They should be encouraged to wonder, observe, and talk about people around them. Directed inquiry can lead young children to discover what people have in common, such as their need for food, water, and air. Children are also able to build on their knowledge by observing that people tend to live in families and communities in which individuals have different roles.

Young children's experience with other people may be limited, but within their family and community they can recognize that each individual is unique. Children can observe and discuss differences in external features, such as size, shape, and color of hair, skin, and eyes. Children in the lower elementary grades should have many opportunities to draw pictures of people in their lives, to become aware of how much their learning depends on observing the things around them.

Students can become aware that each human goes through a life cycle of infancy, childhood, adolescence, adulthood, and old age. They can talk about the size and behavior of brothers and sisters, parents and other family members and can observe and record changes in themselves and their classmates to develop a sense of growth over time. Imagining their parents as children or themselves as old may be impossible for young children, and so observing and talking about animal or plant examples may be the best first step in building this understanding.

Students can become aware that each human goes through a life cycle.

MIDDLE ELEMENTARY

During the middle elementary years, children's curiosity expands beyond themselves. As students progress, they should study some aspects of humans and other animals feeding, sensing, defending, and reproducing. They can observe insects and other living things around the school, at home, and in the community. They can collect data and compare their observations with those of others. Middle elementary students begin to know that, unlike human beings, the behavior of insects and many other species is largely based upon biological inheritance.

Middle elementary students should study some aspects of humans and other animals feeding, sensing, defending, and reproducing.

As families around them grow and change, children can understand that a human fetus develops inside its mother, and that at birth a human baby is unable to care for itself; its survival depends on the care it receives from others. They should know that It takes nine months for a human embryo to develop and that embryos are nourished by the mother, and so substances she takes into her body will affect the baby's development.

As families around them grow and change, children can observe and understand the human life cycle.

Children should be encouraged to generate questions about how human beings grow and to gather information from observation, discussion with families, visits by health workers, and documenting their own growth. Activities like role-playing children at various age , charting personal growth, and observing plant and animal development will help develop students' concepts of human development. Children in middle grades may not be ready to make connections between stages of development and physical and emotional maturity, but they can understand that people are usually capable of bearing children before they are able to care for them properly.

The human experience in the Pacific islands provides good examples of how human roles have changed over time.

Although their concept of death may be limited, children at this age can understand that human beings live longer than most other animals, but all living things die. As they observe many living things, children should develop a sense of life cycles—that there is a usual sequence of physical and mental development among human beings, although individuals differ in their exact rate of development.

Discussing sex differences and roles requires sensitivity. In most species, the roles are biologically determined, whereas in human beings, the roles can be socially dictated. The human experience in the Pacific islands provides good examples of how human roles have changed, from lives focused on fishing and gathering foods, to farming, to work in villages, towns and cities. Exploring roles around them will deepen the children's understanding of the variety of roles currently found in island societies.

Students can begin to understand that people leave artifacts that help others to understand their lives and history. Young learners should begin looking for evidence of the past in their own communities and islands and theorize about life in the islands in the past.

UPPER ELEMENTARY/MIDDLE SCHOOL

In the upper elementary years, students should learn about changes that are taking place in themselves.

Students' should focus on studying the systems of digestion, respiration and reproduction. In learning how both animals and human beings carry out these functions, they can understand some of the commonalties between species.

Upper elementary and middle school students are fascinated by the stages of human growth. They should understand the changes that are taking place in themselves now and that will take place in the near future.

The study of life cycles ties in well with social issues of parenthood. Most students are interested to learn about rites of passage in different cultures and to compare them to their own. Because young people in the middle school years are physically capable of reproducing, scientific knowledge of how fertilization occurs may be included. Students should develop an understanding of the importance of adequate rest, proper food, regular medical check ups, and immunizations to prevent disease to growth. This should include an understanding of the science behind the advice. Conception, both natural and artificial, and the ideas of birth control are important issues for some middle school students.

Students at this age should be introduced to the role that medical technology plays in supporting and enhancing life functions. They should also look at ways in which human beings use various machines to improve speed, mobility, strength, hearing, seeing, etc. As a result, they also learn about human capabilities and limitations.

By the end of grade 8 scientifically literate students will understand that

- fertilization takes place when one of the sperm cells from male testes enters the female egg cell;
- contraceptive measures may incapacitate sperm, block their way to the egg, prevent the release of eggs, or prevent the fertilized egg from implanting in the uterus successfully;
- after fertilization, cell division produces a small cluster of cells which then differentiates by appearance and function to form basic tissues of an embryo. During the first three months of pregnancy, organs begin to form. During the second three months, all organs and body features develop. During the last three months, the organs and features mature enough to function well after birth;
- patterns of human development are similar to those of other vertebrates;
- various body changes occur as humans age. Muscles and joints become less flexible, bones and muscles lose mass, energy levels diminish and the senses become less acute. Women stop releasing eggs and can no longer reproduce. The length and quality of life are influenced by many factors including sanitation, diet, medical care, sex, genes, environmental conditions, and personal health behaviors.

They will be able to

- explain growth and developmental stages in humans,
- describe the changing capacities and needs of humans as they develop and change over time,
- identify actions that can be taken to prevent or enhance the probability of pregnancy.

They will value

- their own developing capacities and needs,
- their responsibilities to themselves and others as they grow and develop.

SECONDARY

By secondary school, similarities of complex molecules, such as DNA, as well as similarities in organs and systems, can be used to determine the relationship of the human species with other related species.

More detailed scientific explanations of human growth is a major focus of secondary students' learning about human development. Students should know enough about atoms and molecules to make sense of the idea that DNA carries instructions that determine the development of humans.

Similarities of complex molecules, such as DNA, as well as similarities in organs and systems illustrate the close relationship of human beings to one another. This information can also be used to determine the relationship of the human species with other related species. Evidence gathered through molecular studies supports information gained from fossil records.

The development of culture is an area where human development exceeds achievement of other species.

Certain characteristics distinguish human beings from other species. The development of culture—communication, arts, and technology—is an area where human development exceeds achievement of other species, although some species have demonstrated the ability to communicate and use tools in a limited fashion.

The development and use of health technologies raise many social issues: What certainty is necessary before a new drug is marketed? Who benefits and who pays? What is a reasonable quality of life and who decides? In many cases the rapid advance of medical research has given rise to legal and ethical issues that remain unresolved. Students can investigate such controversial issues and consider the trade-offs involved.

By the end of secondary school, scientifically literate students will understand that

- the similarity of human DNA sequences and the resulting similarities in cell chemistry and anatomy identify human beings as a single species;
- as successive generations of an embryo's cells form by division, small differences in their immediate environments activate different parts of the DNA information, causing the cells to develop slightly differently than other cells;

- the development and use of technologies to prevent or facilitate pregnancy, maintain, sustain, prolong or terminate life raise social, moral, ethical and legal issues.

They will be able to

- identify actions that can be taken to prevent or enhance the probability of pregnancy,
- take personal actions that contribute to the health and development of family and community members,
- identify and take an informed position on controversial issues in health and health technologies.

They will value

- their unique characteristics as individuals,
- their responsibilities to themselves and others as they grow and develop.

B. Basic Functions

The human body can be described as a collection of systems (organs, tissues, cells). However, rather than focusing on distinct anatomical and physiological systems, instruction should focus on the essential requirements for life: obtaining food and deriving energy from it, protecting against injury, providing internal coordination and reproduction.

LOWER ELEMENTARY

At a very early age, children think that each body part has its own independent function. Knowing the ways in which the body's organs work together is vital for students' growing understanding of basic functions. They should begin to develop an understanding that the human body has parts that help seek, find, and take in food when it feels hunger: eyes, and noses for locating food, legs to get to it, arms to carry it away, and a mouth to eat. During the early grades, children's senses can become the springboard for understanding. Senses can warn individuals about dangers, muscles help them to get out of danger, and the brain enables

During the early grades, children's senses can become the springboard for understanding themselves.

human beings to think and send messages to other body parts to help them work properly.

MIDDLE ELEMENTARY

As children progress, they can view the body as a collection of systems. They can then develop an understanding that each organ affects and is affected by others.

As children progress, they can view the body as a collection of systems in which parts do things for other parts and for the organism as a whole. They can then develop an understanding that each organ affects and is affected by others.

From food, people obtain energy and materials for body growth and repair. The indigestible parts of food are eliminated. By breathing, people take in oxygen they need to live. Skin protects the body from harmful substances and other organism; and from drying out. The brain gets signals from all parts of the body telling what is going on there. The brain also sends signals to parts of the body to influence what they do.

UPPER ELEMENTARY/MIDDLE SCHOOL

Most adolescents can develop more sophisticated understanding of how organs and organ systems work together.

Most adolescents can develop a more sophisticated understanding of how organs and organ systems work together. Asking questions such as What might happen if some of the parts weren't there or weren't working? can stimulate students to reflect on connections among organs. Role-playing various organ systems and creating name games to master the language of body systems can help upper elementary students develop a base of knowledge about systems that will be built on further in high school.

By the end of grade 8 scientifically literate students will understand that

- like other animals, human beings have systems for obtaining and providing energy, defense, reproduction, and the coordination of body functions;

- organs and organ systems are comprised of cells and help to provide all cells with basic needs;

- for the body to use food for energy and building materials, the food must first be digested into molecules that are absorbed and transported to cells. (digestive system);

- to release energy stored in food, oxygen must be supplied to cells, and carbon dioxide removed. Lungs take in oxygen and they eliminate the carbon dioxide produced. The urinary system disposes of dissolved waste molecules, the intestinal tract removes solid wastes. The skin and lungs rid the body of heat energy. The circulatory system moves all these substances to or from cells where they are needed or produced responding to changing demands;

- specialized cells and the molecules they produce identify and destroy microbes that get into the body (immune system);

- hormones are chemicals from glands that affect other body parts. They are involved in helping the body respond to danger and in regulating human growth, development and reproduction. (endocrine system);

- interactions among the senses, nerves and brain make possible the learning that enables human beings to cope with changes in their environment. (nervous system).

They will be able to

- identify some of the interacting human systems and their functions,

- describe actions that they can take to help maintain healthy functioning systems,

- describe and explain the negative effects of drugs, alcohol, and tobacco on human systems.

They will value

- the wonder of their own bodies and the characteristics of life in general,

- maintaining a healthy, functioning body capable of life-long learning.

SECONDARY

By high school, students' understanding of the human organism can expand to encompass molecular energy release, protection by the immune and nervous systems, cognition, and some of the ways in which systems interact to maintain a fairly constant environment for cel' Students can have direct experiences examining the effects of exercise on biological rhythms or of food on body measurement, such as temperature,

By high school, students' understanding of the human organism can expand to the cellular and molecular levels.

pulse, blood pressure, or oxygen consumption. These types of observations can be linked to mathematical descriptions of changes, to physical and chemical measurements, to statistical summaries, and to controlled experiments.

By the end of secondary school scientifically literate students will understand that

- humans are organized into different interacting systems—digestive, respiratory, transport and circulation, excretion, support and locomotion, reproduction—necessary to maintain life;

- the immune system is designed to protect against microscopic organisms and foreign substances that enter from outside the body and against some cancer cells that arise within. The whole immune system can be destroyed by a virus causing the disease of AIDS;

- the nervous system works by electrochemical signals in the nerves and from one nerve to the next. The hormonal system exerts its influences by chemicals that circulate in the blood and attach to cells. These two systems also affect each other in coordinating body systems;

- communication between cells is required to coordinate their diverse activities. Some cells secrete substances that spread only to nearby cells. Others secrete hormones, molecules that are carried in the blood stream to widely distributed cells that have special receptor sites to which the hormones attach. Some drugs block the molecules involved in transmitting nerve or hormone signals and therefore disturb normal operations of the brain and body.

They will be able to

- take personal actions to preserve health and prevent the spread of infectious diseases,

- avoid using drugs, alcohol, tobacco and other substances that can threaten the healthy functioning of human systems,

- appreciate the importance of health technologies to maintaining health and treating malfunctioning systems.

They will value

- the value of good nutrition and exercise in maintaining proper functioning of human systems.

C. Learning

Humans have a unique ability to invent ideas and learn behaviors that can be transmitted from one generation to another, creating culture. The ability to invent has resulted in virtually unlimited variations in ideas and behavior.

LOWER ELEMENTARY

Early childhood is the time to be sure that all children learn that they can learn almost anything they want to. We must encourage the natural urge for students to learn and interact with their surroundings. They should be encouraged to notice how they learn by asking questions like How do you know? This is also a time to have children teach a skill they have learned to someone else.

Young students should learn that people use their senses to find out about their surroundings and themselves.

In this stage of development, students should learn that people use their senses to find out about their surroundings and themselves and that different senses give different kinds of information. Songs and rhymes about the senses, dramatizations, and role-plays can help children explore their senses. Children's awareness of their own learning can be prompted by questions which invite their ideas. For example, rather than asking Who knows about—?, which suggests that some children have knowledge and others do not, teachers can ask What do we know about.—? which communicates the belief that all children can contribute from their experience. During these early years, children begin to understand that some things that people do, like reading and writing must be learned. Practicing helps people to improve what they learn. Sometimes, learning depends on how one does it, how often, and how hard one tries. Children can learn from one another by telling and listening, showing and watching, and imitating what others do.

Middle elementary students should come to know that human beings have different interests, motivations, skills, and talents.

MIDDLE ELEMENTARY

After a few years of schooling, children are more aware of their surroundings and should be given many opportunities to explore areas of personal interest and to develop new skills. Most are able to move from explicit and concrete experiences to ideas which are more abstract. During these years students should come to know that human beings have different interests, motivations, skills, and talents. Human beings can learn from their experiences by remembering them and using them in new situations. People learn some things by imitating others.

In the middle elementary grades, many skills can be practiced until they become automatic. If the right skills are practiced, performance can improve. Human beings tend to repeat behaviors that feel good or have pleasant consequences and avoid behaviors that have unpleasant consequences.

Learning means using what one already knows to make sense out of new experiences.

UPPER ELEMENTARY/MIDDLE SCHOOL

Learning means using what one already knows to make sense out of new experiences or information, not just storing the new information in one's head. By early adolescence, students should figure out what learning has taken place as the consequence of studying something. Students can design and administer different types of tests to individuals and groups for studies of learning. Students can become interested in animal behavior experiments, which can help them understand learning and the nature of scientific inquiry.

By the end of grade 8 scientifically literate students will understand that

- specialized roles and behaviors of individuals within other species are genetically programmed, whereas human beings are able to invent and modify a wide range of social behaviors;
- human beings use technology to match or excel many of the abilities of other species. Technology has helped people with disabilities survive and live productive lives;
- the level of skill a person can gain in any particular activity depends on several factors—ability, practice, and the use of effective strategies for learning;
- attending closely to any one input of information usually reduces the ability to attend to others at the same time;

- learning often results from two perceptions or actions occurring at about the same time. The more often the same combination occurs, the stronger the mental connection between them is likely to be;

- language and tools enable human beings to learn complicated and varied things from others.

They will be able to

- identify learning as one of the characteristics that distinguishes humans from other species,

- identify and describe the importance of communication and information processing technologies to the increasing capabilities of humans to learn about themselves and their world,

- make connections and develop their own knowledge of the world around them.

They will value

- their own capacities as life-long learners,

- the invention of science as one of the successful ways of learning about the world around us,

- the ideas and explanations of others that may help them make connections and build their own knowledge.

SECONDARY

During high school, students should have increasing opportunities to reflect on and generalize about ideas studied in previous grades so that they can consider explanations for how learning takes place. They can also be challenged to consider claims about learning in other species, such as lower primates.

High school students should have opportunities to reflect on how learning takes place.

By the end of secondary school scientifically literate students will understand that

- humans have a very long development period compared to other species. This long period is associated with the role of the human brain and its capacity for life-long learning. Mental abilities once needed mainly for survival are now used for cultural activities like art, literature, ritual and games;

- written records and photographic and electronic devices like computers, enable humans to share massive amounts of information and misinformation;

- differences in the behavior of individuals arise from the interaction of heredity and experience—the effect of each depends on the other. Even instinctive behavior may not develop well if the individual is exposed to abnormal conditions;

- the expectations, moods, and prior experiences of human beings can affect how they interpret new information or ideas. People tend to ignore evidence that challenges their beliefs and to accept evidence that supports them. The context in which something is learned may limit the contexts in which learning can be used;

- human thinking involves the interaction of ideas, and ideas about ideas. People can produce many associations internally without receiving information from their senses.

D. Physical and Mental Health

Knowledge of science can inform choices about nutrition and exercise.

Human beings' knowledge of diseases has helped them understand how the healthy body works, just as knowing about normal body functioning helps to defend and detect diseases. Knowledge of science can inform choices about nutrition and exercise, but that doesn't ensure healthy practice.

Ideas about what constitutes good mental health vary from one culture to another and from one time period to another.

Sound mental and emotional health involves the interaction of psychological, physiological, and cultural systems. It is generally regarded as the ability to cope with the circumstances their personal, profession, and social lives. Ideas about what constitutes good mental health vary from one culture to another and from one time period to another. This concept is perhaps the most important insight students can gain about mental health.

LOWER ELEMENTARY

Young children should learn how to keep healthy, although they may not understand why certain foods, exercise, and rest help. This is a time for hands-on learning. Brainstorming the kinds of foods that they eat, planning a meal together that includes healthy foods, and observing the food choice they and their friends make can expand their awareness of the importance of food choices for health. Children should know that eating a variety of healthy foods and getting enough exercise and rest help people stay healthy. Some things people take into their bodies from the environment can hurt them. Some diseases are caused by germs and some are not. Diseases caused by germs may be spread by people who have them. Soap and water reduce the number of germs that can get into the body. It is vital that children become aware of the difference between healthy foods and foods that can harm them.

Young children should learn how to keep healthy, although they may not understand why certain foods, exercise, and rest help.

Young children should be helped to identify internal feelings and to distinguish them from external sensations. Encouraging children to identify and describe their feelings in various situations is an important step in understanding mental health. However, there are great differences between cultures in the acceptance and acceptability of displays of emotion. These differences need to be respected. For some young children, it will be more comfortable to describe the feelings of children in stories and pictures, rather than in their own lives.

Encouraging children to identify and describe their feelings is an important part of mental health.

As they move through their first years of school, young children should begin to understand that people have many different feelings—sadness, joy, anger, fear, and so forth. They can experience such feelings about themselves, about family, and about others.

Young children can learn that people react to personal problems in different ways and that some ways are more likely to be helpful than others. They can understand that talking to someone may help them understand their feelings and problems and what to do about them.

MIDDLE ELEMENTARY

Children should explore behaviors that promote good health. During the middle elementary years students should be encouraged to actively explore how food provides energy and materials for growth and repair of body parts; and how vitamins and minerals, present in small amounts in foods, are essential to keep everything working well as people grow up. They should also observe their own reactions as they engage in various forms of exercise, collect data about food intake and exercise, and use their growing

Middle elementary children should explore behaviors that promote good health. Special attention should be given to the impact of a variety of substances on their health.

mathematical skills to graph and analyze the data. Discussing and comparing data will deepen their understanding of the body's need for food and exercise.

This is also a time for expanding students' knowledge of the impact of a variety of substances on their health. Study of tobacco, alcohol, other drugs and certain poisons in the environment (pesticides, lead) can have very personal meaning for Pacific children. Coupled with specific knowledge about substances which can harm the body, middle elementary students should begin learning about less tangible threats to health. They can understand that if germs are able to get inside the body they may keep it from working properly; the body has tears, saliva, skin, some blood cells, and stomach secretions as a defense against germs; a healthy body can fight most germs; and there are some germs that interfere with the body's defenses.

Middle elementary students have often had some experience of illness around them. They are able to brainstorm about diseases, act out the path that germs take to invade and go through the body, and discuss characteristics of diseases. Their understanding should include the concept that some diseases in humans can be caught only once and when they recover they never catch it again. Medical technology enables us to protect ourselves against some of these diseases through vaccination.

Children in the middle elementary years are less concerned about identifying emotions than about knowing what to do with them.

Children at this level of development are less concerned about identifying emotions than about knowing what to do with them. Students should be encouraged to wonder why they and others have certain emotions. They can begin to make a connection between physical and emotional well-being and see how one can affect the other. During this period, children should come to know that individuals handle their feelings differently and sometimes they have different feelings in reaction to the same situation. Often human beings do not understand why others act the way they do and sometimes they do not understand their own behaviors and feelings. This is a time for making connections. Physical health can affect people's emotional well being and vice versa. Children need to learn that one way to respond to a strong feeling, either pleasant or unpleasant, is to think what caused the feeling and then consider whether to seek out or avoid similar situations. Role-playing is an effective technique for examining powerful emotions.

UPPER ELEMENTARY/MIDDLE SCHOOL

During these grades, students should extend their study of the healthy functioning of the human body and ways to promote it. Students should examine the labels on food products with a critical eye and knowledge of the wide variety of terms that indicate the presence of sugar, salt, and other additives like nitrites that affect health.

Students are ready for health investigations in which they pursue questions they generate themselves, like bringing together their skills in observing, hypothesizing, data collecting, analyzing, and interpreting. They can demonstrate their learning through exhibits, oral and written reports, portfolios, and actively communicating about their investigation by preparing and teaching lessons to younger students. Students in the upper elementary grades can be challenged to look for health-related issues in their environment, estimate the long term impact of food choices, trace the history of health practices in their culture, and so forth.

Students in the upper elementary grades can be challenged to look for health related issues in their environment.

Students at this level are dealing with intense emotions. Their world is expanding and emotions are coming from internal chemistry, from personal history, values, changing cultures, and changing roles. Many students find themselves moving into adult roles—farming, entering the job market, and financial responsibilities. Peer pressure increases with greater exposure to alcohol, drugs, and sexual relationships.

Faced with these decisions, most of which are imminent after the eighth grade, some individuals may be unable to cope with the emotions (fear, anger, anxiety, loneliness, insecurity) that they evoke. Drug and alcohol abuse, violence, and death may be the final results. This is a time for solving emotional situations in the classroom, for opportunities to work in groups to explore alternative actions to the kinds of situations that children of this age encounter, to re-examine the effects of substance abuse, and to explore the likely outcome of a variety of solutions.

By the end of grade 8, scientifically literate students will understand that:

- human beings have many similarities and differences. Their differences help them create diverse social and cultural arrangements and to solve problems in a variety of ways;

- the technology of food production, sanitation, and disease prevention has dramatically changed how people live and work and has resulted in rapid increase in human populations;

- regular exercise is important for a healthy heart-lung system, good muscle tone, and bone strength;

- toxic substances, dietary habits, and personal behavior may be harmful to one's health. Some effects are immediate, others appear many years later. Avoiding toxic substances (such as tobacco), and eating a diet low in animal fat intake can increase the chances of a longer life;

- viruses, bacteria, fungi, and parasites may infect the human body powerfully and disrupt normal functions;

- faulty genes, inadequate pre- and post-natal care, and maternal substance abuse or inadequate diet may lead to developmental problems;
- individuals differ greatly in their ability to cope with stressful situations. External conditions, chemistry, personal history, and culture influence how people behave;

- often people react to mental distress by denying that they have a problem. Sometimes they do not even know why they feel the way they do. People can learn how to find out why they feel the way they do and can select effective strategies for coping with mental distress.

They will be able to

- take personal actions applying their knowledge to ensure their own physical and mental health,

- identify agencies in the community that assist in maintaining and treating physical and mental health.

They will value

- their own and others physical and mental health,

- the impact of their actions and attitudes on others.

Students should relate their knowledge of normal body functioning to hereditary and environmental factors which lead to impaired functioning.

SECONDARY

Students should relate their knowledge of normal body functioning to hereditary and environmental factors. With the spread of viral infections, increased use of manufactured food products, changes in diet from local to imported foods, increased use of pesticides, increased building and changes in island environments, students need to think about the complex factors around them that produce or inhibit healthy living. Students should know about the immune system and its delicate but powerful role in health.

Students at this age can engage in long-term projects, such as research on their own environment, comparative studies of health practices, the presence or absence of diseases across cultures, and identification of new wavs to detect, diagnose, treat, prevent or monitoring diseases. They should routinely seek explanations for various disease conditions in physiological, molecular, or system terms.

Students are searching for their place in an ever- changing world. Their experience with emotions, stressful situations, and opportunities to observe the consequences of various methods of dealing with emotions can be brought together to deepen understanding of mental health. They are also able to examine other causes of mental problems like chemical imbalances, brain injuries, and the influences of substances such as alcohol and drugs. Investigations at this level may deal with issues that immediately affect students' lives or look far beyond their own surroundings to explore social issues like alcoholism and suicide.

By the end of secondary school scientifically literate students will understand that

- good health depends on sound nutrition and exercise to maintain basic functions of life;

- some allergic reactions are caused by the body's immune response to usually harmless environmental substances. Sometimes the immune system may attack the body's own cells;

- faulty genes can cause body parts or systems to work poorly. Some genetic diseases appear only when an individual has inherited a certain faulty gene from both parents;

- some viral diseases such as AIDS, destroy critical cells of the immune system, leaving the body unable to deal with multiple infections and cancer;

- biological abnormalities, such as brain injuries or chemical imbalances, can cause or increase susceptibility to psychological disturbances; reactions of other people to an individual's emotional distress may increase its effects;

- ideas about what constitutes good mental health and proper treatment for abnormal mental states vary from one culture to another and from one time period to another.

They will be able to

- relate their knowledge of normal body functioning, heredity, and environmental conditions to good health,
- take personal actions that increase the probability of good physical and mental health,
- make use of community health agencies to keep informed of new health threats and developments in health treatment.

They will value

- their own and others' physical and mental health.

HUMAN SOCIETY

The scientifically literate student understands that the patterns of human society differ from place to place, across cultures, and change over time, and that Pacific island societies are among the many societies that have developed across the globe.

People are social beings who live out their lives in the company of other humans. We organize ourselves into various kinds of social groupings, such as families, clans, villages, island communities, cities, and countries, in which we work, trade, play, and interact in many ways. Unlike other species, humans have the ability to modify social behavior and structures according to their needs and the nature of the environment in which they find themselves. This ability has led to the development of a large variety of complex and dynamic social structures. Pacific island societies developed as people struggled to survive in their unique island environments. Like all other societies, island societies are dynamic: they continue to change and develop today.

Pacific island societies developed as people struggled to survive in a variety of unique island environments.

All societies seek to protect their members and meet their survival needs. Achieving this goal means studying and understanding the world around them. Society, science and technology are intertwined, each influencing and being influenced by the other.

Survival meant studying and understanding the world which surrounded them—science, and developing tools and techniques to assist in their meeting their needs—technology.

The social science disciplines, which study human social behavior, use the same evidence-based, hypothesis-testing, model-building approach as scientists in other fields of study. Social scientists study human behavior from a cultural, political, economic, and psychological perspectives, using qualitative and quantitative methods. They look for consistent patterns of individual and social behavior and for scientific explanations of those patterns. Their evidence is found in the legends, stories, chants, storyboards, and drama of a culture. Information from other disciplines such as history and philosophy also contribute significantly to our understanding of ourselves.

Exploring human society requires teachers and students to be both the observers and the observed. Students are being asked to observe the human drama objectively, but at the same time they and their family members, friends, neighbors, schoolmates, teachers, shopkeepers, and local authority figures are also the subject matter. It takes time for students to learn how to shift roles.

Exploring human society requires teachers and students to be both the observers and the observed.

There is a natural tendency on the part of students of almost any age to reject or ridicule ideas that seem unlike those of their culture or age group, and that tendency needs to be taken into account.

For their part, teachers should try to guide their students toward the kind of understanding of human behavior that derives from science. The role of the teacher is to provide opportunities for students to look at society from a variety of perspectives. One useful approach is to organize learning around broad questions rather than specific subject areas. Reasoning with statistics is especially important for making sense out of social phenomena. Therefore, it is useful to get mathematics and social studies teachers to work together to help all students understand social applications of probability and statistics.

Pacific island societies are currently in a state of rapid change as a result of major economic and technological shifts.

Scientific literacy requires a broad-based knowledge of human social behavior. Societies in general, and Pacific island societies, in particular, are currently in a state of rapid change as a result of major economic and technological shifts. Knowledge of human social behavior will help students understand themselves and their societies. When scientific knowledge of how human society works is shared, it can contribute to better personal and public decision-making.

Understanding human society involves students in learning about these related concepts:

A. **Science and Technology In Culture.** Society, science and technology are intertwined, each influencing and being influenced by the other. There is a wealth of scientific understanding and technology embedded in Pacific island traditions, practices, and beliefs.

B. **Social Change, Choices and Conflict.** Societies are in a constant state of change. Many internal and external factors influence this change. Social change involves considering alternatives, understanding consequences, negotiating among different interests, and compromising. Education can help people learn how to deal thoughtfully and constructively with change, decision making, and conflict.

C. **Political and Cultural Systems.** People tend to live in groups, so they must devise ways to dwell and work together peacefully. Political and cultural systems have developed in the Pacific islands that allowed people to live together in an environment where land and resources were very limited.

A. Science and Technology in Culture

There is a wealth of scientific understanding and technology embedded in Pacific island cultures.

Pacific islanders developed a deep understanding of the world around them. A wealth of scientific understanding and technology is embedded in Pacific island traditions, practices and beliefs. Their proverbs, legends, myths, storyboards, and charts reflect the knowledge gained from closely observing their surroundings. This valuable information, as well as other cultural traditions, has been passed from generation to generation by word of mouth.

This knowledge is valued in Pacific island cultures and is often reserved to a specific group of people. As a result, possession of the knowledge often becomes a source of social status and power. Knowledge of navigation, herbal medicines, and fish habitats, are viewed as gifts to be carefully preserved and passed on to qualified young people by respected elders.

Connecting the scientific and technological achievements of Pacific islanders to the science education which is taking place in the school setting will enhance students' understanding of science and of their cultural heritage.

Culture, science, and technology are intertwined in Pacific societies. It is critical to preserve the valuable knowledge, beliefs and perceptions that were generated by Pacific island cultures. Connecting the scientific and technological achievements of Pacific islanders to the science education in the school setting will enhance students' understanding of science and of their cultural heritage.

LOWER ELEMENTARY

Children's first exposure to science and technology in their culture should be based upon events they encounter in the course of their daily lives.

Children's first exposure to science and technology in their culture should be based upon activities they encounter in their daily lives, such as growing and preparing food, hunting and fishing, transportation, and so on. Even at this age, students should be able to a discuss recent changes in the way their community meets its needs. The answer to questions such as How have things changed? will be the foundation for more detailed exploration in later years.

MIDDLE ELEMENTARY

In the middle elementary years, students can begin looking at the mores (rules) and practices of their culture to identify the scientific principles that underlie practices such as planting systems and methods of food preservation and determine how and why they were successful.

Social mores regulating land use, farming, and fishing were established to preserve resources for the good of the community. These regulations are based upon conclusions drawn after many years of carefully observing the surroundings. In almost all situations, they produced an ecological balance that allowed limited resources to meet the food and other needs of their societies. This information has been passed down orally from one generation to the next.

In the middle elementary years, students can begin looking at the mores and practices of their culture to identify the scientific principles which underlie them.

Many traditional practices have allowed for the maintenance of society as well as fragile island ecosystems.

UPPER ELEMENTARY/MIDDLE SCHOOL

Many traditional practices have allowed for the maintenance of people as well as the conservation of plants and animals in fragile island ecosystems. These practices have made survival possible for thousands of years in spite of limited resources and natural disasters.

Most students in upper elementary and middle school have had experiences that involve these cultural practices and should be able to connect them with the science concepts they are learning in school. They should also be able to explain why it is important for many of these practices to continue if the islands are to survive in their present ecological states.

By the end of grade 8, scientifically literate students will understand that

- cultural rules and systems developed over time allowed Pacific island societies to survive while maintaining the fragile ecosystems they are part of;
- many traditional practices, including fishing, farming, and health care are based upon understandings developed through years of study and observation of the environment.

They will be able to

- participate meaningfully in local practices that encourage conservation of island resources.

They will value

- traditional customs that have help people to survive for thousands of years in island environments,
- traditional practices by demonstrating sensitivity and respect.

SECONDARY

Secondary science students can perform more in-depth studies related to traditional practices that preserve the island environment, allow travel over large ocean distances, help people maintain their health, etc.

Secondary students should also be able to discuss and evaluate changes in the science and technology being practiced within their societies which have taken place in recent years.

Secondary students should also be able to discuss and evaluate the recent rapid changes in technology being utilized within their societies.

By the end of secondary school scientifically literate students will understand that

- the development of culture is a uniquely human ability that develops in a wide variety of ways, depending on a people's view of themselves, the world, their needs and the available resources;

- science and technology have both positive and negative impacts on cultures.

They will be able to

- demonstrate sensitivity and respect for the ways that science has evolved throughout the islands over time,

- keep informed of new technologies and their potential impact on community and culture,

- make informed decisions regarding the expansion or constraints on new technologies in the community.

They will value

- the positive impacts of technology on quality of life,

- the trade-offs involved when science, technology and society interact.

B. Social Change, Choices, and Conflict

One purpose of education is to help children learn how to deal thoughtfully and constructively with conflict in their own lives.

Human beings generally live in groups, voluntarily cooperating and competing with one another. Within the general context of interdependence, however, some social conflict is inevitable, from youngsters arguing over toys to adolescent rivalries for friendship to adult debates and war. Human societies spend much time negotiating differences peacefully, heatedly, or violently. One purpose of education is to help children learn how to deal thoughtfully and constructively with conflict in their own lives. School provides opportunities for students to have experiences resolving conflict in positive ways.

Gaining an understanding of the concept of social trade-offs (weighing alternatives and considering the consequences of social choices) may be one of the most important outcomes of education. Because social problems typically involve a variety of factors and interests, it is rare that one solution to a problem will carry all the benefits and avoid all disadvantages. Increasing some advantages is likely to decrease others. Most realistic solutions involve compromise among advantages and disadvantages. Students need repeated experience to develop the ability to consider alternatives and consequence when making decisions.

Social changes can happen very quickly, but change most often occurs slowly over a period of time.

Developing an understanding of the internal and external factors that influence social change takes time—time for students to encounter and experience social change in a variety of contexts. Social changes can happen very quickly, but change most often occurs slowly over a period of time. The way children eventually understand and relate to change in their own lives can influence how they do this when they are older.

Two hundred years ago, Pacific island societies existed in isolation. Today these same islands have access to satellite communication, transportation, and trade which connect the islands to each other and to the rest of the world.

Currently, one of the greatest forces behind social and cultural change is increasing global interdependence. This has been a particularly strong force of change in the Pacific islands. Two hundred years ago Pacific island societies existed in isolation from the rest of the world and in relative isolation from each other. Each society represented an independent, self-sustaining population. Today these same islands have access to satellite communication, transportation, and trade which connect the islands to the rest of the world. Students need to become aware of the growing number of ways in which the Pacific islands are connected to one another as nations, as a region, and as part of even larger systems as well as the resulting pressures on their cultures and societies.

LOWER ELEMENTARY

Life is full of choices, even for very young children. Many choices are made for them, of course, by parents and teachers. They need to understand some of the reasons that particular choices are made. These explanations help children to see what counts as an explanation and gets them into the habit of looking for reasoned decisions. When children do make decisions for themselves, they should be encouraged to anticipate the possible consequences of their choices.

Lower elementary students should be encouraged to anticipate the possible consequences of their choices.

Children can be helped to examine changes that affect their lives, including those they have come to expect (moving to the next grade) and those that are unexpected (moving away). Students should know that sudden and slow changes happen in everyone's life and although people cannot control some changes, they can usually learn to cope with them.

Social change usually involves negotiating some rules. Children know breaking rules carries a penalty, even though they may think some rules are unfair. They often regard all rules as unchangeable and don't know that some rules may be changed through negotiation. Negotiation should be emphasized as a means of resolving conflict with those around them, including other students, and thus avoiding conflict.

MIDDLE ELEMENTARY

Children need guidance to help them identify when their actions are likely to result in conflict with others. They need to learn strategies for avoiding it. Providing opportunities for students to explain their point of view can lead to new insights for children and teachers. Role playing and discussions of various situations involving conflict may also help. Children's own conflicts and stories about those of others provide a rich source of material for discussion, which should include possible consequences of various ways of resolving conflict. Emphasizing conflict resolution is more important than focusing on the dangers of conflict. Many Pacific cultures have their own processes for conflict resolution. The role of these processes to resolve conflict in the community should be explored.

Middle elementary students can take part in discussions: examining options, identifying possible risks, and deciding which risks, if any, are worth taking.

Children can begin to improve their decision making skills and apply them in new and varied situations. The decisions they make and the decisions others make in their behalf can serve as the subject for discussions about trade-offs. Discussions can include examining possible options, considering how various options will affect others, identifying possible risks, and deciding which risks, if any, are worth taking.

Children should continue to have experiences that show their impact on the world around them, such as village or community projects. Through interviews and other encounters with community, business, and government workers, children can develop a wider view of the many ways in which people affect one another.

UPPER ELEMENTARY/MIDDLE SCHOOL

The exploration of experiences they have had with decision making should help students learn about the inevitability of trade-offs.

Exploration of experiences students have had with decision making should help them learn about the inevitability of trade-offs and the need to consider benefits and costs. When people with different interests are involved in solving social problems, compromise is also needed to accommodate their different perceptions of advantages and disadvantages.

As children mature, they can imagine themselves in situations different from their own. Discussions with elders, literary and media accounts of life in times past. and role- playing all provide material for discussions about social change. Students can be helped to see that cultural patterns change because of technological innovations, scientific discoveries, and population changes. Students should begin to see that migration, conquest, and natural disasters have been major factors in causing social change.

By the end of grade 8, scientifically literate students will understand that

- some aspects of family and community life are the same now as they were a generation ago, but some aspects are very different;

- each person must consider trade-offs in making choices that often have life-long consequences;

- treaties are negotiated directly between individual countries or by international organizations to bring about cooperation among countries;

- scientists and others are linked worldwide both personally and through international organizations, therefore, much information is shared.

They will be able to

- demonstrate and practice effective strategies in handling conflict in constructive ways,
- describe the impact of technology, immigration, and population growth on social changes, choices, and conflict in the Pacific region,
- actively participate in community social, and cultural groups.

They will value

- the importance of community and culture to their lives,
- the impact of social change in their community and culture.

SECONDARY

History provides endless examples of conflict, its causes, and its consequences. Adding social and economic analysis to historical narrative helps students better understand both. Discussion and role-playing situations involving conflict can stimulate discussions on possible ways of resolution.

Students in secondary school can examine the complexities of decision making and take into account different types of costs: direct, indirect, economic, social.

Students in secondary school can examine the complexities of decision making and consider different types of costs (direct, indirect, economic, social). They can examine trade-offs across generations and over great distances. They can realize that the people who receive benefits and the people who bear the costs of those benefits are often not the same. Social trade-offs are often generational. The costs of benefits received by one generation may fall on subsequent generations (the depletion of resources to maintain the current standard of living may result in future shortages) Also, the cost of a social trade-off is sometimes borne by one generation although the benefits are enjoyed by their descendants (regulating land use now to preserve the environment for future generations). Social, environmental, political, technological, and scientific case studies offer a rich foundation for developing decision-making skills in weighing alternatives and making choices.

The development and use of technology is a major cause of social change. Students at the secondary level can consider how technology has affected the mobility of people, especially Pacific islanders. They can examine the causes and results of social changes occurring as a result of increased contact with other cultures. Increased contact between cultures leads to extensive borrowing among cultures, has led to changes in some cultures, and the virtual disappearance of others.

By the end of secondary school, scientifically literate students will understand that

- the size and rate of growth of populations is affected by economic, political, religious, technological, and especially environmental factors;

- mass media, migrations, and conquest affect social change by exposing one culture to another. Extensive borrowing has led to the disappearance of some cultures, but only a modest change in others;

- migration across borders, temporary and permanent, legal and illegal, plays a major role in the availability and distribution of labor in many nations. It can bring both economic benefits and political problems;

- the growing interdependence of world social, economic, and ecological systems does not always bring greater worldwide stability and often increases the costs of conflict.

They will be able to

- think both regionally and globally when considering issues of widespread concern, such as ensuring a safe environment for tomorrow,

- explore, weigh alternatives, and think critically to make wise decisions in solving problems,

- describe some of the complex interactions of science, technology, economics, politics, religion, and environment.

They will value

- the changes occurring in the Pacific and their impact on their own culture and traditions.

C. Political and Cultural Systems

People tend to live in groups and must devise ways of living and working together that will allow everyone to meet their life needs. Societies throughout the world have developed complex political and cultural systems to do this.

In most of the Pacific islands, political and cultural systems are in transition. Although the exact political status varies from one island group to another, all of the region's entities have assumed a more active role in governing themselves in recent years. The rapid influx of new technologies and a changing economic system are putting pressure on the cultural systems to make similar adjustments.

The rapid influx of new technology and a changing economic system are putting pressure on the cultural systems to make similar adjustments.

Although these systems are very complex, they are based upon very simple and basic premises that children can grasp, first mostly in personal terms and later in societal terms. When reduced to their simplest terms, political and cultural models describe how people organize themselves to satisfy their needs and maintain harmony.

LOWER ELEMENTARY

In the early years of schooling children should become aware of the range of their society's rules. Students can begin by finding out what the rules are in different classrooms, families, and villages observing how children respond to the rules and recording their findings in drawings and notes. Discussions can focus on how the rules and behaviors resemble or differ from those in their own classroom or family. Such observations should introduce students to the idea of cultural diversity.

Emphasis in the first years of schooling can be given to help children become aware of the range of their society's rules.

Young children can engage in discussions about rules in their communities. They have a sense of what is and is not fair and are interested in discussing it. They know about negotiation and compromise when expressed in terms of sharing in decisions. Children should have many opportunities to identify meaningful roles for themselves through a variety of personal interactions in school, at home, and in the community. Children need to see themselves and what they do as important to others enabling them to notice and appreciate how what others do affects them. They should have experiences in which everyone must do their part in order to achieve success.

MIDDLE ELEMENTARY

Children in middle elementary school can understand that when people live together in groups there need to be rules defining appropriate behavior and ways of deciding who will do what. These rules are part of the cultural and political systems.

Middle elementary students should become aware of the purpose of many of the rules in their own cultures and aware of some of the rules of other cultures in other places.

Each of the Pacific's unique cultures has it own set of rules. Children should become aware of the purpose of many of the rules in their own cultures and some of the rules of other cultures in other places.

They also need to begin to understand the role of government to maintain order and to provide services needed by all. Investigating the types of services provided by local and national government is appropriate for middle elementary students.

UPPER ELEMENTARY/MIDDLE SCHOOL

Simulations can involve upper elementary students in planning the use of available resources for the greatest benefit and making choices about wants and needs.

As students mature, they should continue to have experiences that show their impact on the world around them. Books, films, other media, and direct personal experiences can expand students' world beyond the borders of their community, state, and country. The study of geographical differences in climate and natural resources will make the advantages of trade evident. Simulations can involve students in planning the use of available resources for the greatest benefit and making choices about what, how much, and how to produce things to meet wants and needs.

As students mature, they can begin to understand more fully how people in different situations might behave. Students can conduct careful surveys to gather information about traditional practices and behavior. Data can be collected and graphed.

By the end of grade 8 scientifically literate students will understand that

- however they are formed, governments usually have most of the power to make, interpret, and enforce the rules and decisions that determine how a community, state, or nation will be run;

- governments use money collected from taxes to provide goods and services to citizens;

- in many Pacific nations, traditional leaders share in decision making in these processes;

- each culture has distinctive patterns of behavior, usually practiced by most of the people who grow up in it.

They will be able to

- describe the governing systems applicable to their community and the roles and responsibilities of each,

- participate in community and cultural governing systems as responsible citizens.

They will care about and value

- traditional and new community, state, and national governing systems,

- their role as responsible citizens of the community, state, region and world.

SECONDARY

Students in the secondary grades are participating more in issues regarding their community through traditional political systems. More studies and discussions can be facilitated about these traditional systems within each entity.

The newspaper and radio broadcasts provide good material for stimulating discussions on political models. Trade negotiations, global warming issues, balance of payments and productivity are the focus of much international tension. In analyzing these matters, students should try to understand what is going on rather than to judge what is desirable. Students should come to understand that the growing interdependence of world social, economic, and ecological systems does not always bring greater worldwide stability and often increases the cost of conflict.

Secondary students should come to understand that the growing interdependence of world social, economic, and ecological systems does not always bring greater worldwide stability.

Students can use descriptive and statistical information about different cultures to stimulate discussion about how circumstances, beliefs, and patterns of behavior are linked. It may be easier for students to describe influences on other people's thinking, but the goal is for them to see what influences have an effect on their own ideas and behavior.

By the end of secondary school, scientifically literate students will understand that

- the wealth of a country depends partly on the effort and skill of its workers, its natural resources, and the capital and technology available. It also depends on the balance between how much of its products are sought by other nations, and how much of other nations' products it needs;

- cultural beliefs strongly influence the values and behavior of the people who grew up in the culture;
- heredity, culture, and personal experience interact in shaping behavior.

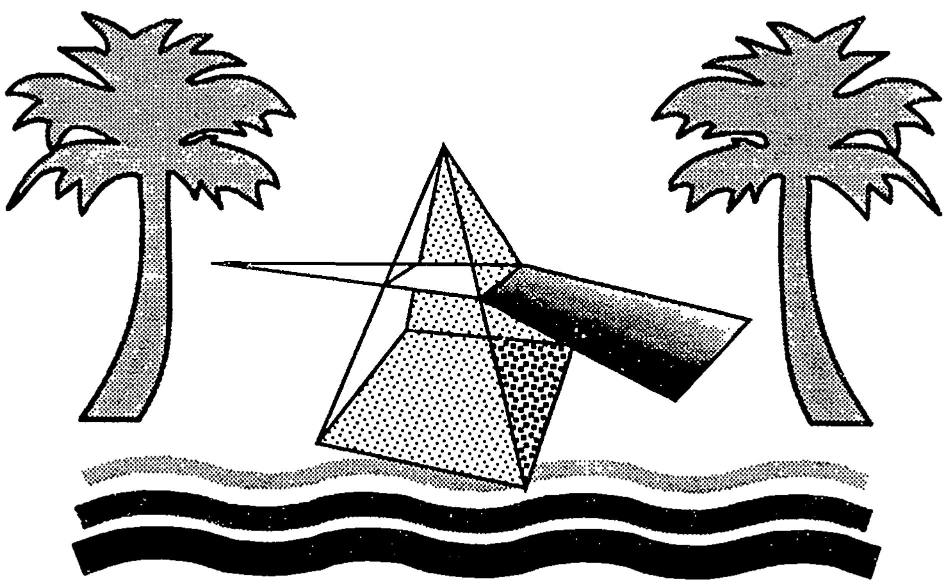
They will be able to

- describe how people's opinions are influenced by others,
- participate responsibly in community affairs and governance,
- make informed decisions affecting their own lives and the lives of others in the community.

They will value

- their role as responsible citizens of the community, state, region and world.

APPENDICES



TERMS OF SCIENCE

It is easy to misunderstand or loosely use scientific terms such as observation, fact, and hypothesis. But when we communicate about science, terms must be used with their proper meanings.

Observation—All science is based on observations. We use our senses to gather information about the world around us. Even when we use hand lenses, microscopes, telescopes, and other instruments, the information we gather must be filtered through our senses.

Fact—When our observations are confirmed and found to be repeatable, they become facts. The repeatability of an observation means there is little doubt about it, though it cannot be accepted with absolute certainty. For example, everyone can observe that a student in the classroom is smiling. Therefore, this is a fact.

Inference—An inference is reasoning based on observation and experience. To infer is to arrive at a decision or opinion by reasoning from known facts. For example, I can see that the student described above is smiling. From this, I can infer from my experience that he is happy. It is particularly easy to think that an inference is a fact. It takes critical thinking to distinguish between the two. In the example of the smiling student, I do not know that the student is happy. He may be smiling for some other reason.

Hypothesis—A hypothesis is a tentative explanation of existing data that is based on previous knowledge and that guides further inquiry through observing or experimenting. Hypotheses are derived from inferences drawn from observations and based on theory. They are offered as possible explanations and are generally stated in such a way that they lead to testable predictions.

Prediction—Prediction means to state what will happen or be observed as the result of some action or experiment. Predictions are based on previous observations, experience, or reasoning.

Law—A law is a statement of what always occurs under certain circumstances. It generally refers to a sequence of events in nature that have been observed to occur with unvarying uniformity under the same conditions. Examples include the law of gravitation, the gas laws, the laws of motion, and the law of conservation of energy.

Theory—A scientific theory is a logical explanation or model based on observation, facts, hypotheses, experimentation, and reasoning that attempts to explain a range of natural phenomena. Scientific theories are constantly subject to testing, modification, and refutation as new evidence and ideas emerge. Theories also have predictive capabilities that guide further investigation. Theory and hypothesis are sometimes confused. Theory implies a greater body of tested evidence and a greater degree of probability than hypothesis. Examples of current theories are the theory of evolution, the theory of plate tectonics, the kinetic molecular model of matter, the big bang theory for the origin of the universe, and the theory of relativity.

Sensory Skills—These include seeing, hearing, smelling, touching, and tasting; all the ways that we take in information about the world around us.

Manipulative Skills—These include correctly handling organisms, making and assembling equipment, and using measuring instruments and tools.

Communication Skills—These skills enable students to obtain and share information effectively with others. They include the ability to express basic ideas, instructions, and information clearly both orally and in writing, to organize information in tables and simple graphs, and to draw diagrams. Communicating effectively also includes the ability to read and comprehend science and technology news as presented in newspapers and news broadcasts.

Computational Skills—These include the ability to make mental calculations rapidly and accurately; to perform calculations using paper and pencil and calculators; and to estimate approximate answers to check on the reasonableness of other computations.

Computer Skills—Increasingly science and technology rely on effective use of computers to collect data, store and retrieve information, organize data in spreadsheets and graphs, communicate with other computers and researchers, and prepare written reports of research. Science teachers should also emphasize student development of computer skills of measuring using sensors, analyzing data, storing and retrieving data in various forms, and reporting and displaying results of their scientific investigations.

Interpersonal Skills—These are related to communication skills, but are more specific about individual behaviors. They include cooperating, sharing, listening, participating, and leading. They also include respecting others. Interpersonal skills enable students to work well with others to get a job done.

Organizational Skills—In getting a job done, especially in group work, organizational skills are called for. These include organizing group members and equipment for action, initiating leadership, taking responsibility for getting and returning equipment and supplies, keeping data neatly arranged in tables, keeping science notebooks neat and orderly so that needed data can easily be retrieved, and arranging science apparatus in efficient ways. Organizational skills enable students to plan and carry out activities effectively.

Imaginative Skills—Much of science and technology relies on the human capacity to create new ideas and solutions. Imagining, inventing, modeling, and creative thinking all play an important part in furthering our understanding in science and technology.
Decision-making Skills—These thinking skills enable students to arrive at appropriate solutions to problem situations, to judge assertions, to separate facts from opinions. These skills include identifying problems, seeking alternative solutions, applying knowledge, evaluating alternatives, and selecting a course of action.

Process Skills—Scientists use their senses to collect information about the world around them, *observing* its characteristics as objectively as possible. These observations may include *measuring* properties of matter or time of events. They test what they know against what they don't know by *comparing* features and behaviors for similarities and differences. They organize their understandings by *ordering* and *categorizing* them into broader, more general groupings. They study interactions among objects and describe the events, *relating* factors that reveal deeper understanding about causes and effects. Scientists *hypothesize* and *predict* what will happen based on their accumulated knowledge and upon the events they expect to take place, *inferring* something that they have not yet observed. They *test* their hypotheses against observed phenomena using designed experiments. The collect and *analyze* their data, *synthesizing* what is known with what is being revealed. As their knowledge grows they *apply* both knowledge and processes to useful purposes to extend explanation or create new artifacts.

Observing is the most fundamental scientific thinking process. Only through observing are we able to acquire information about the world around us. Given objects to play with the young student will look, touch, smell, taste, and listen to them. These sensory actions enable the learner to construct a view of the world and how it works. Similarly, scientists gather information about Mars by placing a space probe that can observe its surface and thereby extend their human capabilities. By observing, humans gather information as raw material for constructing fundamental knowledge.

Measuring length, weight, mass, volume, temperature, density, time, and so on is essential to understanding science. To find out more about unfamiliar objects, scientists often measure them using appropriate tools. Measuring is a skill that assumes knowledge of measuring instruments and systems and the ability to communicate the results of the measurements taken.

Comparing builds on the process of observing. We learn much about the size, shape, color, texture and so on of objects by comparing them to different objects. We separate objects on the basis of similarities and differences. When we do, we develop concepts of higher-order relationships than we do by merely describing observations. To find out more about an unfamiliar object, scientists often match or compare it to something they know well. In fact, all scientific measures using rulers, balances, thermometers, watches, and so on, rely on comparing an unknown object to something that is known: the instrument.

Ordering is the process of putting objects or events into a linear format. There are two kinds of ordering, seriation and sequencing. *Seriation* is organizing objects along a continuum—from rough to smooth, dim to light, sharp to dull, light to heavy, soft to loud, and so on. Seriating objects can involve an almost limitless number of properties and are useful in establishing scientific scales such as for wind speed (Beaufort scale), temperature (Celsius and Fahrenheit scales), elevation (above and below sea level), brightness (star magnitude scales), and sound (decibel scale).

Events arranged in a sequence tell a logical story. In *sequencing*, events are ordered by time from earliest to latest action, from first moment to last moment, and so on. Sequences tell stories of two types, linear and cyclical. Linear sequences tell us about the growth and decay of a plant or animal, the motion of an object, and the cause and effect of an event. Cyclical sequences tell us about recurring events such as the water cycle, the passing of seasons, or the phases of the moon.

Categorizing is the process of putting objects or events together on the basis of a logical rationale. There are two kinds of categorizing, *grouping* and *classifying*. When scientists group objects, they put them together on the basis of a single property. Leaves might be grouped by type of venation, size, shape, and so on. Grouping is useful in revealing similarities and differences that otherwise might go unnoticed. Classifying involves putting items together on the basis of more than a single property at a time. For example, leaves with net venation and red color might be grouped together on these two characteristics while leaves with net venation and green color would be placed in a separate group. Scientists in all fields use the categorizing process to group and classify objects they work with.

Relating means seeing relationships between and among things in our environment. Relationships might involve interactions, dependencies, and cause and effect events. In the sciences, information about relationships can be descriptive (as it is in much of ecology) or experimental (as it generally is in physical science). Descriptive relationships are derived in situations where direct experimentation is not possible. Many of the ideas in astronomy are based on description. We cannot do direct experiments on galaxies or black holes, yet we know a great deal about them. Determining relationships experimentally frequently *involves controlling and manipulating variables* in such a way that the scientist can determine which of the factors affects the observed event the most. The ability to separate variables and systematically test each one while holding others constant to determine which are relevant and which have no effect is very powerful. By manipulating variables the scientist is able to test hypotheses.

Hypothesizing uses the understandings derived from experiments and theory along with the relating process to form testable statements. A hypothesis is a tentative explanation that guides further inquiry through observing or experimenting. They are generally stated in such a way that they lead to testable predictions.

Predicting is the process by which we state what will happen or be observed as the result of some action or experiment. Predictions are derived from theory and hypotheses and set expectations for a future event. The hallmark of a good hypothesis is an accurate prediction.

Inferring is the process of making logical conclusions through reasoning from evidence. In inferring we make logical statements about events that cannot be dealt with directly because of time or space. For example, we know a great deal about life on Earth in the age of dinosaurs by making inferences from existing data. Similarly, we know a great deal about our universe by making inferences from observable data here on Earth. Through evidence and reasoning, we make inferences about the movement of continents, and from those inferences develop a theory of plate tectonics. But inferences, no matter how logical, are never final. They must be tested to determine if they are true.

Testing is the process of designing and carrying out experiments to determine if our hypotheses, predictions, and inferences are true. The test usually consists of asking questions of nature, questions that are implied in the hypotheses. The theory and hypotheses we are dealing with also guide the kinds of observations we will make to determine if our ideas are correct.

Analyzing is the process used to make sense of the data collected in the testing of hypotheses. Analyzing may include organizing and categorizing data, graphing, or computer analysis to search for patterns in the data. Through analyzing we try to interpret the data in light of existing knowledge and evidence.

Synthesizing is the process of connecting existing knowledge with new discoveries to develop a new or deeper understanding of phenomena. It is through synthesizing that we build our own personal knowledge as well as build the body of knowledge known as science.

Applying refers to the use of knowledge. Sometimes knowledge is used to expand explanation or theory; sometimes it is used to revise or build new hypotheses or theory. These are examples of application within science. Sometimes, however, knowledge or processes are used in practical ways such as building a bridge, inventing a new instrument or technique, or improving on an existing product or design. These are examples of application in technology.

OBTAINING MORE INFORMATION ABOUT THE STANDARDS

Further information regarding the *Pacific Standards for Excellence in Science* and other documents in the Pacific Standards for Excellence Series can be obtained from:

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