Alignment of the Foundational Approaches in Science Teaching (FAST)

and

Marine Science Studies (*H*MSS) Programs

with the National Science Education Standards

Grades 9–12

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FOREWORD

Alignment of the Foundational Approaches in Science Teaching (FAST) and Hawai‘i Marine Science Studies (HMSS) Programs with the National Science Education Standards

The Foundational Approaches in Science Teaching (FAST) program is a series of three inquiry courses designed for grades 6–10. FAST has been designed for students to replicate the activities characteristic of the science disciplines by providing investigative experiences in the physical, biological, and earth sciences. Content is organized into three strands called physical science, ecology, and relational study. Relational study focuses on the interrelationships of the science disciplines and the interactions of science and society. The three courses are: *FAST 1, The Local Environment*; *FAST 2, Matter & Energy in the Biosphere*; *FAST 3, Change over Time*. *Change over Time* is designed for use with students in grades 9–12.

The Hawai‘i Marine Science Studies (HMSS) program is a one-year multidisciplinary course set in a marine context for students in grades 9–12. There are two companion student books (*The Fluid Earth* and *The Living Ocean*.) which explore the physics, chemistry, biology, and geology of the oceans and their applications in ocean engineering and related technologies.

FAST is validated as an exemplary program by the U.S. Department of Education’s Program Effectiveness Panel. Both FAST and HMSS are included in the U.S. Department of Education’s publication *Promising Practices in Mathematics and Science Education* as meeting the standards for science education reform in the United States. Both FAST and HMSS are products of the Curriculum Research & Development Group (CRDG) of the University of Hawai‘i.

The National Science Education Standards is a product of the National Research Council of the National Academy of Science. The standards are designed to enable the nation to achieve its goal of scientific literacy for all.

The following analysis describes how FAST and HMSS address the recommended national standards for science content.

Alignment of *FAST* and *HMSS* Programs with the National Science Education Standards

National Science Education Content Standards for Grades 9-12	Foundational Approaches in Science Teaching (*FAST*) (*FAST* 3, Change over Time) & Hawai‘i Marine Science Studies (Fluid Earth; Living Ocean)
1. Science As Inquiry	
Abilities Necessary To Do Scientific Inquiry (Identifying questions and concepts that guide scientific investigations, designing and conducting science investigations, using technology and mathematics to improve investigations and communications, formulating and revising scientific explanations and models using logic and evidence, recognizing and analyzing alternative explanations and models, communicating and defending a scientific argument)	In FAST and HMSS students conduct their own inquiry laboratory and field investigations. As in science, values and attitudes such as the following are developed and established: knowing why it is important to keep honest, clear, and accurate records; knowing that hypotheses are valuable, even if they turn out not to be true, if they lead to fruitful investigations; and knowing that often different explanations can be given for the same evidence, and it is not always possible to tell which one is correct. Students develop their own texts out of the investigations they do and the data they collect, analyze, interpret, and draw conclusions from. Students develop their basic laboratory measurement skills in FAST and HMSS. Students assemble and disassemble laboratory equipment used in their investigations. They invent and calibrate a wide variety of instruments needed in their investigations. In FAST data tables and graphs are used extensively to analyze data and search for patterns and relationships. Students generate data from their own investigations and compare their findings with those of others. Students keep a log of their investigations and findings in their student notebooks which become their textbook. Communication through oral and written scientific reports and student seminars and debates form a central focus in FAST and HMSS. Just as in science, communication is essential to students in constructing their knowledge of science. Library research is first introduced through the use of the FAST classroom library and later extended to the research literature relevant to student investigations that can be found in the library and in computer databases.

1. Science as Inquiry (Continued)

Understandings About Scientific Inquiry	
• Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists. • Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories. • Scientist rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used. • Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results. • Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modifications; and it must be based on historical and current scientific knowledge. • Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation.	Scientists and how they work are examined in the studies of astronomy, chemistry, physics, geophysics and organic chemistry. Students conduct actual investigations as physical scientists, ecologists, and technologists. Throughout FAST students design and carry out their own investigations. Careful attention is paid to valid experimental design including the use of controls, replication of experimental results, and setting of proper standards. FAST investigations rely on replication of data and group consensus on the interpretation of results. FAST students develop a scientific world view by doing science—designing and carrying out experiments, collecting and analyzing data, and drawing conclusions based on evidence. Students respond to differences in data collected by looking for patterns and relationships, setting standards, examining the effects of human and instrument error, graphing data and looking for generalizations. Generalizations are based on data and consensus. Actual data from earlier experiments are used to determine experimental relationships as for example the study of organic chemistry. The nature of scientific inquiry is investigated in FAST 3 Unit 3, The Changing Universe, Unit 4, Life on Earth, and Unit 5, Continental Drift. Students make hypotheses based on their own understanding of phenomena and their developing understanding of the nature of science. Hypotheses based on different world views are examined especially in FAST 3 Unit 3, The Changing Universe and Unit 5, Continental Drift. In addition to learning about the nature of science by doing scientific investigations, FAST also causes students to focus on the nature of science by embedding case studies of historical events. See particularly, FAST 3, Change over Time—Unit 3, The Changing Universe; Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 7, Humans in the Environment. In *HMSS*, students engage in several observational studies such as wave watching, and animal behavior of fish, crayfish, and sea urchins to name a few. Wave watching can be simulated in the lab, but it is encouraged that animal observations take place in the animals' natural environment. Good reasoning and collection of careful data are stressed in *HMSS*. Students construct their own meaning of data and observations based upon what they know and have read or observed. Imagination has its place in putting the pieces together and imagining missing links even when the evidence doesn't reveal it. This imagination leads to further study. Through discovery activities such as animal behavior observations in HMSS, students try to explain what they observe and identify evidence to support their explanations. Often students' reasons are in conflict with each other, which directs them to support their statements. More observations leads to support of one or another of the explanations.

2. Physical Science

Structure of Atoms • Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons hold the atom together. • The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element. • The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars. • Radioactive isotopes are unstable and undergo spontaneous nuclear reactions, emitting particles and/or wavelike radiation. The decay of any one nucleus cannot be predicted, but a large group of identical nuclei decay at a predictable rate. This predictability can be used to estimate the age of materials that contain radioactive isotopes.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 4. Life on Earth. and in HMSS The Fluid Earth—Unit 4, Chemical Oceanography
Structure And Properties Of Matter • Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element. • An element is composed of a single type of atom. When elements are listed in order according to the number of protons (called the atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This "Periodic Table" is a consequence of the repeating pattern of outermost electrons and their permitted energies. • Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically. • The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 4. Life on Earth. and in HMSS The Fluid Earth—Unit 4, Chemical Oceanography

2. Physical Science (Continued)

• Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart. • Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 4. Life on Earth. and in HMSS The Fluid Earth—Unit 4, Chemical Oceanography
Chemical Reactions • Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies. • Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog. • A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions. • Chemical reactions can take place in time periods ranging from the few femtoseconds (10^{-15} seconds) required for an atom to move a fraction of a chemical bond distance to geologic time scales of billions of years. Reaction rates depend on how often the reacting atoms and molecules encounter one another, on temperature, and on the properties—including shape—of the reacting species. • Catalysts, such as metal surfaces, accelerate chemical reactions. Chemical reactions in living systems are catalyzed by protein molecules called enzymes.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 4. Life on Earth. and in HMSS The Fluid Earth—Unit 4, Chemical Oceanography
Motions and Forces • Objects change their motions only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F=ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe. and in HMSS The Fluid Earth—Unit 2, Waves and Beaches; Unit 3, Physical Oceanography; and Unit 5, Transportation.

2. Physical Science (Continued)

• Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square distance between them. • The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them. • Between any two charged particles, electric force is vastly greater than gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules. • Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students to understand electric motors and generators.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 3, The Changing Universe; Unit 5, Continental Drift and in HMSS The Fluid Earth—Unit 4, Chemical Oceanography
Conservation Of Energy And Increase In Disorder • The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered. • All energy is considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves. • Heat consists of random motion and vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion. • Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 4. Life on Earth; Unit 5, Continental Drift; and Unit 7, Humans in the Environment. and in HMSS The Living Ocean—Unit 4, Ecology
Interactions Of Energy And Matter • Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter. • Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 3, The Changing Universe. and in HMSS The Fluid Earth—Unit 2, Waves and Beaches.

2. Physical Science (Continued)

• Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance. • In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semi-conducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons.	FAST 3, Change over Time—Unit 3, The Changing Universe. HMSS The Fluid Earth—Unit 1, Earth and Ocean Basins.

3. Life Science

The Cell • Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material. • Most cell functions involve chemical reactions. Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules. Both breakdown and synthesis are made possible by a large set of protein catalysts, called enzymes. The breakdown of some of the food molecules enables the cell to store energy in specific chemicals that are used to carry out the many functions of the cell. • Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires. • Cell functions are regulated. Regulation occurs both through changes in activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division. • Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen into the environment. This process of photosynthesis provides a vital connection between the sun and the energy needs of living systems. • Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues and organs that comprise the final organism. This differentiation is regulated through the expression of different genes.	These concepts are introduced and developed in HMSS The Living Ocean—Unit 1, Fish; Unit 2, Invertebrates; Unit 3, Plants; Unit 4, Ecology.

3. Life Science (Continued)

Molecular Basis Of Heredity • In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by templating mechanisms). Each DNA molecule in a cell forms a single chromosome. • Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome—and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next. • Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism's offspring.	
Biological Evolution • Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring. • The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms. • Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms. • The millions of different species of plants, animals and microorganisms that live on earth today are related by descent from common ancestors. • Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 4. Life on Earth; Unit 5, Continental Drift; and Unit 6, Changing Ecosystems. HMSS The Living Ocean—Unit 1, Fish.

3. Life Science (Continued)

Interdependence of Organisms • The atoms and molecules on the earth cycle among the living and nonliving components of the biosphere. • Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers. • Organisms both cooperate and compete in ecosystems. The interrelationships and interdependencies of these organisms may generate ecosystems that are stable for hundreds or thousands of years. • Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms. • Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 3, The Changing Universe; Unit 4. Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems; and Unit 7, Humans in the Environment. and in HMSS The Living Ocean—Unit 4, Ecology.
Matter, Energy, And Organization In Living Systems • All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations. With death, and the cessation of energy input, living systems rapidly disintegrate. • The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes. • The chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken and new compounds with lower energy bonds are formed. Cells usually store this energy temporarily in phosphate bonds of a small high-energy compound called ATP. • The complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism. • The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy and the ability of the ecosystem to recycle materials.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 4. Life on Earth; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment and in HMSS The Living Ocean—Unit 4, Ecology HMSS The Fluid Earth—Unit 4, Chemical Oceanography

3. Life Science (Continued)

• As matter and energy flows through different levels or organization of living systems—cells, organs, organisms, communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 4. Life on Earth; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment and in HMSS The Living Ocean—Unit 4, Ecology
Behavior of Organisms • Multicellular animals have nervous systems that generate behavior. Nervous systems are formed from specialized cells that conduct signals rapidly though the long cell extensions that make up nerves. The nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules. In sense organs, specialized cells detect light, sound, and specific chemicals and enable animals to monitor what is going on in the world around them. • Organisms have behavioral responses to internal changes and to external stimuli. Responses to external stimuli can result from interactions with the organism's own species and others, as well as environmental changes; these responses either can be innate or learned. The broad patterns of behavior exhibited by animals have evolved to ensure reproductive success. Animals often live in unpredictable environments, and so their behavior must be flexible enough to deal with uncertainty and change. Plants also respond to stimuli. • Like other aspects of an organism's biology, behaviors have evolved through natural selection. Behaviors often have an adaptive logic when viewed in terms of evolutionary principles. • Behavioral biology has implications for humans, as it provides links to psychology, sociology, and anthropology.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 6, Changing Ecosystems. and in HMSS The Living Ocean—Unit 1, Fish; Unit 2, Invertebrates; Unit 3, Plants; and Unit 4, Ecology

4. Earth and Space Science

Energy In The Earth System • Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the earth's original formation. • The outward transfer of earth's internal heat drives convection circulation in the mantle that propels the plates comprising earth's surface across the face of the globe. • Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. • Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 1, Force, Work,, and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift; Unit 7, Humans in the Environment. and in HMSS The Living Ocean—Unit 4, Ecology. HMSS The Fluid Earth—Unit 1, Earth and Ocean Basins; Unit 2, Waves and Beaches; Unit 3, Physical Oceanography.

4. Earth and Space Science (Continued)

Geochemical cycles • The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles. • Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 5, Continental Drift and in HMSS The Living Ocean—Unit 4, Ecology. HMSS The Fluid Earth—Unit 1, Earth and Ocean Basins; Unit 3, Physical Oceanography; Unit 4, Chemical Oceanography.
Origin And Evolution Of The Earth System • The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early earth was very different from the planet we live on today. • Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed. • Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years. • Evidence for one-celled forms of life—the bacteria—extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the earth's atmosphere, which did not originally contain oxygen.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 4, Life on Earth. and in HMSS The Fluid Earth—Unit 1, Earth and Ocean Basins. HMSS The Living Ocean—Unit 4, Ecology
Origin And Evolution Of The Universe • The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since. • Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars,. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe. • Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 3, The Changing Universe

5. Science and Technology

Abilities Of Technological Design (identify appropriate problem or design an opportunity; propose designs and choose between alternative solutions; implement a proposed solution; evaluate the solution and its consequences; communicate the problem, process, and solution)	Student-made inventions and devices are analyzed for how well they work and for their impact on the environment and society. FAST and HMSS design projects offer many opportunities to evaluate alternative solutions to problems. In Change over Time, students specifically study the interaction of technology and society from an historical perspective and in the present including such topics as population growth, energy and land use, and resource management. Decision making is practiced in a simulation called Ostrich Bay where students get to see the consequences of decision regarding the use of technologies. In HMSS students design and build their own tools for investigation including wave tanks, hydrometers, manometers, etc. In addition they design and build ship models and examine their designs for stability, strength, practicality, and capacity. In studies of the living ocean, students design their own aquaculture systems to study marine productivity.
Understandings About Science And Technology • Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines. • Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. • Creativity, imagination, and a good knowledge base are all required in the work of science and engineering. • Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world. • Technological knowledge is often not made public because of patents and the financial potential of the idea or invention. Scientific knowledge is made public through presentations at professional meeting and publications in scientific journals.	These relationships between science and technology are specifically studied in FAST 3, Change over Time—Unit 3, The Changing Universe, Unit 4, Live on Earth, and Unit 5, Continental Drift. In HMSS students deal specifically with the technologies related to the marine environment including transportation, ship design, stability and capacity, mining for mineral resources, underwater diving, aquaculture, and satellite remote sensing of Earth features. Both courses deal with issues related to the interaction and interdependence of science and technology.

6. Science in Personal and Social Perspectives

Personal And Community Health • Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability, or death may be present. Humans have a variety of mechanisms—sensory, motor, emotional, social, and technological—that can reduce and modify hazards. • The severity of disease symptoms is dependent on many factors, such as human resistance and the virulence of the disease-producing organism. Many diseases can be prevented, controlled, or cured. Some diseases, such as cancer, result from specific body dysfunctions and cannot be transmitted. • Personal choice concerning fitness and health involves multiple factors. Personal goals, peer and social pressures, ethnic and religious beliefs, and understanding of biological consequences can all influence decisions about health practices. • An individual's mood and behavior may be modified by substances. The modification may be beneficial or detrimental depending on the motives, type of substance, duration of use, pattern of use, level of influence, and short- and long-term effects. Students should understand that drugs can result in physical dependence and can increase the risk of injury, accidents, and death. • Selections of foods and eating patterns determine nutritional balance. Nutritional balance has a direct effect on growth and development and personal well-being. Personal and social factors—such as habits, family income, ethnic heritage, body size, advertising, and peer pressure—influence nutritional choices. • Families serve basic health needs, especially for young children. Regardless of the family structure, individuals have families that involve a variety of physical, mental, and social relationships that influence the maintenance and improvement of health. • Sexuality is basic to the physical, mental, and social development of humans. Students should understand that human sexuality involves biological functions, psychological motives, and cultural, ethnic, religious, and technological influences. Sex is a basic and powerful force that has consequences to individuals' health and to society. Students should understand various methods of controlling the reproduction process and that each method has a different type of effectiveness and different health and social consequences.	The nutritional contributions to the world's human food sources are discussed with each major phyla. Ocean fisheries and their contribution to the world food supply are extensively studied in the supplemental materials, *Fishing in the Pacific.*

6. Science in Personal and Social Perspectives (Continued)

Population Growth • Populations grow or decline through the combined effects of births and deaths, and through emigration and immigration. Populations can increase through linear or exponential growth, with effects on resource use and environmental pollution. • Various factors influence birth rates and fertility rates, such as average levels of affluence and education, importance of children in the labor force, education and employment of women, infant mortality rates, costs of raising children, availability and reliability of birth control methods, and religious beliefs and cultural norms that influence personal decisions about family size. • Populations can reach limits to growth. Carrying capacity is the maximum number of individuals that can be supported in a given environment. The limitation is not the availability of space, but the number of people in relation to resources and the capacity of earth systems to support human beings. Changes in technology can cause significant changes, either positive or negative, in carrying capacity.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment. HMSS The Living Ocean—Unit 4, Ecology
Natural Resources • Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations. • The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed. • Humans use many natural systems as resources. Natural systems have the capacity to reuse waste, but that capacity is limited. Natural systems can change to an extent that exceeds the limits of organisms to adapt naturally or humans to adapt technologically.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 7, Humans in the Environment. and in HMSS The Fluid Earth—Unit 4, Chemical Oceanography. HMSS The Living Ocean—Unit 4, Ecology.
Environmental Quality • Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans. • Materials from human societies affect both physical and chemical cycles of the earth. • Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, overconsumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the earth.	These concepts are recurring themes throughout FAST 3, Change over Time, HMSS The Fluid Earth, and HMSS The Living Ocean.

6. Science in Personal and Social Perspectives

Natural And Human-Induced Hazards • Normal adjustments of earth may be hazardous for humans. Humans live at the interface between the atmosphere driven by solar energy and the upper mantle where convection creates changes in the earth's solid crust. As societies have grown, become stable, and come to value aspects of the environment, vulnerability to natural processes of change has increased. • Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change. • Some hazards, such as earthquakes, volcanic eruption, and severe weather, are rapid and spectacular. But there are slow and progressive changes that also result in problems for individuals and societies. For example, change in stream channel position, erosion of bridge foundations, sedimentation in lakes and harbors, coastal erosions, and continuing erosion and wasting of soil and landscapes can all negatively affect society. • Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards—ranging from those with minor risk to a few people to major catastrophes with major risk to many people. The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations.	These concepts are introduced and developed in FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment. and in HMSS The Fluid Earth—Unit 1, Earth and Ocean Basins; Unit 2, Waves and Beaches; Unit 4, Chemical Oceanography. HMSS The Living Ocean—Unit 4, Ecology.
Science And Technology In Local, National, And Global Challenges • Science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen. The latter involves human decisions about the use of knowledge. • Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science- and technology-related challenges. However, understanding science alone will not resolve local, national, or global challenges. • Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology. • Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them. Students should understand the appropriateness and value of basic questions—"What can happen?"—"What are the odds?"—and "How do scientists and engineers know what will happen?"	These are recurring themes in FAST 3, Change over Time, HMSS The Living Ocean, and HMSS The Fluid Earth.

6. Science in Personal and Social Perspectives (Continued)

• Humans have a major effect on other species. For example, the influence of humans on other organisms occurs through land use—which decreases space available to other species—and pollution—which changes the chemical composition of air, soil, and water.	FAST 3, Change over Time—Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment. and in HMSS The Living Ocean—Unit 4, Ecology HMSS The Fluid Earth—Unit 4, Chemical Oceanography

7. History and Nature of Science

Science As A Human Endeavor • Individuals and teams have contributed and will continue to contribute to the scientific enterprise. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question or technological problem. Pursuing science as a career or as a hobby can be both fascinating and intellectually rewarding. • Scientists have ethical traditions. Scientists value peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work. Violations of such norms do occur, but scientists responsible for such violations are censured by their peers. • Scientists are influenced by societal, cultural, and personal beliefs and ways of viewing the world. Science is not separate from society but rather science is a part of society.	These concepts are a specific recurring theme in FAST 3, Change over Time. See Unit 3, The Changing Universe, Unit 4, Life on Earth, and Unit 5, Continental Drift.
Nature Of Scientific Knowledge • Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world. • Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public. Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific.	FAST investigations are taken from a historical approach. The history of science provides examples of how humans first dealt with foundational science concepts. In their investigations, students also examine how ideas have changed over time and the cumulative contributions of scientists worldwide. Specifically, the nature of the scientific enterprise is the focus of investigations of the FAST 3 sections on the history of astronomy, organic chemistry, plate tectonics, and human intervention in environments. The structure of FAST is to integrate the study of science over several years thus focusing on the elements common to the disciplines of science as well as the ideas and structures that separate the disciplines. FAST 3 includes the study of physics, earth and space sciences, astronomy, geophysics, ecology, and human systems. In *HMSS*, many disciplines are brought together under the theme of a marine environment. Students learn to retrieve information from past activities and experiments that can be applied to present topics, such as using knowledge obtained in an activity about sand components (geology), and relating that to currents (physics) affecting nutrient availability (chemistry) and the life (biology) found where the sand is produced.

7. History and Nature of Science (Continued)

• Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore unlikely to change in the areas in which they have been tested. In areas where data or understanding are incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest.	In HMSS and FAST students are strongly encouraged to question all experimental results and insist that explanations of data be supported. With the teacher as facilitator of learning and discovery instead of disseminator of information, students learn that their ideas are valid when based upon what they know or have observed. The nature of science is portrayed as public. Data, processes, and ideas are open to public scrutiny, testing, replication, and refutation. Conclusions are based on data and patterns of relationships, not opinion.
Historical Perspectives • In history, diverse cultures have contributed scientific knowledge and technologic inventions. Modern science began to evolve rapidly in Europe several hundred years ago. During the past two centuries, it has contributed significantly to the industrialization of Western and non-Western cultures. However, other, non-European cultures have developed scientific ideas and solved human problems through technology. • Usually, changes in science occur as small modifications in extant knowledge. The daily work of science and engineering results in incremental advances in our understanding of the world and our ability to meet human needs and aspirations. Much can be learned about the internal workings of science and the nature of science from study of individual scientists, their daily work, and their efforts to advance scientific knowledge in their area of study. • Occasionally, there are advances in science and technology that have important and long-lasting effects on science and society. Examples of such advances include the following: Copernican revolution, Newtonian mechanics, Relativity, Geologic time scale, Plate tectonics, Atomic theory, Nuclear physics, Biological evolution, Germ theory, Industrial revolution, Molecular biology, Information and communication, Quantum theory, Galactic universe, and Medical and health technology. • The historical perspective of scientific explanations demonstrates how scientific knowledge changes by evolving over time, almost always building on earlier knowledge.	FAST investigations are taken from an historical approach. We have looked to the history of science for examples of how humans first dealt with foundational science concepts. In their investigations, students also examine how ideas have changed over time and the cumulative contributions of scientists worldwide. Scientists and how they work are studied in the disciplines of astronomy, chemistry, physics, geophysics and organic chemistry. Students conduct actual investigations as physical scientists, ecologists, and technologists. Specifically, the nature of the scientific enterprise is the focus of investigations in the FAST 3 sections on the history of astronomy, organic chemistry, plate tectonics, and human intervention in environments. FAST students are engaged in conducting inquiry investigations approximately 80% of the time. Class organization is in research teams in which students develop their own hypotheses, experimental designs, and explanations. The teacher's role is research director. Explanation must be supported by evidence and openly communicated to peer groups for support. Healthy skepticism is part of the learning environment. In this way, FAST replicates scientific inquiry. In addition to learning about the nature of science by doing scientific investigations, FAST also causes students to focus on the nature of science by embedding case studies of historical events. See particularly, FAST 3, Change over Time, Unit 3, The Changing Universe; Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 7, Humans in the Environment.

8. Unifying Concepts and Processes

Systems, Order, And Organization	Systems is a common unifying theme throughout FAST 3, Change over Time, HMSS The Fluid Earth, and HMSS The Living Ocean. FAST make extensive use of systems analysis diagrams to help organize thinking and make predictions about interactions of matter and energy. Similarly, order and organization are exemplified in investigating cause-and-effect relationships, cosmological theories to explain the origin and organization of the universe, trophic relationships among organisms in the environment, and exchanges of matter and energy in bioenergetics..
Evidence, Models, and Explanation	Evidence as in student-generated data and interpretation is the primary focus of the FAST and HMSS programs. Student-generated data provide the substance for small group and class discussion. Interpretation and explanation are a matter of class consensus, just as they are in science. The use and study of indirect evidence is introduced in FAST 2 with the search for evidence for atoms and continued in FAST 3 where students encounter competing explanations for continental drift, stellar evolution, biological evolution, and cosmological theories. A continuing major focus is on how do we know what we think we know. The concept of model is a major organizing theme of both FAST 3, Change over Time and HMSS (models of Earth, cosmological models, models of stellar evolution, models of organisms, molecular models, models of Earth change, models of ecosystems, and models of human interaction with ecosystems).
Change, Constancy, and Measurement	Measurement, computation, and estimation are integral parts of FAST and HMSS. Emphasis is placed on developing laboratory skills of measuring distance, mass, area, volume, temperature, time, energy transfer, rates of change, heat, work, force, specific heat, solar constant, movement of the sun, moon, planets, and constellations, and so on. Students construct and calibrate many of their own instruments such as those for measuring forces, location, salinity, and many others. Constancy and change in physical and biological systems are developed in investigations in: FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment. HMSS The Living Ocean—Unit 4, Ecology; HMSS The Fluid Earth—Unit 4, Chemical Oceanography.

8. Unifying Concepts and Processes (Continued)

Evolution and Equilibrium	These concepts are developed in: Evolution of life: FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems. Evolution in physical systems: FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift; Unit 7, Humans in the Environment. HMSS The Fluid Earth—Unit 1, Earth and Ocean Basins; Unit 2, Waves and Beaches; Unit 4, Chemical Oceanography Equilibrium in Systems: HMSS The Living Ocean—Unit 4, Ecology HMSS The Fluid Earth—Unit 3, Physical Oceanography; Unit 4, Chemical Oceanography.
Form and Function	These concepts are major organizing themes in FAST 3, Change over Time—Unit 4, Life on Earth, molecular structure and function; Unit 6, Changing Ecosystems, biological adaptations. HMSS The Living Ocean—Unit 1, Fish; Unit 2, Invertebrates; Unit 3, Plants.

CURRICULUM RESEARCH & DEVELOPMENT GROUP

The Curriculum Research & Development Group (CRDG), including the University Laboratory School, conducts systematic research, design, development, publication, staff development, and related services for elementary and secondary schools. The CRDG has curriculum development projects in science, mathematics, English, Pacific and Asian studies, marine studies, environmental studies, Hawai‘ian and Polynesian studies, Japanese language and culture, music, nutrition, art, drama, technology, health, and computer education. Research and school service projects focus on educational evaluation, teacher development, reduction of in-school segregation of students, and programs for students educationally at risk. The CRDG is the senior member of a cooperative program of ten universities in the United States to improve schooling in science, health, and technology in elementary and secondary schools. It is a founding member of the Pacific Circle Consortium of universities, major school systems, and educational ministries in Australia, Canada, Japan, New Zealand, and the United States. CRDG-developed programs are being used experimentally in other countries, including Australia, Israel, New Zealand, Russia, Indonesia, Singapore, and Slovakia. The CRDG provides professional development institutes and support services for all its projects. CRDG publishes and distributes its materials nationally and internationally.