Alignment of the Foundational Approaches in Science Teaching (FAST)

and the

Hawai‘i Marine Science Studies Program (HMSS)

with the AAAS Benchmarks for Science Literacy Grades 9–12

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FOREWORD

Alignment of the Foundational Approaches in Science Teaching (FAST) and the Hawai‘i Marine Science Studies (HMSS) Programs with the AAAS Benchmarks for Science Literacy

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*.

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 by the U.S. Department of Education’s Program Effectiveness Panel and disseminated through the National Diffusion Network. 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. CRDG, including the University Laboratory School, conducts systematic research, design, development, publication, staff development, and related services for the elementary and secondary schools of Hawai‘i and other schools in the university’s service area. 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.

Benchmarks for Science Literacy is a product of the AAAS Project 2061 Science For All Americans effort to reform science education in the United States. The benchmarks specify how students should progress toward science literacy, recommending what they should know and be able to do by the time they reach certain grade levels—K–2, 3–5, 6–8, and 9–12. The following describes how FAST and HMSS address the recommended benchmarks for science education in grades 9–12.

AAAS *Benchmark Analysis*

Analysis of FAST and HMSS Match to the AAAS Benchmarks for Science Literacy

The AAAS Benchmarks for Grades 9–12	Foundational Approaches in Science Teaching (FAST) (FAST 3, Change Over Time) & Hawai‘i Marine Science Studies (HMSS) (Fluid Earth and Living Ocean)

1. The Nature of Science

1A. Scientific World View • Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere. The rules may range from very simple to extremely complex, but scientists operate on the belief that the rules can be discovered by careful, systematic study. • From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Change and continuity are persistent features of science. • No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observation. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an understanding of how things work in the world but not an absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions.	FAST and HMSS 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. Scientific world view is specifically developed in all seven units of FAST 3. Specific scientific revolutions and their impact are studied in FAST 3 Unit 3, The Changing Universe (Copernican revolution) and Unit 5, Continental Drift (Plate tectonics). Uniformitarianism and its inherent assumptions are studied in FAST 3 Units 1, 2, and 6. Major focus on the nature of science is developed in FAST 3 Unit 2, The Changing Earth, Unit 3, The Changing Universe, Unit 4, Life on Earth, and Unit 5, Continental Drift.

1B. Scientific Inquiry	
• 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. • Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available). • Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. • There are different traditions in science about what is investigated and how, but they all have in common certain basic beliefs about the value of evidence, logic, and good arguments. And there is agreement that progress in all fields of science depends on intelligence, hard work, imagination, and even chance. • Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings. For that reason, scientific teams are expected to seek out the possible sources of bias in the design of their investigations and in their data analysis. Checking each other's results and explanations helps, but that is no guarantee against bias. • In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism. In the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings. • New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators.	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. 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. FAST investigations include exploration of phenomena such as the formation and life cycle of stars, cosmological theories, and evidences for plate tectonics for which there is little direct experimental evidence. Therefore, we must rely on patterns and generalizations to arrive at possible explanations. 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.

1C. The Scientific Enterprise	
• The early Egyptian, Greek, Chinese, Hindu, and Arabic cultures are responsible for many scientific and mathematical ideas and technological inventions. • Modern science is based on traditions of thought that came together in Europe about 500 years ago. People from all cultures now contribute to that tradition. • Progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments. • Science disciplines differ from one another in what is studied, techniques used, and outcomes sought, but they share a common purpose and philosophy, and all are part of the same scientific enterprise. Although each discipline provides a conceptual structure for organizing and pursuing knowledge, many problems are studied by scientists using information and skills from many disciplines. Disciplines do not have fixed boundaries, and it happens that new scientific disciplines are being formed where existing ones meet and that some subdisciplines spin off to become new disciplines in their own right. • Current ethics in science hold that research involving human subjects may be conducted only with the informed consent of the subjects, even if this constraint limits some kinds of potentially important research or influences the results. When it comes to participation in research that could pose risks to society, most scientists believe that a decision to participate or not is a matter of personal ethics rather that professional ethics. • Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects. Outside their areas of expertise, however, scientists should enjoy no special credibility. And where their own personal, institutional, or community interests are at stake, scientists as a group can be expected to be no less biased than other groups are about their perceived interests. • The strongly held traditions of science, including its commitment to peer review and publication, serve to keep the vast majority of scientists well within the bounds of ethical professional behavior. Deliberate deceit is rare and likely to be exposed sooner or later by the scientific enterprise itself. When violations of these scientific ethical traditions are discovered, they are strongly condemned by the scientific community, and the violators then have difficulty regaining the respect of other scientists. • Funding influences the direction of science by virtue of the decisions that are made on which research to support. Research funding comes from various federal government agencies, industry, and private foundations.	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. 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.

2. Nature of Mathematics

2A. Patterns and Relationships • Mathematics is the study of any patterns or relationships, whereas natural science is concerned only with those patterns that are relevant to the observable world. Although mathematics began long ago in practical problems, it soon focused on abstractions from the material world, and then on even more abstract relationships among those abstractions. • As in other sciences, simplicity is one of the highest values in mathematics. Some mathematicians try to identify the smallest set of rules from which many other propositions can be logically derived. • Theories and applications in mathematical work influence each other. Sometimes a practical problem leads to the development of new mathematical theories; often mathematics developed for its own sake turns out to have practical applications. • New mathematics continues to be invented, and connections between different parts of mathematics continue to be found.	Graphing is used extensively in FAST and HMSS as a tool to search for patterns and relationships. For example, students use graphs to find averages and compare with calculated means in comparing densities of substances. Since FAST and HMSS both integrate the study of several disciplines of science, mathematics is seen as a valuable tool for summarizing patterns and relationships.

2B. Mathematics, Science and Technology • Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave. • Mathematics and science as enterprises share many values and features: belief in order, ideals of honesty and openness, the importance of criticism by colleagues, and the essential role played by imagination. • Mathematics provides a precise language for science and technology—to describe objects and events, to characterize relationships between variables, and to argue logically. • Developments in science or technology often stimulate innovations in mathematics by presenting new kinds of problems to be solved. In particular, the development of computer technology (which itself relies on mathematics) has generated new kinds of problems and methods of work in mathematics. • Developments in mathematics often stimulate innovations in science and technology.	Mathematics plays a central role in FAST and HMSS beginning with initial investigations on calculating force, work, and energy, using scientific notation, predicting the energy involved in mountain formation and erosion, stellar formation, and human and ecological systems.

2C. Mathematical Inquiry • Some work in mathematics is much like a game—mathematicians choose an interesting set of rules and then play according to those rules to see what can happen. The more interesting the results, the better. The only limit on the set of rules is that they should not contradict one another. • Much of the work of mathematicians involves a modeling cycle, which consists of three steps: (1) using abstractions to represent things or ideas, (2) manipulating the abstractions according to some logical rules, and (3) checking how well the results match the original things or ideas. If the match is not considered good enough, a new round of abstraction and manipulation may begin. The actual thinking need not go through these processes in logical order but may shift from one to another in any order.	

3. The Nature of Technology

3A. Technology and Science	
• Technological problems often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances. • Mathematics, creativity, logic, and originality are all needed to improve technology. • Technology usually affects society more directly than science because it solves practical problems and serves human needs (and may create new problems and needs). In contrast, science affects society mainly by stimulating and satisfying people's curiosity and occasionally by enlarging or challenging their views of what the world is like.	The growth of technology and the subsequent impact on scientific knowledge is noted in such areas as the history of plate tectonics, and the development of astronomy and astronomical instruments (FAST 3). Changing technology leads to scientific discovery as explored in HMSS underwater diving technologies, "Mineral Resources," and "Ocean Color and Satellite Remote Sensing." Creativity and model building and testing are used to design and build things from instruments to ship hulls. Interactions between natural factors and human technology are examined in both FAST and HMSS. Many topics expand student awareness of world conditions by studying events that are not readily observable, such as stellar evolution, plate tectonics, and corals and coral reefs. Students learn about necessary conditions globally for coral growth and factors that impact growth and in plankton studies students discover conditions required for healthy and plentiful plankton growth.

3B. Design and Systems	
• In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design. • The value of any given technology may be different groups of people and at different points in time. • Complex systems have layers of controls. Some controls operate particular parts of the system and some control other controls. Even fully automatic systems require human control at some point. • Risk analysis is used to minimize the likelihood of unwanted side effects of a new technology. The public perception of risk may depend, however, on psychological factors as well as scientific ones. • The more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass, or compensate for minor failures. • To reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems, or just the parts of the system thought to be least reliable.	Student-made inventions and devices are analyzed for how well they work and for their impact on the environment and society. Such 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 systems are thoroughly explored through many activities such as environmental changes both natural and human, impacts of human interference on beaches, wind and currents on Earth, acid rain and greenhouse effect, and bioenergetics.

3C. Issues in Technology	
• Social and economic forces strongly influence which technologies will be developed and used. Which will prevail is affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition and tax incentives. • Technological knowledge is not always as freely shared as scientific knowledge unrelated to technology. Some scientists and engineers are comfortable working in situations in which some secrecy is required, but others prefer not to do so. It is generally regarded as a matter of individual choice and ethics, not one of professional ethics. • In deciding on proposals to introduce new technologies or to curtail existing ones, some key questions arise concerning alternatives, risks, costs, and benefits. What alternative ways are there to achieve the same ends, and how do the alternatives compare to the plan being put forward? Who benefits and who suffers? What are the financial and social costs, do they change over time, and who bears them? What are the risks associated with using (or not using) the new technology, how serious are they, and who is in jeopardy? What human, material, and energy resources will be needed to build, install, operate, maintain, and replace the new technology, and where will they come from? How will the new technology and its waste products be disposed of and at what costs? • The human species has a major impact on other species in many ways: reducing the amount of the earth's surface available to those other species, interfering with their food sources, changing the temperature and chemical composition of their habitats, introducing foreign species into their ecosystems, and altering organisms directly through selective breeding and genetic engineering. • Human inventiveness has brought new risks as well as improvements to human existence.	Communication is essential to science and to FAST/HMSS. Students record their own and their classmates experiments in their science notebooks, they identify generalizations and conclusions through class consensus, they frequently report to their peers on their investigations through oral and written reports and seminars. Examples of FAST studies that focus on the feats of technology include Kepler's inventions and his interpretation of Brahe's data (FAST 3), techniques of analyzing matter used by early chemists (FAST 2 and FAST 3), and Galileo's and Newton's inventions (FAST 3). The impact of technology on the course of history is specifically included in FAST investigations on agricultural technology (FAST 2 and FAST 3), the Copernican revolution (FAST 3), and the role of technology in the scientific revolution over plate tectonics (FAST 3). Risk-benefit analysis is included in studies of slash and burn agriculture, energy resource use, population studies and limiting factors in the environment, the impact of fertilizers and pesticides, and case studies of population effects. Complexity of technological issues is the focus on studies of energy/land use by humans past and present (FAST 3). In the HMSS <u>Fishing in the Pacific</u> series; through reading and discussions students consider current issues in the fishing industry focusing on the Pacific rim nations. Discussions initiated from study of many topics bring out human crowding of other species, our population demands and its impact on environments and species, and competition with introduced species.

4. The Physical Setting

4A. The Universe	
• The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements that are found on the earth and to behave according to the same physical principles. Unlike the sun, most stars are in systems of two or more stars orbiting around one another.	In FAST 3, Change over Time, students make astrolabes and sunscopes to measure the movement of the sun, moon, planets, and constellations. They then research the history of astronomy and different models of the Earth's environment to explain their observations. Later investigations focus on current cosmological theories, stellar life cycles, and the formation of elements, Earth, and early atmospheres.
• On the basis of scientific evidence, the universe is estimated to be over ten billion years old. The current theory is that its entire contents expanded explosively form a hot, dense, chaotic mass. Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years. Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense. The process of star formation and destruction continues.	FAST 3, Change over Time—Unit 3, The Changing Universe.

4A. The Universe (continued)	
• Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed.	FAST 3, Change over Time—Unit 3, The Changing Universe.
• Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe.	FAST 3, Change over Time—Unit 3, The Changing Universe.

4B. The Earth	
• Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of radiation from the sun that allows water to cycle between liquid and vapor.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe.
• Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall and such circulation, influenced by the rotation of the earth, produces winds and ocean currents.	HMSS studies on fish form and function demonstrate how fish have adapted to various conditions. In other investigations students determine the impact of environmental conditions on location of life especially what resources organisms can expect to find and why they are there. Global energy budget studies of properties of water, wind, waves, currents, and photosynthesis in the ocean relate Earth's constant changes to the cycles to which all life must adapt.

4C. Processes That Shape The Earth	
• Plants alter the earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air.	FAST 3, Change over Time—Unit 3, The Changing Universe; Unit 4, Life on Earth HMSS Living Ocean Unit 3 and Unit 4.
• The formation, weathering, sedimentation, and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same as its forms change.	FAST 3, Change over Time—Unit 2, The Changing Earth
• The slow movement of material within the earth results from heat flowing out from the deep interior and the action of gravitational forces on regions of different density.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 5, Continental Drift. HMSS Fluid Earth Unit 1.
• The solid crust of the earth—including both the continents and the ocean basins—consists of separate plates that ride on a denser, hot, gradually deformable layer of the earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Ocean-floor plates may slide under continental plates, sinking deep into the earth. The surface layers of these plates may fold, forming mountain ranges.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 5, Continental Drift. HMSS Fluid Earth Unit 1.
• Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 5, Continental Drift.

4D The Structure of Matter • Atoms are made of a positive nucleus surrounded by negative electrons. An atom's electron configuration, particularly the outermost electrons, determines how the atom can interact with other atoms. Atoms form bonds to other atoms by transferring or sharing electrons. • The nucleus, a tiny fraction of the volume of an atom, is composed of protons and neutrons, each almost two thousand times heavier than an electron. The number of positive protons in the nucleus determines what an atom's electron configuration can be and so defines the element. In a neutral atom, the number of electrons equals the number of protons. But an atom may acquire an unbalanced charge by gaining or losing electrons. • Neutrons have a mass that is nearly identical to that of protons, but neutrons have no electric charge. Although neutrons have little effect on how an atom interacts with others, they do affect the mass and stability of the nucleus. Isotopes of the same element have the same number of protons (and therefore of electrons) but differ in the number of neutrons. • The nucleus of radioactive isotopes is unstable and spontaneously decays, emitting particles and/or wave like radiation. It cannot be predicted exactly when, if ever, an unstable nucleus will decay, but a large group of identical nuclei decay at a predictable rate. This predictability of decay rate allows radioactivity to be used for estimating the age of materials that contain radioactive substances.	FAST 3, Change over Time—Unit 4, Life on Earth In HMSS simple electrolysis experiments reveal the nature of water molecules. Other experiments add to building knowledge about water characteristics as compared to other liquids. By graphing the components in seawater, students discover the importance of water to the planet. Experiments with attractive and repulsive forces provide a means to explore the existence of ionic charges.
4D The Structure of Matter (continued) • Scientists continue to investigate atoms and have discovered even smaller constituents of which electrons, neutrons, and protons are made. • When elements are listed in order by the masses of their atoms, the same sequence of properties appears over and over again in the list. • Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal 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 configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others. • The rate of reactions among atoms and molecules depends on how often they encounter one another, which is affected by the concentration, pressure, and temperature of the reacting materials. Some atoms and molecules are highly effective in encouraging the interaction of others.	FAST 3, Change over Time—Unit 1, Force, Work & Energy; Unit 3, The Changing Universe; Unit 4, Life on Earth. HMSS: Comparison of polar and nonpolar molecules leads students to an awareness that molecules have varying characteristics that permit varying reactions. FAST 3, Change over Time—Unit 4, Life on Earth HMSS studies of water as a solvent provide students the opportunity to test that all things are not miscible.

4E. Energy Transformations	
• Whenever the amount of energy in one place or form diminishes, the amount in the other places or forms increases by the same amount.	FAST 3, Change over Time—one of the major themes of Change over Time is energy transformations; a major component of all seven units of study.
• Heat energy in a material consists of the disordered motions of its atoms or molecules. In any interactions of atoms or molecules, the statistical odds are that they will end up with less order than they began—that is, with the heat energy spread out more evenly. With huge numbers of atoms and molecules, the greater disorder is almost certain.	HMSS Fluid Earth—Unit 4; students study the transfer of energy in the water cycle and carbon dioxide cycle.
• Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much total energy remains, its being spread out more evenly means less can be done with it.	HMSS—heat exchange is examined through study of the greenhouse effect and the carbon dioxide cycle, as well as the water cycle.
• Different energy levels are associated with different configurations of atoms and molecules. Some changes of configuration require an input of energy whereas others release energy.	
• When energy of an isolated atom or molecule changes, it does so in a definite jump from one value to another, with no possible values in between. The change in energy occurs when radiation is absorbed or emitted, so the radiation also has distinct energy values. As a result, the light emitted or absorbed by separate atoms or molecules (as in gas) can be used to identify what the substance is.	
• Energy is released whenever the nuclei of very heavy atoms, such as uranium or plutonium, split into middleweight ones, or when very light nuclei, such as those of hydrogen and helium, combine into heavier ones. The energy released in each nuclear reaction is very much greater than the energy given off in each chemical reaction.	

4F. Motion	
• The change in motion of an object is proportional to the applied force and inversely proportional to the mass.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 3, The Changing Universe
• All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion.	
• Accelerating electric charges produce electromagnetic waves around them. A great variety of radiations are electromagnetic waves: radio waves, microwaves, radiant heat, visible light, ultraviolet radiation, x-rays, and gamma rays. These wavelengths very from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed—the "speed of light".	HMSS—students are introduced to the components of sunlight as they explore plants of aquatic and terrestrial environments. FAST 3, Change over Time—Unit 3, The Changing Universe
• Whenever one thing exerts a force on another, an equal amount of force is exerted back on it.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy
• The observed wavelength of a wave depends upon the relative motion of the source and the observer. If either is moving toward the other, the observed wavelength is shorter; if wither is moving away, the wavelength is longer. Because the light seen from almost all distant galaxies has longer wavelengths than comparable light her on earth, astronomers believe that the whole universe is expanding.	FAST 3, Change over Time—Unit 3, The Changing Universe
• Waves can superpose on one another, bend around corners, reflect off surfaces, be absorbed by materials they enter, and changes direction when entering a new materials. All these effects vary with wavelength. The energy of waves (like any form of energy) can be changed into other forms of energy.	HMSS—using ocean waves as examples, students create beach models to explore wave reflection, refraction, impact on beaches and nearshore structures, along with fundamental characteristics of waves.

4 G. Forces of Nature • 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. As 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. In materials, there are almost exactly equal proportions of positive and negative charges, making the materials as a whole electrically neutral. Negative charges, being associated with electrons, are far more mobile in materials than positive charges are. A very small excess of deficit of negative charges in a material produces noticeable electric forces. • Different kinds of materials respond differently to electric forces. In conducting materials such as metals, electric charges flow easily, whereas in insulating materials such as glass, they can move hardly at all. At very low temperatures, some materials become superconductors and offer no resistance to the flow of current. In between these extremes, semi-conducting materials differ greatly in how well they conduct, depending on their exact composition.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe In HMSS “Properties of Water”, students observe adhesion, cohesion (siphoning), solubility, and density of several liquids compared with fresh water. HMSS—using easily obtained materials, students test for positive or negative charges in these materials; students attempt to show how these charges affect a stream of water from the tap, thus examining the polarity of water.

4 G. Forces of Nature (continued) • Magnetic forces are very closely related to electric forces and can be thought of as different aspects of a single electromagnetic force. Moving electric charges produce magnetic forces and moving magnets produce electric forces. The interplay of electric and magnetic forces is the basis for electric motors, generators, and many other modern technologies, including the production of electromagnetic waves. • The forces that hold the nucleus of an atom together are much stronger than the electromagnetic force. That is why such great amounts of energy are released from the nuclear reactions in the sun and other stars.	HMSS—testing different materials for static activity demonstrates the electrostatic properties for each of the materials.

5. The Living Environment

5A. Diversity of Life • The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions, and 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 similarity of their DNA sequences, which often closely matches their classification based on anatomical similarities.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems. HMSS—study of “Fish form and function” demonstrates that living things are specially adapted to their niche, and as follow-up, students design their own fish to specific conditions. HMSS—invertebrates are used to show similarities between organisms by examining their physical as well as behavioral characteristics.

5B. Heredity • Some new gene combinations make little difference, some can produce organisms with new and perhaps enhanced capabilities, and some can be deleterious. • The sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents. • 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 mutations can be passed on to offspring; if they occur in other cells, they can be passed on to descendant cells only. The experiences an organism has during its lifetime can affect its offspring only if the genes in its own sex cells are changed by the experience. • The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and this have essentially identical genetic instructions. Different parts of the instructions are used in different types of cells, influenced by the cell’s environmental and past history.	

5C. Cells	
• Every cell is covered by a membrane that controls what can enter and leave the cell. In all but quite primitive cells, a complex network of proteins provides organization and shape and, for animal cells, movement.	FAST 3, Change over Time—Unit 4, Life on Earth
• Within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback, and even movement. In addition to these basic cellular functions common to all cells, most cells in multicellular organisms perform some special functions that others do not.	HMSS—studies of fish internal anatomy and dissection of fish, squid, shrimp, worms, and clams. Later topics reinforce cellular specialties as students examine plants from both terrestrial and aquatic environments, and comparing them by testing for stomates, lignin, and cuticle. As students learn about photosynthesis, they are introduced to specialized cellular parts, such as chloroplasts.
• 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 20 different kinds of amino-acid molecules. The function of each protein molecule depends on its specific sequence of amino acids and the shape the chain takes is a consequence of attractions between the chain's parts.	FAST 3, Change over Time—Unit 4, Life on Earth
• The genetic information in DNA molecules provides instructions for assembling protein molecules. The code used is virtually the same for all life forms.	
• Complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Cell behavior can also be affected by molecules from other parts of the organism or even other organisms.	FAST 3, Change over Time—Unit 4, Life on Earth
• Gene mutation in a cell can result in uncontrolled cell division, called cancer. Exposure of cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer.	
• Most cells function best within a narrow range of temperature and acidity. At very low temperatures, reaction rates are too slow. High temperatures and/or extremes of acidity can irreversibly change the structure of most protein molecules. Even small changes in acidity can alter the molecules and how they interact. Both single cells and multicellular organisms have molecules that help to keep the cell's acidity within a narrow range.	FAST 3, Change over Time—Unit 6, Changing Ecosystems
• A living cell is composed of a small number of chemical elements mainly carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. Carbon, because of its small size and four available bonding electrons, can join to other carbon atoms in chains and rings to form large and complex molecules.	FAST 3, Change over Time—Unit 4, Life on Earth

5D. Interdependence of Life	
• Ecosystems can be reasonably stable over hundreds of thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.	HMSS—through diagrams, drawings, and class discussions, students identify the many facets involved in environmental changes.

5D. Interdependence of Life (continued)	
• Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.	FAST 3, Change over Time—Unit 5, Continental Drift; Unit 6, Changing Ecosystems HMSS—using the greenhouse effect as a current issue, students discuss long term effects and its reversibility.
• Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—in "Agents of Change", human interaction with the environment is explored from small to large scale changes, both beneficial and destructive. Students collect local data on debris and water pollution to determine human impact on their local environment.

5E. Flow of Matter and Energy	
• At times, environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure to the overlying earth. By burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide.	FAST 3, Change over Time—Unit 5, Continental Drift; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment HMSS—"Bioenergetics" game in *The Living Ocean;* "Earth's Energy Budget".
• The amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials. Human activities and technology can change the flow and reduce the fertility of the land.	FAST 3, Change over Time—Unit 5, Continental Drift; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment HMSS—"Bioenergetics" game; activities in the Chemical and Physical Oceanography Units on mineral and water cycles.
• 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.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment HMSS—following the "Bioenergetics" game, students diagram the flow of energy from one level of the food web to another. Discussions include the impact of removing or severely depleting any one of the levels.

5F. Evolution of Life	
• The basic idea of biological evolution is that the earth's present-day species developed from earlier, distinctly different species.	FAST 3, Change over Time—Unit 3, The Changing Universe; Unit 4, Life on Earth; Unit 6, Changing Ecosystems. HMSS—Living Ocean
• Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another.	HMSS—Living Ocean; students document how less advanced phyla lead to more complex phyla. Changes throughout Earth's history in animal characteristics is one focus for the comparison table.
• Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species, some of these characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely than others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase.	FAST 3, Change over Time—Unit 6, Changing Ecosystems
• Heritable 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, and therefore influence how likely it is to survive and reproduce.	FAST 3, Change over Time—Unit 4, Life on Earth

5F. Evolution of Life	
• New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells of an organism cannot be passed on to the next generation.	
• Natural selection leads to organisms that are well suited for survival in particular environments. Chance alone can result in the persistence of some heritable characteristics having no survival or reproductive advantage or disadvantage for the organism. When an environment changes, the survival value of some inherited characteristics may change.	FAST 3, Change over Time—Unit 6, Changing Ecosystems
• The theory of natural selection provides a scientific explanation for the history of life on earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms.	FAST 3, Change over Time—Unit 6, Changing Ecosystems
• Life on earth is thought to have begun as simple, one-celled organisms about 4 billion years ago. During the first 2 billion years, only single-cell microorganisms existed, but once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 4, Life on Earth; Unit 6, Changing Ecosystems
• Evolution builds on what already exists, so the more variety there is, the more there can be in the future. But evolution does not necessitate long-term progress in some set direction. Evolutionary changes appear to be like the growth of a bush: Some branches survive from the beginning with little or no change, many die out altogether, and others branch repeatedly, sometimes giving rise to more complex organisms.	FAST 3, Change over Time—Unit 5, Continental Drift; Unit 6, Changing Ecosystems

6. The Human Organism

6A. Human Identity	
• The similarity of human DNA sequences and the resulting similarity in cell chemistry and anatomy identify human beings as a single species.	
• Written records and photographic and electronic devices enable human beings to share, compile, use, and misuse great amounts of information and misinformation. No other species uses such technologies.	HMSS—Ecology Unit elicits student discussions on human impact on the environment. Technology studies in both Fluid Earth and Living Ocean

6B. Human Development	
• As successive generations of an embryo's cells form by division, small differences in their immediate environments cause them to develop slightly differently, by activating or inactivating different parts of the DNA information.	
• Using artificial means to prevent or facilitate pregnancy raises questions of social norms, ethics, religious beliefs, and even politics.	
• The very long period of human development (compared to that of other species) is associated with the prominent role of the brain in human evolution. The ability to learn persists throughout life and may improve as people build a base of ideas and come to understand how to learn well. Human mental abilities that apparently evolved for survival are used for newly invented cultural purposes such as art, literature, ritual, and games.	
• The development and use of technologies to maintain, prolong, sustain, or terminate life raise social, moral, ethical, and legal issues.	

6C. Basic Functions • The immune system is designed to protect against microscopic organisms and foreign substances that enter from out side the body and against some cancer cells that arise within. • 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. 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 bloodstream to widely distributed cells that have special receptor sites to which they attach. Along nerve cells, electrical impulses carry information much more rapidly than is possible by diffusion or blood flow. Some drugs mimic or block the molecules involved in transmitting nerve or hormone signals and therefore disturb normal operations of the brain and body. • Reproduction is necessary for the survival of any species. Sexual behavior depends strongly on cultural, personal, and biological factors.	

6D. Learning	
• Differences in the behavior of individuals arise from the interaction of heredity and experience—the effect of each depends on what the other is. Even instinctive behavior may not develop well if the individual is exposed to abnormal conditions.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• The expectations, moods, and prior experiences of human beings can affect how they interpret new perceptions 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 the learning can be used.	FAST 3, Change over Time—Unit 3, The Changing Universe; Unit 5, Continental Drift HMSS—issues incorporated into the *Fishing in the Pacific* series, (who has the right to fish, where, and how can the salmon population problem be solved) develop understanding of how people are affected by their experiences and beliefs.
• Human thinking involves the interaction of ideas, and ideas about ideas. People can produce many associations internally without receiving information from their senses.	FAST 3, Change over Time—Unit 3, The Changing Universe; Unit 5, Continental Drift

6E. Physical Health • Some allergic reactions are caused by the body's immune responses to usually harmless environmental substances. Sometimes the immune system may attack some of 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. • New medical techniques, efficient health care delivery systems, improved sanitation, and a fuller understanding of the nature of disease give today's human beings a better chance of staying healthy than their forebears had. Conditions now are very different from the conditions in which the species evolved. But some of the differences may not be good for human health.	
6E. Physical Health (continued) • Some viral diseases, such as AIDS, destroy critical cells of the immune system, leaving the body unable to deal with multiple infection agents and cancerous cells.	

6F. Mental Health	
• Stresses are especially difficult for children to deal with and may have long-lasting effects. • 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 disturbance may increase its effects. • Human beings differ greatly in how they cope with emotions and may therefore puzzle one another. • 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.	

7. Human Society

7A. Cultural Effects on Behavior	
• Cultural beliefs strongly influence the values and behavior of the people who grow up in the culture, often without their being fully aware of it. Response to these influences varies among individuals.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• The ways that unacceptable social behavior is punished depend partly on beliefs about the purposes of punishment and about its effectiveness. Effectiveness is difficult to test scientifically because circumstances vary greatly and because legal and ethical barriers interfere.	
• Social distinctions are a part of every culture, but take many different forms, ranging from rigid classes based solely on percentage to gradations based on the acquisition of skill, wealth, or education. Differences in speech, dress, behavior, or physical features are often taken by people to be signs of social class. The difficulty of moving from one social class to another varies greatly with time, place, and economic circumstances.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• Heredity, culture, and personal experience interact in shaping human behavior. Their relative importance in most circumstances is not clear.	FAST 3, Change over Time—Unit 7, Humans in the Environment

7B. Group Behavior	
• The behavior of a group may not be predictable from an understanding of each of its members. • Social organizations may serve business, political, or social purposes beyond those for which they officially exist, including unstated ones such as excluding certain categories of people from activities.	

7C. Social Change	
• The size and rate of growth of the human population in any location is affected by economic, political, religious, technological, and environmental factors. Some of these factors, in turn, are influenced by the size and rate of growth of the population.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• The decisions of one generation both provide and limit the range of possibilities open to the next generation.	FAST 3, Change over Time—Unit 7, Humans in the Environment

7C. Social Change (continued)	
• Mass media, migrations, and conquest affect social change by exposing one culture to another. Extensive borrowing among cultures has led to the virtual disappearance of some cultures but only modest change in others. To various degrees, governments try to bring about social change or to impede it through policies, laws, incentives, or direct coercion. Sometimes such efforts achieve their intended results and sometimes they do not.	FAST 3, Change over Time—Unit 7, Humans in the Environment

7D. Social Trade-Offs	
• Benefits and costs of proposed choices include consequences that are long-term as well as short-term, and indirect as well as direct. The more remote the consequences of a personal or social decision, the harder it usually is to take them into account in considering alternatives. But benefits and costs may be difficult to estimate.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—*Fishing in the Pacific* series, students simulate cross–cultural decisions on fishing rights for 5 nations.
• In deciding among alternatives, a major question is who will receive the benefits and who (not necessarily the same people) will bear the costs.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—*Fishing in the Pacific* series
• Social trade-offs are often generational. The cost of benefits received by one generation may fall on subsequent generations. Also, the cost of a social trade-off is sometimes borne by one generation although the benefits are enjoyed by their descendants.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—*Fishing in the Pacific* series

7E. Political and Economic Systems	
• In the free-market mode, the control of production and consumption is mainly in private hands. The best allocation of resources is believed to be achieved by individuals and organizations competing in the marketplace. Individual initiative, talent, and hard work are expected to be rewarded with success and wealth. Government's role is primarily to protect political and economic freedoms for society as a whole--even at the cost of some individual or group material benefits.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—*Fishing in the Pacific* series
• In the central-planning model, production and consumption are controlled by the government. The best allocation of resources is thought to be achieved through government planning by experts. Dedication to the good of the society as a whole is expected to motivate initiative, talent, and hard work. The main purpose of government is to promote comparable welfare for all individuals and groups—even at the cost of some individual and group freedoms.	
• In practice, countries make compromises with regard to economic models. Central planning has to allow for some individual initiative, and markets have to provide some protection for unsuccessful competitors. The countries of the world use elements of both systems and are neither purely free-market nor entirely centrally controlled. Countries change, some adopting more free-market policies and practices, others more central-planning ones, and still others doing some of each.	HMSS—*Fishing in the Pacific* series

7F. Social Conflict	
• Conflict between people or groups arises from competition over ideas, resources, power, and status. Social change, or the prospect of it, promotes conflict because social, economic, and political changes usually benefit some groups more than others. That, of course, is also true of the status quo.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—*Fishing in the Pacific* series
• Conflicts are especially difficult to resolve in situations in which there are few choices and little room for compromise. Some informal ways of responding to conflict—use of pamphlets, demonstrations, cartoons, etc.—may sometimes reduce tensions and lead to compromise but at other times they may be inflammatory and make agreement more difficult to reach.	
• Conflict within a group may be reduced by conflict between it and other groups.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—*Fishing in the Pacific* series
• Inter group conflict does not necessarily end when one segment of society gets a decision in its favor, for the “losers” may then work all the harder to reverse, modify, or circumvent the change. Even when the majority of the people in a society agree on a social decision, the minority who disagree must be protected from oppression, just as the majority may need protection against unfair retaliation from the minority.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—*Fishing in the Pacific* series

7G. Global Interdependence	
• The wealth of a country depends partly on the effort and skills of its workers, its natural resources, and the capital and technology available to it. It also depends on the balance between how much its products are sought by other nations and how much of other nations’ products it seeks. Even if a country could produce everything it needs for itself, it would still benefit from trade with other countries.	
• Because of increasing international trade, the domestic products of any country may be made up in part by parts made in other countries. The international trade picture is often complicated by political motivations taking priority over economic ones.	
• 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.	

8. The Designed World

8A. Agriculture	
• New varieties of farm plants and animals have been engineered by manipulating their genetic instructions to produce new characteristics.	
• Government sometimes intervenes in matching agricultural supply to demand in an attempt to ensure a stable, high-quality, and inexpensive food supply. Regulations are often also designed to protect farmers from abrupt changes in farming conditions and from competition by farmers in other countries.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• Agricultural technology requires trade-offs between increased production and environmental harm and between efficient production and social values. In the past century, agricultural technology led to a huge shift of population from farms to cities and a great change in how people live and work.	FAST 3, Change over Time—Unit 7, Humans in the Environment HMSS—Aquaculture, specifically fish farming, shrimp and oyster farming and seaweed farming. *Fishing in the Pacific* series

8B. Materials and Manufacturing	
• Manufacturing processes have been changed by improved tools and techniques based on more thorough scientific understanding, increases in the forces that can be applied and the temperatures that can be reached, and the availability of electronic controls that make operations occur more rapidly and consistently.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• Waste management includes considerations of quantity, safety, degradability, and cost. It requires social and technological innovations, because waste-disposal problems are political and economic as well as technical.	
• Scientific research identifies new materials and new uses of known materials.	FAST 3, Change over Time—Unit 5, Continental Drift; Unit 7, Humans in the Environment
• Increased knowledge of the molecular structure of materials helps in the design and synthesis of new materials for special purposes.	FAST 3, Change over Time—Unit 4, Life on Earth

8C. Energy Sources and Use	
• A central factor in technological change has been how hot a fire could be made. The discovery of new fuels, the design of better ovens and furnaces, and the forced delivery of air or pure oxygen have progressively increased the available temperature. Lasers are a new tool for focusing radiation energy with great intensity and control.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• At present, all fuels have advantages and disadvantages so that society must consider the trade-offs among them.	
• Nuclear reactions release energy without the combustion products of burning fuels, but the radioactivity of fuels and by-products poses other risks, which may last for thousands of years.	FAST 3, Change over Time—Unit 3, The Changing Universe
• Industrialization brings an increased demand for and use of energy. Such usage contributes to the high standard of living in the industrially developing nations but also leads to more rapid depletion of the earth's energy resources and to environmental risks associated with the use of fossil and nuclear fuels.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• Decisions to slow the depletion of energy sources through efficient technology can be made at many levels, from personal to national, and they always involve trade-offs of economic costs and social values.	FAST 3, Change over Time—Unit 7, Humans in the Environment

8D. Communication • 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 from internal and external noise, and repeating information, but all of these increase costs. Digital coding of information (using only 1's and 0's) makes possible more reliable transmission of information. • As technologies that provide privacy in communication improve, so do those for invading privacy.	

8E. Information Processing • 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. • Redundancy can reduce errors in storing or processing information but increases costs. • Miniaturization of information-processing hardware can increase processing speed and portability, reduce energy use, and lower cost. Miniaturization is made possible through higher-purity materials and more precise fabrication technology.	FAST 3, Change over Time—Unit 5, Continental Drift

8F. Health Technology	
• Owing to the large amount of information that computers can process, they are playing an increasingly larger role in medicine. They are used to analyze data and to keep track of diagnostic information about individuals and statistical information on the distribution and spread of various maladies in populations.	
• Almost all body substances and functions have daily or longer cycles. These cycles often need to be taken into account in interpreting normal ranges for body measurements, detecting disease, and planning treatment of illness. Computers aid in detecting, analyzing, and monitoring these cycles.	FAST 3, Change over Time—Unit 6, Changing Ecosystems
• Knowledge of genetics is opening whole new fields of health care. In diagnosis, mapping of genetic instructions in cells makes it possible 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.	
• Inoculations use weakened germs (or parts of them) to stimulate the body's immune system to react. This reaction prepares the body to fight subsequent invasions by actual germs of that type. Some inoculations last for life.	
• Knowledge of molecular structure and interactions aids in synthesizing new drugs and predicting their effects.	FAST 3, Change over Time—Unit 4, Life on Earth
• The diagnosis and treatment of mental disorders are improving but not as rapidly as for physical health. Techniques for detecting and diagnosing these disorders include observation of behavior, in-depth interviews, and measurements of body chemistry. Treatments range from conversation to affecting the brain physically with chemicals, electric shock, or surgery.	
• Biotechnology has contributed to health improvement in many ways, but its cost and application have led to a variety of controversial social and ethical issues.	

9. The Mathematical World

9A. Numbers	
• Comparison of numbers of very different size can be made approximately by expressing them as nearest powers of 10.	FAST 3, Change over Time—Unit 2, The Changing Earth; scientific notation
• Numbers can be written with bases different from ten (which people probably use because of their 10 fingers). The simplest base, 2, uses just two symbols (1 and 0, or on and off).	HMSS—scientific notation
• When calculations are made with measurements, a small error in the measurements may lead to a large error in the results.	
• The effects of uncertainties in measurements on a computed result can be estimated.	

9B. Symbolic Relationships	
• In come cases, the more of something there is, the more rapidly it may change (as the number of births is proportional to the size of the population). In other cases, the rate of change of something depends on how much there is of something else (as the rate of change of speed is proportional to the amount of force acting).	FAST 3, Change over Time—Unit 6, Changing Ecosystems

9B. Symbolic Relationships (continued)	
• Symbolic statements can be manipulated by rules of mathematical logic to produce other statements of the same relationship, which may show some interesting aspect more clearly. Symbolic statements can be combined to look for values of variables that will satisfy all of them at the same time.	
• Any mathematical model, graphic or algebraic, is limited in how well it can represent how the world works. The usefulness of a mathematical model for predicting may be limited by uncertainties in influences, or by requiring too much computation.	FAST 3, Change over Time—Unit 3, The Changing Earth; Unit 5, Continental Drift; Unit 7, Humans in the Environment
• Tables, graphs, and symbols are alternative ways of representing data and relationships that can be translated from one to another.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• When a relationship is represented in symbols, numbers can be substituted for all but one of the symbols and the possible value of the remaining symbol computed. Sometimes the relationship may be satisfied by one value, sometimes more than one, and sometimes maybe not at all.	
• The reasonableness of the result of a computation can be estimated from what the inputs and operations are.	

9C. Shapes	
• Distances and angles that are inconvenient to measure directly can be found from measurable distances and angles using scale drawings or formulas.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 4, Life on Earth; Unit 5 Continental Drift
• There are formulas for calculating the surface areas and volumes of regular shapes. When the linear size of a shape changes by some factor, its area and volume change disproportionately: area in proportion to the square of the factor, and volume in proportion to its cube. Properties of an object that depend on its area or volume also change disproportionately.	
• Geometric shapes and relationships can be described in terms of symbols and numbers—and vice versa. For example, the position of any point on a surface can be specified by two numbers; a graph represents all the values that satisfy an equation; and if two equations have to be satisfied at the same time, the values that satisfy them both will be found where their graphs intersect.	FAST 3, Change over Time
• Different ways to map a curved surface (like the earth's) onto a flat surface have different advantages.	FAST 3, Change over Time—Unit 2, The Changing Earth HMSS—Fluid Earth Unit 1 Earth and Ocean Basins

9D. Uncertainty	
• Even when there are plentiful data, it may not be obvious what mathematical model to use to make predictions from them or there may be insufficient computing power to use some models.	FAST 3, Change over Time—Unit 3, The Changing Universe; Unit 5, Continental Drift; Unit 7, Humans in the Environment
• When people estimate a statistic, they may also be able to say how far off the estimate might be.	
• The middle of a data distribution may be misleading—when the data are not distributed symmetrically, or when there are extreme high or low values, or when the distribution is not reasonably smooth.	
• The way data are displayed can make a big difference in how they are interpreted.	

9D. Uncertainty (continued)	
• Both percentages and actual numbers have to be taken into account in comparing different groups; using either category by itself could be misleading. • Considering whether two variables are correlated requires inspecting their distributions, such as in two-way tables or scatter plots. A believable correlation between two variables doesn't mean that either one causes the other; perhaps some other variable causes them both or the correlation might be attributable to chance alone. A true correlation means that differences in one variable imply differences in the other when all other things are equal. • The larger a well-chosen sample of a population is, the better it estimates population summary statistics. For a well-chosen sample, the size of the sample is much more important than the size of the population. To avoid intentional or unintentional bias, samples are usually selected by some random system.	
• A physical or mathematical model can be used to estimate the probability of real-world events.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift

9E. Reasoning	
• To be convincing, an argument needs to have both true statements and valid connections among them. Formal logic is mostly about connections among statements, not about whether they are true. People sometimes use poor logic even if they begin with true statements, and sometimes they use logic that begins with untrue statements. • Logic requires a clear distinction among reasons: A reason may be *sufficient* to get a result, but perhaps is not the only way to get there; or, a reason may be *necessary* to get the result, but it may not be enough by itself; some reasons may be both sufficient and necessary. • Wherever a general rule comes from, logic can be used in testing how well it works. Proving a generalization to be false (just one exception will do) is easier than proving it to be true (for all possible cases). Logic may be of limited help in finding solutions to problems if one isn't sure that general rules always hold or that particular information is correct; most often, one has to deal with probabilities rather than certainties.	
• Once a person believes in a general rule, he or she may be more likely to notice cases that agree with it and to ignore cases that don't. To avoid biased observations, scientific studies sometimes use observers who don't know what the results are "supposed" to be.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Very complex logical arguments can be made from a lot of small logical steps. Computers are particularly good at working with complex logic but not all logical problems can be solved by computers. High-speed computers can examine the validity of some logical propositions for a very large number of cases, although that may not be a perfect proof.	

10. Historical Perspectives

10A. Displacing the Earth from the Center of the Universe	
• People perceive that the earth is large and stationary and that all other objects in the sky orbit around it. That perception was the basis for theories of how the universe is organized that prevailed for over 2,000 years.	FAST 3, Change over Time—Unit 3, The Changing Universe
• Ptolemy, an Egyptian astronomer living in the second century A.D., devised a powerful mathematical model of the universe based on constant motion in perfect circles, and circles on circles. With the model, he was able to predict the motions of the sun, moon, and stars, and even of the irregular "wandering stars" now called planets.	FAST 3, Change over Time—Unit 3, The Changing Universe
• In the 16th century, a Polish astronomer named Copernicus suggested that all those same motions could be explained by imagining that the earth was turning around once a day and orbiting around the sun once a year. This explanation was rejected by nearly everyone because it violated common sense and required the universe to be unbelievably large. Worse, it flew in the face of the belief, universally held at the time, that the earth was at the center of the universe.	FAST 3, Change over Time—Unit 3, The Changing Universe
• Johannes Kepler, a German astronomer who lived at about the same time as Galileo, showed mathematically that Copernicus' idea of a sun-centered system worked well if uniform circular motion was replaced with uneven (but predictable) motion along off-center ellipses.	FAST 3, Change over Time—Unit 3, The Changing Universe
• Using the newly invented telescope to study the sky, Galileo made many discoveries that supported the ideas of Copernicus. It was Galileo who found the moons of Jupiter, sunspots, craters and mountains on the moon, and many more stars than were visible to the unaided eye.	FAST 3, Change over Time—Unit 3, The Changing Universe
• Writing in Italian rather than in Latin (the language of scholars at the time), Galileo presented arguments for and against the two main views of the universe in a way that favored the newer view. That brought the issue to the educated people of the time and created political, religious, and scientific controversy.	FAST 3, Change over Time—Unit 3, The Changing Universe

10B. Uniting the Heavens and the Earth	
• Isaac Newton created a unified view of force and motion in which motion everywhere in the universe can be explained by the same few rules. His mathematical analysis of gravitational force and motion showed that planetary orbits had to be the very ellipses that Kepler had proposed two generations earlier.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe
• Newton's system was based on the concepts of mass, force, and acceleration, his three laws of motion relating them, and a physical law stating that the force of gravity between any two objects in the universe depends only upon their masses and the distance between them.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy
• The Newtonian model made it possible to account for such diverse phenomena as tides, the orbits of planets and moons, the motion of falling objects, and the earth's equatorial bulge.	FAST 3, Change over Time—Unit 3, The Changing Universe

10B. Uniting the Heavens and the Earth (continued)	
• For several centuries, Newton's science was accepted without major changes because it explained so many different phenomena, could be used to predict many physical events (such as the appearance of Halley's comet), was mathematically sound, and had many practical applications.	FAST 3, Change over Time—Unit 3, The Changing Universe
• Although overtaken in the 20th century by Einstein's relativity theory, Newton's ideas persist and are widely used. Moreover, his influence has extended far beyond physics and astronomy, serving as a model for other sciences and even raising philosophical questions about free will and the organization of social systems.	FAST 3, Change over Time—Unit 3, The Changing Universe

10C. Relating Matter & Energy and Time & Space	
• As a young man, Albert Einstein, a German scientist, formulated the special theory of relativity, which brought about revolutionary changes in human understanding of nature. A decade later, he proposed the general theory of relativity, which, along with Newton's work, ranks as one of the greatest human accomplishments in all of history.	
• Among the surprising ideas of special relativity is that nothing can travel faster than the speed of light, which is the same for all observers no matter how they or the light source happen to be moving.	
• The special theory of relativity is best known for stating that any form of energy has mass, and that matter itself is a form of energy. The famous relativity equation, $E = mc^2$, holds that the transformation of even a tiny amount of matter will release an enormous amount of other forms of energy, in that the *c* in the equation stands for the immense speed of light.	FAST 3, Change over Time—Unit 3, The Changing Universe
• General relativity theory pictures Newton's gravitational force as a distortion of space and time.	
• Many predictions from Einstein's theory of relativity have been confirmed on both atomic and astronomical scales. Still, the search continues for an even more powerful theory of the architecture of the universe.	

10D. Extending Time	
• Scientific evidence implies that some rock near the earth's surface is several billion years old. But until the 19th century, most people believed that the earth was created just a few thousand years ago.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift
• The idea that the earth might be vastly older than most people believed made little headway in science until the publication of Principles of Geology by an English scientist, Charles Lyell, early in the 19th century. The impact of Lyell's book was a result of both the wealth of observations it contained on the patterns of rock layers in mountains and the locations of various kinds of fossils, and of the careful logic he used in drawing inferences from his data.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift
• In formulating and presenting his theory of biological evolution, Charles Darwin adopted Lyell's belief about the age of the earth and his style of buttressing his argument with vast amounts of evidence.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems

10E. Moving Continents	
• The idea of continental drift was suggested by the matching shapes of the Atlantic coasts of Africa and South America, but rejected for lack of other evidence. It just seemed absurd that anything as massive as a continent could move around.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift
• Early in the 20th century, Alfred Wegener, a German scientist, reintroduced the idea of moving continents, adding such evidence as the underwater shapes of the continents, the similarity of life forms and land forms in corresponding parts of Africa and South America, and the increasing separation of Greenland and Europe. Still, very few contemporary scientists adopted this theory.	FAST 3, Change over Time—Unit 5, Continental Drift
• The theory of plate tectonics was finally accepted by the scientific community in the 1960s, when further evidence had accumulated in support of it. The theory was seen to provide an explanation for a diverse array of seemingly unrelated phenomena, and there was a scientifically sound physical explanation of how such movement could occur.	FAST 3, Change over Time—Unit 5, Continental Drift HMSS Fluid Earth

10F. Understanding Fire	
• Lavoisier invented a whole new field of science based on a theory of materials, physical laws, and quantitative methods, with the conservation of matter at its core. He persuaded a generation of scientists that his approach accounted for the experimental results better than other chemical systems.	
• Lavoisier's system for naming substances and describing their reactions contributed to the rapid growth of chemistry by enabling scientists everywhere to share their findings about chemical reactions with one another without ambiguity.	
• John Dalton's modernization of the ancient Greek ideas of element, atom, compound, and molecule strengthened the new chemistry by providing a physical explanation for reactions that could be expressed in quantitative terms.	FAST 3, Change over Time—Unit 4, Life on Earth
• While the basic ideas of Lavoisier and Dalton have survived, the advancement of chemistry since their time now makes possible an explanation of the bonding that takes place between atoms during chemical reactions in terms of the inner workings of atoms.	

10G. Splitting the Atom	
• The Curies made radium available to researchers all over the world, increasing the study of radioactivity and leading to the realization that one kind of atom may change into another kind, and so must be made up of smaller parts. These parts were demonstrated by other scientists to be small, dense nucleus that contains protons and neutrons and is surrounded by a cloud of electrons.	
• Ernest Rutherford of New Zealand and his colleagues discovered that the heavy radioactive element uranium spontaneously splits itself into a slightly lighter nucleus and a very light helium nucleus.	

10G. Splitting the Atom (continued)	
• Later, Austrian and German scientist showed that when uranium is struck by neutrons, it splits into two nearly equal parts plus one or two extra neutrons. Lisa Meitner, an Austrian physicist, was the first to point out that if these fragments added up to less mass than the original uranium nucleus, then Einstein's special relativity theory predicted that a large amount of energy would be released. Enrico Fermi, an Italian working with colleagues in the United States, showed that the extra neutrons trigger more fission's and so create a sustained chain reaction in which a prodigious amount of energy is given off.	
• A massive effort went into developing the technology and building the nuclear fission bombs used in Japan in World War II, the nuclear fusion weapons that followed, and the reactors for the controlled release of nuclear energy to produce electric power. Nuclear weapons and energy remain matters of public concern and controversy.	
• Radioactivity has many uses other than generating energy, including in medicine, industry, and scientific research in many different fields.	

10H. Explaining the Diversity of Life	
• The scientific problem that led to the theory of natural selection was how to explain similarities within the great diversity of existing and fossil organisms.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 6, Changing Ecosystems
• Prior to Charles Darwin, the most widespread belief was that all known species were created at the same time and remained unchanged throughout history. Some scientists at the time believed that features an individual acquired during its lifetime could be passed on to its offspring, and the species could thereby gradually change to fit its environment better.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 6, Changing Ecosystems
• Darwin argued that only biologically inherited characteristics could be passed on to offspring. Some of these characteristics were advantageous in surviving and reproducing. The offspring would also inherit and pass on those advantages, and over generations the aggregation of these inherited advantages would lead to a new species.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 6, Changing Ecosystems
• The quick success of Darwin's book *Origin of Species*, published in the mid-1800s, came from the clear and understandable argument it made, including the comparison of natural selection to the selective breeding of animals in wide use at the time, and from the massive array of biological and fossil evidence it assembled to support the argument.	
• After the publication of *Origin of Species*, biological evolution was supported by the rediscovery of the genetics experiments of an Austrian monk, Gregor Mendel, by the identification of genes and how they are sorted in reproduction, and by the discovery that the genetic code found in DNA is the same for almost all organisms.	

10H. Explaining the Diversity of Life (continued)	
• By the 20th century, most scientists had accepted Darwin's basic idea. Today that still holds true, although differences exist concerning the details of the process and how rapidly evolution of species takes place. People usually do not reject evolution for scientific reasons but because they dislike its implications, such as the relation of human beings to other animals, or because they prefer a biblical account of creation.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 6, Changing Ecosystems

10J. Harnessing Power	
• The Industrial Revolution happened first in Great Britain because that country made practical use of science, had access by sea to world resources and markets, and had an excess of farm workers willing to become factory workers.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• The Industrial Revolution increased the productivity of each worker but it also increased child labor and unhealthy working conditions, and it gradually destroyed the craft tradition. The economic imbalances of the Industrial Revolution led to a growing conflict between factory owners and workers and contributed to the main political ideologies of the 20th century.	FAST 3, Change over Time—Unit 7, Humans in the Environment
• The Industrial Revolution is still underway as electric, electronic, and computer technologies change patterns of work and bring with them economic and social consequences.	FAST 3, Change over Time—Unit 7, Humans in the Environment

11. Common Themes

11A. Systems	
• A system usually has some properties that are different from those of its parts, but appear because of the interaction of those parts.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Understanding how things work and designing solutions to problems of almost any kind can be facilitated by systems analysis. In defining a system, it is important to specify its boundaries and subsystems, indicate its relation to other systems, and identify what its input and its output are expected to be.	FAST 3, Change over Time
• The successful operation of a designed system usually involves feedback. The feedback of output from some parts of a system to input of other parts can be used to encourage what is going on in a system, discourage it, or reduce its discrepancy from some desired value. The stability of a system can be greater when it includes appropriate feedback mechanisms.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Even in some very simple systems, it may not always be possible to predict accurately the result of changing some part or connection.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean

11B. Models	
• The basic idea of mathematical modeling is to find a mathematical relationship that behaves in the same ways as the objects or processes under investigation. A mathematical model may give insight about how something really works or may fit observations very well without any intuitive meaning.	FAST 3, Change over Time HMSS—Fluid Earth

11B. Models (continued)	
• Computers have greatly improved the power and use of mathematical models by performing computations that are very long, very complicated, or repetitive. Therefore computers can show the consequences of applying complex rules or of changing the rules. The graphic capabilities of computers make them useful in the design and testing of devices and structures and in the simulation of complicated processes.	
• The usefulness of a model can be tested by comparing its predictions to actual observations in the real world. But a close match does not necessarily mean that the model is the only "true" model or the only one that would work.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean

11C. Constancy and Change	
• A system in equilibrium may return to the same state of equilibrium if the disturbances it experiences are small. But large disturbances may cause it to escape that equilibrium and eventually settle into some other state of equilibrium.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Along with the theory of atoms, the concept of the conservation of matter led to revolutionary advances in chemical science. The concept of conservation of energy is at the heart of advances in fields as diverse as the study of nuclear particles and the study of the origin of the universe.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Things can change in detail but remain the same in general (the players change, but the team remains; cells are replaced, but the organism remains). Sometimes counterbalancing changes are necessary for a thing to retain its essential constancy in the presence of changing conditions.	
• Graphs and equations are useful (and often equivalent) ways for depicting and analyzing patterns of change.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• In many physical, biological, and social systems, changes in one direction tend to produce opposing (but somewhat delayed) influences, leading to repetitive cycles of behavior.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• In evolutionary change, the present arises from the materials and forms of the past, more or less gradually, and in ways that can be explained.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Most systems above the molecular level involve so many parts and forces and are so sensitive to tiny differences in conditions that their precise behavior is unpredictable, even if all the rules for change are known. Predictable or not, the precise future of a system is not completely determined by its present state and circumstances but also depends on the fundamentally uncertain outcomes of events on the atomic scale.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean

11D. Scale	
• Representing large numbers in terms of powers of ten makes it easier to think about them and to compare things that are greatly different.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Because different properties are not affected to the same degree by changes in scale, large changes in scale typically change the way that things work in physical, biological, or social systems.	
• As the number of parts of a system grows in size, the number of possible internal interactions increases much more rapidly, roughly with the square of the number of parts.	

12. Habits of Mind

12A. Values and Attitudes	
• Know why curiosity, honesty, openness, and skepticism are so highly regarded in science and how they are incorporated into the way science is carried out; exhibit those traits in their own lives and value them in others.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• View science and technology thoughtfully, being neither categorically antagonistic nor uncritically positive.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean

12B. Computation and Estimation	
• Use ratios and proportions, including constant rates, in appropriate problems.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Find answers to problems by substituting numerical values in simple algebraic formulas and judge whether the answer is reasonable by reviewing the process and checking against typical values.	
• Make up and write out simple algorithms for solving problems that take several steps.	
• Use computer spreadsheet, graphing, and database programs to assist in quantitative analysis.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Compare data for two groups by representing their averages and spreads graphically.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Express and compare vary small and very large numbers using powers-of-ten notation.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Trace the source of any large disparity between an estimate and the calculated answer.	
• Recall immediately the relations among 10, 100, 1000, 1 million, and 1 billion (knowing, for example, that 1 million is a thousand thousands).	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Consider the possible effects of measurement errors on calculations.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean

12C. Manipulation and Observation	
• Learn quickly the proper use of new instruments by following instructions in manuals or by taking instructions from an experienced user.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Use computers for producing tables and graphs and for making spreadsheet calculations.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Troubleshoot common mechanical and electrical systems, checking for possible causes of malfunction, and decide on that basis whether to make a change or get advice from an expert before proceeding.	
• Use power tools safely to shape, smooth, and join wood, plastic, and soft metal.	

12D. Communication Skills	
• Make and interpret scale drawings.	FAST 3, Change over Time
• Write clear, step-by-step instructions for conducting investigations, operating something, or following a procedure.	HMSS—Fluid Earth; Living Ocean FAST 3, Change over Time
• Choose appropriate summary statistics to describe group differences, always indicating the spread of the data as well as the data's central tendencies.	HMSS—Fluid Earth; Living Ocean
• Describe spatial relationships in geometric terms such as perpendicular, parallel, tangent, similar, congruent, and symmetrical.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean

12D. Communication Skills (continued)	
• Use and correctly interpret relational terms such as *if...then..., and, or, sufficient, necessary, some, every, not, correlates with,* and *causes*	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Use tables, charts, and graphs in making arguments and claims in oral and written presentations.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean

12E. Critical-Response Skills	
• Notice and criticize arguments based on the faulty, incomplete, or misleading use of numbers, such as in instances when (1) average results are reported, but not the amount of variation around the average, (2) a percentage or fraction is given, but not the total sample size (as in "9 out of 10" dentists recommend..."), (3) absolute and proportional quantities are mixed (as in "3,400 more robberies in our city last year whereas other cities had an increase of less than 1%), or (4) results are reported with overstated precision (as in representing 13 out of 19 students as 68.42%).	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Check graphs to see that they do not misrepresent results by using inappropriate scales or by failing to specify the axes clearly.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Wonder how likely it is that some event of interest might have occurred just by chance.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position being taken—whether one's own or that of others--can be judged.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Be aware, when considering claims, that when people try to prove a point, they may select only the data that support it and ignore any that would contradict it.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean
• Suggest alternative ways of explaining data and criticize arguments in which data, explanations, or conclusions are represented as the only ones worth consideration, with no mention of other possibilities. Similarly, suggest alternative trade-offs in decisions and designs and criticize those in which major trade-offs are not acknowledged.	FAST 3, Change over Time HMSS—Fluid Earth; Living Ocean