Alignment of the Foundational Approaches in Science Teaching Program (FAST)

and the AAAS Benchmarks for Science Literacy

Grades 6–8

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FOREWORD

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The *Foundational Approaches in Science Teaching* (FAST) program is a series of three inquiry science courses designed specifically 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 goal of FAST is the development of a scientifically literate student who has 1) the background necessary for understanding the environmental concerns arising in our technological society, and 2) the foundational tools for further study in the sciences. The principal objectives of FAST are to develop thinking skills, laboratory skills, and knowledge of foundational concepts of the disciplines of science.

FAST is validated by the U.S. Department of Education's Program Effectiveness Panel and disseminated through the National Diffusion Network. It is also included in the U.S. Department of Education's recently published *Promising Practices in Mathematics and Science* as meeting the standards for science reform in the United States. Developmental funding was provided by the University of Hawai‘i.

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 and 3–5 for elementary schools; grades 6–8 for middle schools; and grades 9–12 for high schools.

The following analysis describes how FAST addresses the recommended Benchmarks for science education.

Analysis of FAST Match
to the AAAS Benchmarks for Science Literacy

The AAAS Benchmarks for Grades 6–8	Foundational Approaches in Science Teaching (FAST) (FAST 1, The Local Environment; FAST 2, Matter and Energy; FAST 3, Change Over Time)

1. The Nature of Science

1A. Scientific World View • When similar investigations give different results, the scientific challenge is to judge whether the differences are trivial or significant, and it often takes studies to decide. Even with similar results, scientists may wait until an investigation has been repeated many times before accepting the results as correct. • Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way. • Some scientific knowledge is very old and yet is still applicable today. • Some matters cannot be examined usefully in a scientific way. Among them are matters that by their nature cannot be tested objectively and those that are essentially matters of morality. Science can sometimes be used to inform ethical decisions by identifying the likely consequences of particular actions but cannot be used to establish that some is either moral or immoral.	FAST students develop a scientific world view by doing science—designing and carrying out experiments, collecting and analyzing data, and drawing conclusions based on evidence. Students respond to differences in data collected by looking for patterns and relationships, setting standards, examining the effects of human and instrument error, graphing data and looking for generalizations. Generalizations are based on data and consensus. For example, in the design of investigations such as the effect of scarification on seed germination and the effects of environmental conditions on plant propagation, students learn valid experimental design and analysis. Definitions written in student books are reviewed and modified as new information is collected in investigations. A definition can always be revised as new information becomes available. Actual data from earlier experiments are used to determine experimental relationships as for example the study of combining gaseous substances in the Literature of Chemistry section of FAST 2. Ethical dilemmas are examined in topics such as population growth, energy sources and needs, human world food production, and decision making for the future.
1B. Scientific Inquiry • Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence. • If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but collaboration among investigators can often lead to research designs that are able to deal with such situations.	Scientists and how they worked are studied in the disciplines 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.

1B. Scientific Inquiry (continued) • What people expect to observe often affects what they actually do observe. Strong beliefs about what should happen in particular circumstances can prevent them from detecting other results. Scientists know about this danger to objectivity and take steps to try and avoid it when designing investigations and examining data. One safeguard is to have different investigators conduct independent studies of the same questions.	FAST investigations rely on replication of data and group consensus on the interpretation of results. Specific examples of where students examine bias include the use of the coldwater potometer, replication in experimental design, and data collection on air and water quality in FAST 1.
1C. The Scientific Enterprise • Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times. • Until recently, women and racial minorities, because of restrictions on their education and employment opportunities, were essentially left out of much of the formal work of the science establishment; the remarkable few who overcame those obstacles were even then likely to have their work disregarded by the science establishment. • No matter who does science and mathematics or invents things, or when or where they do it, the knowledge and technology that result can eventually become available to everyone in the world. • Scientists are employed by colleges and universities, business and industry, hospitals and many government agencies. Their places of work include offices, classrooms, laboratories, farms, factories, and natural field settings ranging from space to ocean floor. • In research involving human subjects, the ethics of science require that political subjects be fully informed about the risks and benefits associated with the research and of their right to refuse to participate. Science ethics also demand that scientists must not knowingly subject coworkers, students, the neighborhood, or the community to health or property risks without prior knowledge and consent. Because animals cannot make informed choices, special care must be taken in using them in scientific research. • Computers have become invaluable in science because they speed up and extend people's ability to collect, store, compile and analyze data, prepare research reports, and share data and ideas with investigators all over the world. • Accurate record-keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.	FAST investigations are taken from an historical approach. We have looked to the history of science for examples of how humans first dealt with foundational science concepts. In their investigations, students also examine how ideas have changed over time and the cumulative contributions of scientists worldwide. Specifically, the nature of the scientific enterprise is the focus of investigations of Dalton's Atomic Theory (FAST 2) and the FAST 3 sections on the history of astronomy, organic chemistry, plate tectonics, and human intervention in environments. Students are required to keep notebooks of their investigations. Their notebook is their science textbook in FAST.

2. Nature of Mathematics

2A. Patterns and Relationships • Usually there is no one right away to solve a mathematical problem; different methods have different advantages and disadvantages. • Logical connections can be found between different parts of mathematics.	Graphing is used extensively in FAST 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. Measuring is an important part of mathematics and science. In FAST students learn basic skills in linear, area, volume, mass, temperature, density, energy, work, chromatography, astronomical, and other measurements.
2B. Mathematics, Science and Technology • Mathematics is helpful in almost every kind of human endeavor- from laying bricks to prescribing medicine or drawing a face. In particular, mathematics has contributed to progress in science and technology for thousands of years and still continues to do so.	Mathematics plays a central role in FAST beginning with initial investigations on buoyancy and density (FAST 1), study of Dalton's Atomic Theory (FAST 2), predicting the energy involved in mountain formation and erosion, calculating force, work, and energy, and using scientific notation.
2C. Mathematical Inquiry • Mathematicians often represent things with abstract ideas, such as numbers or perfectly straight lines, and then work with those ideas alone. The "things" from which they abstract can be ideas themselves (for example, a proposition about "all equal-sided triangles" or "all odd numbers"). • When mathematicians use logical rules to work with representations of things, the results may or may not be valid for the things themselves. Using mathematics to solve a problem requires choosing what mathematics to use; probably making some simplifying assumptions, estimates, or approximations; doing computations; and then checking to see whether the answer makes sense. If an answer does not seem to make enough sense for its intended purpose, then any of these steps might have been inappropriate.	Ratios also play an important role in FAST as in density, humidity, law of combining volumes, and gas laws. Angle measurements are employed in the study of light, azimuth and altitude calculations using astrolabes and sunscopes, and the formation and erosion of landforms. Students use a variety of formulae for the calculation of density, energy, work, mechanical equivalent of heat, calories in food, the specific heat of metals and liquids, universal laws of gravitation, and energy flow through ecosystems.

3. The Nature of Technology

3A .Technology and Science • In earlier times, the accumulated information and techniques of each generation of workers were taught on the job directly to the next generation of workers. Today, the knowledge base for technology can be found as well in libraries of print and electronic resources and is often taught in the classroom. • Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information. • Engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems. But they usually have to take human values and limitations into account as well.	The growth of technology and the subsequent impact on scientific knowledge is noted in such areas as the development of the balance (FAST 1), methods of handling gases (FAST 2), the history of plate tectonics, and the development of astronomy and astronomical instruments (FAST 3). Students build their own instruments for field mapping, weather measurement, air pollution studies, water quality studies, and astronomy. Design projects such as submarines, moving fluids project give students opportunities to solve practical problems through technology. These problems have multiple solutions, but solutions must be evaluated in terms of feasibility and human value.
3B. Design and Systems • Design usually requires taking constraints into account. Some constraints, such as gravity or the properties of the materials to be used are unavoidable. Other constraints, including economic, political, social, ethical, and aesthetic ones, limit choices. • All technologies have effects other than those intended by the design, some of which may have been predictable and some not. In either case, these side effects may turn out to be unacceptable to some of the population and therefore lead to conflict between groups. • Almost all control systems have inputs, outputs, and feedback. The essence of control is comparing information about what is happening to what people want to happen and then making appropriate adjustments. This procedure requires sensing information, processing it, and making appropriate adjustments. This procedure requires sensing information, processing it, and making microprocessors serve as centers of performance control. • Systems fail because they have faulty or poorly matched parts, are used in ways that exceed what was intended by the design, or were poorly designed to begin with. The most common ways to prevent failure are pre-testing parts and procedures, overdesign, and redundancy.	Student-made inventions and devices are analyzed for how well they work and for their impact on the environment and society. FAST 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 FAST 1, design technologies are analyzed in studies of weather, air pollution, and water resource management. In FAST, investigations of anomalies often result in failure of students' first attempts to solve them. For example, in measuring the heat from sunlight in FAST 2, the design flaws in initial devices and the need for standard measurements are identified by students. A return to this project is successful when knowledge of materials and skills gained in FAST investigations have been completed.
3C. Issues in Technology • The human ability to shape the future comes from a capacity for generating knowledge and developing new technologies—and for communicating ideas to others. • Technology cannot always provide successful solutions for problems or fulfill every human need.	Communication is essential to science and to FAST. 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. Students find examples of the limitations of technology in their investigations of air and water quality (FAST 1), measurements of the solar constant and forced ecosystems (FAST 2), and the interaction of science, technology, and society (FAST 3).

3C. Issues in Technology (continued) • Throughout history, people have carried out impressive technological feats, some of which would be hard to duplicate today even with modern tools. The purposes served by these achievements have sometimes been practical, sometimes ceremonial. • Technology has strongly influenced the course of history and continues to do so. It is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live. • New technologies increase some risks and decrease others. Some of the same technologies that have improved the length and quality of life for many people have also brought new risks. • Rarely are technology issues simple and one-sided. Relevant facts alone, even when known and available, usually do not settle matters entirely in favor of one side or another. That is because the contending groups may have different values and priorities. They may stand to gain or lose in different degrees, or may make very different predictions about what the future consequences of the proposed action will be. • Societies influence what aspects of technology are developed and how these are used. People control technology (as well as science) and are responsible for its effects.	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 air pollution and water resource management (FAST 1), the productivity project and world food production (FAST 2), and energy/land use by humans past and present (FAST 3).

4. The Physical Setting

4A. The Universe	
• The sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars, part of which can be seen as a glowing band of light that spans the sky on a very clear night. The universe contains many billions of galaxies, and each galaxy contains many billions of stars. To the naked eye, even the closest of these galaxies is no more than a dim, fuzzy spot.	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.
• The sun is many thousands of times closer to the earth than any other star. Light from the sun takes a few minutes to reach the earth, but light from the next nearest star takes a few years to arrive. The trip to that star would take the fastest rocket thousands of years. Some distant galaxies are so far away that their light takes several billions of years to reach the earth. People on earth, therefore, see them as they were that long ago in the past.	FAST 3, Change over Time—Unit 3, The Changing Universe.
• Nine planets of very different size, composition, and surface features move around the sun in nearly circular orbits. Some planets have a great variety of moons and even flat rings of rock and ice particles orbiting around them. Some of these planets and moons show evidence of geologic activity. The earth is orbited by one moon, many artificial satellites, and debris.	FAST 3, Change over Time—Unit 3, The Changing Universe.
• Large numbers of chunks of rock orbit the sun. Some of those that the earth meets in its yearly orbit around the sun glow and disintegrate from friction as they plunge through the atmosphere—and sometimes impact the ground. Other chunks of rocks mixed with ice have long, off-center orbits that carry them close to the sun, where the sun's radiation (of light and particles) boils off frozen material from their surfaces and pushes it into a long, illuminated tail.	FAST 3, Change over Time—Unit 3, The Changing Universe.
4B. The Earth	
• We live on a relatively small planet, the third from the sun in the only system of planets definitely known to exist (although other, similar systems may be discovered in the universe).	FAST 3, Change over Time—Unit 3, The Changing Universe.
• The earth is mostly rock. Three-fourths of its surface is covered by a relatively thin layer of water (some of it frozen), and the entire planet is surrounded by a relatively thin blanket of air. It is the only body in the solar system that appears able to support life. The other planets have compositions and conditions very different from the earth's.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift.
• Everything on or anywhere near the earth is pulled toward the earth's center by gravitational force.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift.
• Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in heating of the earth's surface produces the planet's seasons and weather patterns.	FAST 2, Matter & Energy in the Biosphere—PS Unit 1, Light and Heat; E Unit 3, The Cycling of Matter; RS Unit 1, Productivity Project; FAST 3, Change over Time—Unit 3, The Changing Universe.
• The moon's orbit around the earth once in about 28 days changes what part of the moon is lighted by the sun and how much of that part can be seen from the earth—the phases of the moon.	FAST 3, Change over Time—Unit 3, The Changing Universe.

4B. The Earth (continued)	
• Climates have sometimes changed abruptly in the past as a result of changes in the earth's crust, such as volcanic eruptions or impacts of huge rocks from space. Even relatively small changes in atmospheric or ocean content can have widespread effects on climate if the change lasts long enough.	FAST 1, The Local Environment—E Unit 2, The Physical Environment; FAST 3, Change over Time—Unit 3, The Changing Universe; Unit 4, Unit 5, Continental Drift.
• The cycling of water in and out of the atmosphere plays an important role in determining climatic patterns. Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the ocean.	FAST 1, The Local Environment—E Unit 2, The Physical Environment; Unit 4, Field Ecology; RS Unit 2, Water Resource Management; FAST 2, Matter & Energy in the Biosphere—E Unit 3, The Cycling of Matter.
• Fresh water, limited in supply, is essential for life and also for most industrial processes. Rivers, lakes, and ground water can be depleted or polluted, becoming unavailable or unsuitable for life.	FAST 1, The Local Environment—E Unit 2, The Physical Environment; RS Unit 1, Air Pollution; RS Unit 2, Water Resource Management; FAST 3, Change over Time—Unit 6, Changing Ecosystems.
• Heat energy carried by ocean currents has a strong influence on climate around the world.	FAST 1, The Local Environment—E Unit 2, The Physical Environment; PS Unit 3, Temperature and Heat; FAST 3, Change over Time—Unit 6, Changing Ecosystems.
• Some minerals are very rare and some exist in great quantities, but—for practical purposes—the ability to recover them is just as important as their abundance. As minerals are depleted, obtaining them becomes more difficult. Recycling and the development of substitutes can reduce the rate of depletion but may also be costly.	
• The benefits of the earth's resources—such as fresh water, air, soil, and trees—can be reduced by using them wastefully or by deliberately or inadvertently destroying them. The atmosphere and the oceans have a limited capacity to absorb wastes and recycle materials naturally. Cleaning up polluted air, water, or soil or restoring depleted soil, forests, or fishing grounds can be very difficult and costly.	FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time
4C. Processes That Shape The Earth	
• The interior of the earth is hot. Heat flow and movement of material within the earth cause earthquakes and volcanic eruptions and create mountains and ocean basins. Gas and dust from large volcanoes can change the atmosphere.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift.
• Some changes in the earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains). The earth's surface is shaped in part by the motion of water and wind over very long times, which act to level mountain ranges.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems.
• Sediments of sand and smaller particles (sometimes containing the remains of organisms) are gradually buried and are cemented together by dissolved minerals to form solid rock again.	FAST 1, The Local Environment—E Unit 2, The Physical Environment; FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift.

4C. Processes That Shape The Earth (continued)	
• Sedimentary rock buried deep may be reformed by pressure and heat, perhaps melting and recrystallizing into different kinds of rock. These re-formed rock layers may be forced up again to become land surface and even mountains. Subsequently, this new rock too will erode. Rock bears evidence of the minerals, temperatures, and forces that created it.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift.
• Thousands of layers of sedimentary rock confirm the long history of the changing surface of the earth and the changing life forms whose remains are found in successive layers. The youngest layers are not always found on top, because of folding, breaking, and uplift of layers.	FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift.
• Although weathered rock is the basic component of soil, the composition and texture of soil and its fertility and resistance to erosion are greatly influenced by plant roots and debris, worms, insects, rodents and other organisms.	FAST 1, The Local Environment—E Unit 2, The Physical Environment; FAST 2, Matter & Energy in the Biosphere—RS Unit 1, Productivity Project; FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 5, Continental Drift.
• Human activities, such as reducing the amount of forest cover, increasing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.	FAST 1, The Local Environment—E Unit 4, Field Ecology; RS Unit 1, Air Pollution; RS Unit 2, Water Resource Management FAST 2, Matter & Energy in the Biosphere—E Unit 3, Cycling of Matter FAST 3, Change over Time—Unit 4, Life on Earth; Unit 6, Changing Ecosystems
4D. The Structure of Matter	
• All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.	FAST 2, Matter & Energy in The Biosphere—PS Unit 2, Evidence for an Atomic Theory; FAST 3, Change over Time—Unit 4, Life on Earth.
• Equal volumes of different substances usually have different weights.	FAST 1, The Local Environment—PS Unit 1, Properties of Matter.
• Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy of motion, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy of motion and are free of one another except during occasional collisions.	FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory; PS Unit 3, A Model of Matter; FAST 3, Change over Time—Unit 1, Force, Work & Energy; Unit 3, The Changing Universe; Unit 4, Life on Earth.

4D. The Structure of Matter (continued) • The temperature and acidity of a solution influence reaction rates. Many substances dissolve in water, which may greatly facilitate reactions between them.	FAST 1, The Local Environment—PS Unit 2, Changes of State in Matter; FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory; FAST 3, Change over Time—Unit 4, Life on Earth.
• Scientific ideas about elements were borrowed from some Greek philosophers of 2,000 years earlier, who believed that everything was made from four basic substances; air, earth, fire, and water. It was the combination the these "elements" in different proportions that gave other substances their observable properties. The Greeks were wrong about those four, but now over 100 different elements have been identified, some rare and some plentiful, out of which everything is made. Because most elements tend to combine with others, few elements are found in their pure form.	FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory; FAST 3, Change over Time—Unit 4, Life on Earth.
• There are groups of elements that have similar properties, including highly reactive metals, less reactive metals, highly reactive nonmetals (such as chlorine, fluorine, and oxygen), and some almost completely nonreactive gases (such as helium and neon). An especially important kind of reaction between substances involves combination of oxygen with something else—as in burning or rusting. Some elements don't fit into any of the categories; among them are carbon and hydrogen, essential elements of living matter.	FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory; FAST 3, Change over Time—Unit 4, Life on Earth.
• No matter how substances within a closed system interact with one another, or how they combine or break apart, the total weight of the system remains the same. The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same.	FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory; E Unit 3, Cycling of Matter; FAST 3, Change over Time—Unit 4, Life on Earth.
4E. Energy Transformations • Energy cannot be created or destroyed, but only changed from one form to another.	FAST 1, The Local Environment—PS Unit 3, Temperature and Heat
• Most of what goes on in the universe—from exploding stars and biological growth to the operation of machines and the motion of people—involves some form of energy being transformed into another. Energy in the form of heat is almost always one of the products of an energy transformation.	FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time
• Heat can be transferred through materials by the collisions of atoms across space by radiation. If the material is fluid, currents will be set up in it that aid the transfer of heat.	FAST 1, The Local Environment—PS Unit 3, Temperature and Heat; FAST 2, Matter & Energy in the Biosphere—PS Unit 1, Light and Heat; PS Unit 3, A Model of Matter.
• Energy appears in different forms. Heat energy is in the disorderly motion of molecules and radiation; chemical energy is in the arrangement of atoms; mechanical energy is in moving bodies or in elasticity distorted shapes; gravitational energy is in the separation of mutually attracting masses.	FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time.

4F. Motion	
• Light from the sun is made up of a mixture of many different colors of light, even though to the eye the light looks almost white. Other things that give off or reflect light have a different mix of colors.	FAST 2, Matter & Energy in the Biosphere—PS Unit 1, Light and Heat; E Unit 1, Primary Production; FAST 3, Change over Time—Unit 3, The Changing Universe.
• Something can be "seen" when light waves emitted or reflected by it enter the eye—just as something can be "heard" when sound waves from it enter the ear.	FAST 2, Matter & Energy in the Biosphere—PS Unit 1, Light and Heat; E Unit 1, Primary Production; FAST 3, Change over Time—Unit 3, The Changing Universe.
• An unbalanced force acting on an object changes its speed or path of motion, or both. If the force acts towards a single center, the objects path may curve into an orbit around the center.	FAST 3, Change over Time—Unit 1, Force, Work, and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift.
• Vibrations in materials set up wavelike disturbances that spread away from the source. Sound and earthquake waves are examples. These and other waves move at different speeds in different materials.	FAST 2, Matter and Energy in the Biosphere—PS Unit 3, A Model of Matter; FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift.
• Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation—visible light. Differences of wavelength within that range are perceived as differences in color.	FAST 2, Matter & Energy in the Biosphere—PS Unit 1, Light and Heat; FAST 3, Change over Time—Unit 3, The Changing Universe.

4G. Forces of Nature • Every object exerts gravitational force on every other object. The force depends on how much mass the objects have and on how far apart they are. The force is hard to detect unless at least one of the objects has a lot of mass.	FAST 3, Change over Time—Unit 1, Force, Work and Energy; Unit 2, The Changing Earth; Unit 3, The Changing Universe.
• The sun's gravitational pull holds the earth and other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them.	FAST 3, Change over Time—Unit 3, The Changing Universe.
• Electric currents and magnets can exert a force on each other.	

5. The Living Environment

5A. Diversity of Life • One of the most general distinctions among organisms is between plants, which use sunlight to make their own food, and animals, which consume energy-rich foods. Some kinds of organisms, many of them microscopic, cannot be neatly classified as either plants or animals.	FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time
• Animals and plants have a great variety of body plans and internal structures that contribute to their being able to make or find food and reproduce.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift.
• Similarities among organisms are found in internal anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more important than behavior or general appearance.	
• For sexually reproducing organisms, a species comprises all organisms that can mate with one another to produce fertile offspring.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems.
• All organisms, including the human species, are part of and depend on two main interconnected global food webs. One includes microscopic ocean plants, the animals that feed on them, and finally the animals that feed on those animals. The other web includes land plants, the animals that feed on them, and so forth. The cycles continue indefinitely because organisms decompose after death to return food material to the environment.	FAST 2, Matter & Energy in the Biosphere; FAST 3, Change over Time
5B. Heredity • In some kinds of organisms, all the genes come from a single parent, whereas in organisms that have sexes, typically half of the genes come from each parent.	
• In sexual reproduction, a single specialized cell from a female merges with a specialized cell from a male. As the fertilized egg, carrying genetic information from each parent, multiplies to form the complete organism with about a trillion cells, the same genetic information is copied in each cell.	
• New varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits.	FAST 1, The Local Environment—E Unit 1, Plant Growth; E Unit 3, Animal Care; E Unit 4, Field Ecology; FAST 2, Matter & Energy in the Biosphere—RS Unit 1, Productivity Project; FAST 3, Change over Time—Unit 4, Life on Earth; Unit 6, Changing Ecosystems.

5C. Cells • All living things are composed of cells, from just one to many millions, whose details usually are visible only through a microscope. Different body tissues and organs are made up of two different kinds of cells. The cells in similar tissues and organs in other animals are similar to those in human beings but differ somewhat from cells found in plants. • Cells continually divide to make more cells for growth and repair. Various organs and tissues function to serve the needs of cells for food, air, and waste removal. • Within cells, many of the basic functions of organisms—such as extracting energy from food and getting rid of waste—are carried out. The way in which cells function is similar in all living organisms. • About two thirds of the weight of cells is accounted for by water, which gives cells many of their properties.	
5D. Interdependence of Life In all environments—freshwater, marine, forest, desert, grassland, mountain, and others—organisms with similar needs may compete with one another for resources, including food, space, water, air and shelter. In any particular environment, the growth and survival of organisms depend on the physical conditions. • Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other.	FAST 1, The Local Environment—E Unit 4, Field Ecology; FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment. FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems.
5E. Flow of Matter and Energy • Food provides the fuel and the building material for all organisms. Plants use the energy from light to make sugars from carbon dioxide and water. This food can be used immediately or stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms. • Over a long time, matter is transformed from one organism to another repeatedly and between organisms and their physical environment. As in all material systems, the total amount of matter remains constant, even though its form and location change. • Energy can change from one form to another in living things. Animals get energy from oxidizing their food, releasing some of its energy as heat. Almost all food energy comes originally from sunlight.	FAST 2, Matter & Energy in the Biosphere FAST 2, Matter & Energy in the Biosphere FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time

5F. Evolution of Life	
• Small differences between parents and offspring can accumulate (through selective breeding) in successive generations so that descendants are very different from their ancestors.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems.
• Individual organisms with certain traits are more likely than others to survive and have offspring. Changes in environmental conditions can affect the survival of individual organisms and entire species.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems.
• Many thousands of layers of sedimentary rock provide evidence for the long history of the earth and for the long history of changing life forms whose remains are found in the rocks. More recently deposited rock layers are more likely to contain fossils resembling existing species.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems.

6. The Human Organism

6A. Human Identity	
• Like other animals, human beings have body systems for obtaining and providing energy, defense, reproduction, and the coordination of body functions.	FAST 1, The Local Environment FAST 3, Change over Time.
• Human beings have many similarities and differences. The similarities make it possible for human beings to reproduce and to donate blood and organs to one another throughout the world. Their differences enable them to create diverse social and cultural arrangements and to solve problems in a variety of ways.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment.
• Fossil evidence is consistent with the idea that human beings evolved from earlier species.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems.
• Specialized rules of individuals within other species are genetically programmed, whereas human beings are able to invent and modify a wide range of social behavior.	
• Human beings use technology to match or excel many of the abilities of other species. Technology has helped people with disabilities survive and live more conventional lives.	FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time
• Technologies having to do with food production, sanitation, and disease prevention have dramatically changed how people live and work and have resulted in rapid increases in the human population.	FAST 1, The Local Environment—RS Unit 1, Air Pollution; RS Unit 2, Water Resource Management; FAST 2, Matter & Energy in the Biosphere—RS Unit 2, World Food Production; FAST 3, Change over Time—Unit 4, Life on Earth; Unit 7, Humans in the Environment.
6B. Human Development	
• Fertilization occurs when the sperm cells from a male's testes are deposited near an egg cell from the female ovary, and one of the sperm cells enters the egg cell. Most of the time, by chance or design, a sperm never arrives or an egg isn't available.	FAST Human Biology Supplement (optional)
• Contraception measures may incapacitate sperm, block their way to the egg, prevent the release of eggs, or prevent the fertilized egg from implanting successfully.	

6B. Human Development (continued) • Following fertilization, cell division produces a small cluster of cells that then differentiate by appearance and function to form the basic tissues of an embryo. During the first three months of pregnancy, organs begin to form. During the second three months, all organs and body features develop. During the last three months, the organs and features mature enough to function well after birth. Patterns of human development are similar to those of other vertebrates. The developing embryo—and later the newborn infant—encounters many risks from faults in its genes, its mother's inadequate diet, her cigarette smoking or use of alcohol or other drugs, or from infection. Inadequate child care may lead to lower physical and mental ability. • Various body changes occur as adults age. Muscles and joints become less flexible, bones and muscles lose mass, energy levels diminish, and the senses become less acute. Women stop releasing eggs and hence can no longer reproduce. The length and quality of human life are influenced by many factors, including sanitation, diet, medical care, sex, genes, environmental conditions, and personal health behaviors.	FAST Human Biology Supplement (optional)
6C. Basic Functions • Organs and organ systems are composed of cells and help to provide all cells with basic needs. • For the body to use fuel for energy and building materials, the food must first be digested into molecules that are absorbed and transported to cells. • To burn food for the release of energy stored in it, oxygen must be supplied to cells, and carbon dioxide removed. Lungs take in oxygen for the combustion of food and they eliminate the carbon dioxide produced. The urinary system disposes of dissolved water molecules, the internal tract removes solid wastes, and the skin and lungs rid the body of heat energy. The circulatory system moves all these substances to or from cells where they are needed or produced, responding to changing demands. • Specialized cells and the molecules they produce identify and destroy microbes that get inside the body. • Hormones are chemicals from glands that affect other body parts. They are involved in helping the body respond to danger and in regulating human growth, development, and reproduction. • Interactions among the senses, nerves, and brain make possible the learning that enables human beings to cope with changes in their environment.	FAST Human Biology Supplement (optional)

6D. Learning • Some animal species are limited to a repertoire of genetically determined behaviors; others have more complex brains and can learn a wide variety of behaviors. All behavior is affected by both inheritance and experience. • The level of skill a person can reach in any particular level of activity depends on innate abilities, the amount of practice, and the use of appropriate learning technologies. • Human beings can detect a tremendous range of visual and olfactory stimuli. The strongest stimulus they can tolerate may be more than a trillion times as intense as the weakest they can detect. Still, there are many kinds of signals in the world that people cannot detect directly. • Attending closely to any one input of information usually reduces the ability to attend at the same time. • Learning often results from two perceptions or actions occurring at about the same time. The more often the same combination occurs, the stronger the mental connection between them is likely to be. Occasionally a single vivid experience will connect two things permanently in people's minds. • Language and tools enable human beings to learn complicated and varied things from others.	
6E. Physical Health • The amount of food energy (calories) a person requires varies with body weight, age, sex, activity level, and natural body efficiency. Regular exercise is important to maintain a healthy heart/lung system, good muscle tone, and bone strength. • Toxic carbons, some dietary habits, and personal behavior may be bad for one's health. Some effects show up right away, others may not show up for many years. Avoiding toxic substances, such as tobacco, and changing dietary habits to reduce the intake of such things as animal fat increases the chances of living longer. • Viruses, bacteria, fungi, and parasites may infect the human body and interfere with normal body functions. A person can catch a cold many times because there are many varieties of cold viruses that cause similar symptoms. • White blood cells engulf invaders or produce antibodies that attack them or mark them for killing by other white cells. The antibodies produced will remain and can fight off subsequent invaders of the same kind. • The environment may contain dangerous levels of substances that are harmful to human beings. Therefore, the good health of individuals requires monitoring the soil, air, and water taking steps to keep them safe.	FAST 2, Matter & Energy in the Biosphere—E Unit 1, Primary Production; E Unit 2, Respiration. FAST 1, The Local Environment—RS Unit 1, Air Pollution; RS Unit 2, Water Resource Management.
6F. Mental Health • Individuals differ greatly in their ability to cope with stressful situations. Both external and internal conditions (chemistry, personal history, values) influence how people behave. • Often people react to mental distress by denying that they have any problem. Sometimes they don't know why they feel the way they do, but with help they can sometimes uncover the reasons.	

7. Human Society

7A. Cultural Effects on Behavior • Each culture has distinctive patterns of behavior, usually practiced by most of the people who grew up in it. • Within a large society, there may be many groups, with distinctly different subcultures associated with region, ethnic origin, or social class. • Although within any society there is usually broad general agreement on what behavior is unacceptable, the standards used to judge behavior vary for different settings and different subgroups, and they may change with time and different political and economic conditions. Moreover, the punishments vary widely among, and even within different societies. • Technology, especially in transportation and communication, is increasingly important in spreading ideas, values, and behavior patterns within a society and among different societies. New technology can change cultural values and social behavior.	FAST 3, Change over Time—Unit 7, Humans in the Environment. FAST 3, Change over Time—Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment. FAST 3, Change over Time
7B. Group Behavior • Affiliation with a group can increase the power of members through pooled resources and concerted action. Joining a group often has personal advantages, such as companionship, a sense of identity, and recognition by others inside and outside the group. Group identity may create a feeling of superiority, which increases group cohesion but may also entail hostility toward other groups. • People sometimes react to all members of a group as though they were the same and perceive in their behavior only those qualities that fit preconceptions of the group. Such stereotyping leads to uncritical judgments, such as showing blind respect for members of some groups and equally blind disrespect for some members of other groups.	
7C. Social Change • Some aspects of family and community life are the same now as they were a generation ago, but some aspects are very different. What is taught in school and school policies toward student behavior have changed over the years in response to family and community pressures. • By the way they depict the ideas and customs of one culture, communications media may stimulate changes in others. • Migration, conquest, and natural disasters have been major factors in causing social and cultural change.	FAST 3, Change over Time—Unit 7, Humans in the Environment.

7D. Social Trade-Offs • There are trade-offs that each person must consider in making choices—about personal popularity, health, family relations, and education, for example—that often have life-long consequences. • One common aspect of all social trade-offs pits personal benefit and the rights of the individual, on one side, against the social good and the rights of society, on the other. • Trade-offs are not always between desirable possibilities. Sometimes social and personal trade-offs require accepting an unwanted outcome to avoid some other unwanted one.	
7E. Political and Economic Systems • Government provides some goods and services through its own agencies and some through contracts with private individuals or businesses. To pay for the goods and services, government must obtain money by taxing people or by borrowing the money. • Government leaders come into power by election, appointment, or force. • However they are formed, governments usually have most of the power to make, interpret, and enforce the rules and decisions that determine how a community, state, or nation will be run. Many of the rules established by governments are designed to reduce social conflict. The rules affect a wide range of human affairs, from marriage and education to scientific research and commerce. • In a central-planning model, a single authority, usually a national government, decides what to produce, how to produce it, and for whom. In a free-market model, consumers and producers (individually or in organizations) make these decisions based on what they believe will benefit themselves. No real-world economy is a pure example of either model; all economies have some features of each kind.	FAST 2, Matter & Energy in the Biosphere—RS Unit 2, World Food Production; FAST 3, Change over Time—Unit 7, Humans in the Environment.
7F. Social Conflict • Being a member of a group can increase an individual's social power or hostile actions against other individuals. It may also subject that person to the hostility of people who are outside the group. • Most groups have formal or informal procedures for arbitrating disputes among their members.	FAST 3, Change over Time—Unit 7, Humans in the Environment.

7G. Global Interdependence • Trade between nations occurs when natural resources are unevenly distributed and the costs of production are very different in different countries. A nation has a trade opportunity whenever it can create more of a product or service at lower cost than another. • The major ways to promote economic health are to encourage technological development, to increase the quantity or quality of a nation's productive resources—more or better-trained worker's, better equipment and methods—and to engage in trade with other nations.	FAST 2, Matter & Energy in the Biosphere—RS Unit 2, World Food Production; FAST 3, Change over Time—Unit 7, Humans in the Environment.

7G. Global Interdependence (continued) • The purpose of treaties being negotiated directly between individual countries or by international organizations is to bring about cooperation among countries. • Scientists are linked to other scientists worldwide both personally and through international scientific organizations. • The global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and population.	FAST 2, Matter & Energy in the Biosphere—RS Unit 2, World Food Production. FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time

8. The Designed World

8A. Agriculture • Early in human history, there was an agricultural revolution in which people changed from hunting and gathering to farming. This allowed changes in the division of labor between men and women and between children and adults, and the development of new patterns of government.	FAST 3, Change over Time—Unit 7, Humans in the Environment.
• People control the characteristics of plants and animals they raise by selective breeding and by preserving varieties of seeds (old and new) to use if growing conditions change. • In agriculture, as in all technologies, there are always trade offs to be made. Getting food from many different places makes people less dependent on weather in any one place, yet more dependent on transportation and communication among far-flung markets. Specializing in one crop may risk disaster if changes in weather or increase in populations wipe out that crop. Also, the soil may be exhausted of some nutrients, which can be replenished by rotating the right crops.	FAST 1, The Local Environment—E Unit 1, Plant Growth; E Unit 3, Animal Care; FAST 2, Matter & Energy in the Biosphere—RS Unit 1, Productivity Project; RS Unit 2, World Food Production; Change over Time—Unit 4, Life on Earth; Unit 7, Humans in the Environment.
• Many people work to bring food, fiber, and fuel to US markets. With improved technology, only a small fraction of workers in the United States actually plant and harvest the produce that people use. Most workers are engaged in processing, packaging, transporting, and selling what is produced.	FAST 3, Change over Time—Unit 7, Humans in the Environment
8B. Material and Manufacturing • The choice of materials for a job depends on their properties and on how they interact with other materials. Similarly, the usefulness of some manufactured parts of an object depends on how well they fit together with the other parts. • Manufacturing usually involves a series of steps, such as designing a product, obtaining and preparing raw materials, processing the materials mechanically or chemically, and assembling, testing, inspecting, and packaging. The sequence of these steps is also often important.	FAST 1, The Local Environment—Submarine Project; Weather Balloon Project; Solar Heating Project; Field Mapping; FAST 2, Matter & Energy in the Biosphere—Solar Constant Project; A Model of Heat; FAST 3, Change over Time—Energy Conversion Project; Organism Design Project.
• Modern technology reduces manufacturing costs, produces more uniform products, and creates new synthetic materials that can help reduce the depletion of some natural resources.	FAST 3, Change over Time—Unit 7, Humans in the Environment.

8B. Material and Manufacturing (continued) • Automation, including the use of robots, has changed the nature of work on most fields, including manufacturing. As a result, high skill, high-knowledge jobs in engineering, computer programming, quality control, supervision, and maintenance are replacing many routine, manual-labor jobs. Workers therefore need better learning skills and flexibility to take on new and rapidly changing jobs.	
8C. Energy Sources and Use	
• Energy can change from one form to another, although in the process some energy is always converted to heat. Some systems transform energy with less loss of heat than others.	FAST 1, The Local Environment—PS Unit 3, Temperature and Heat; FAST 2, Matter & Energy in the Biosphere; FAST 3, Change over Time.
• Different ways of obtaining, transforming, and distributing energy have different environmental consequences.	FAST 3, Change over Time—Unit 7, Humans in the Environment.
• In many instances, manufacturing and other technological activities are performed at a site close to an energy source. Some forms of energy are transported easily, others are not.	
• Electrical energy can be produced from a variety of energy sources and can be transformed into almost any other form of energy. Moreover, electricity is used to distribute energy quickly and conveniently to distant locations.	FAST 3, Change over Time—Unit 1, Force, Work, & Energy; Unit 7, Humans in the Environment.
• Energy from the sun (and the wind and water energy derived from it) is available indefinitely. Because the flow of energy is weak and variable, very large collection systems are needed. Other sources don't renew or renew only slowly.	FAST 2, Matter & Energy in the Biosphere; FAST 3, Change over Time.
• Different parts of the world have different amounts and kinds of energy resources to use and use them for different purposes.	FAST 2, Matter & Energy in the Biosphere; FAST 3, Change over Time.

8D. Communications • Errors in coding, transmitting, or decoding information, and some means of checking for accuracy is needed. Repeating the message is a frequently used method. • Information can be carried by many media, including sound, light, and objects. In this century, the ability to code information as electric currents in wires, electromagnetic waves in space, and light in glass fibers has made communication millions of times faster than is possible by mail or sound.	 FAST 3, Change over Time—Unit 3, The Changing Universe.
8E. Information Processing • Most computers use digital codes containing only two symbols, 0 and 1, to perform all operations. Continuous signals (analog) must be transformed into digital codes before they can be processed by a computer. • What use can be made of a large collection of information depends upon how it is organized. One of the values of computers is that they are able, on command, to recognize information in a variety of ways, thereby enabling people to make more and better uses of the collection. • Computer control of mechanical systems can be much quicker than human control. In situations where events happen faster than people can react, there is little choice but to rely on computers. Most complex systems still require human oversight, however, to make certain kinds of judgments about the readiness of the parts of the system (including the computers) and the system as a whole to operate properly, to react to unexpected failures, and to evaluate how well the system is serving its intended purposes. • An increasing number of people work at jobs that involve processing or distributing information. Because computers can do these tasks faster and more reliably, they have become standard tools both in the workplace and at home.	
8F. Health Technology • Sanitation measures such as the use of sewers, landfills, quarantines, and safe food handling are important in controlling the spread of organisms that cause disease. Improving sanitation to prevent disease has contributed more to saving human life than any advance in medical treatment. • The ability to measure the level of substance in body fluids has made it possible for physicians to make comparisons with normal levels, make very sophisticated diagnoses, and monitor the effects of the treatments they prescribe. • It is becoming increasingly possible to manufacture chemical substances such as insulin and hormones that are normally found in the body. They can be used by individuals whose own bodies cannot produce the amounts required for good health.	FAST 1, The Local Environment—RS Unit 1, Air Pollution; RS Unit 2, Water Resource Management; FAST 2, Matter & Energy in the Biosphere—Chromatography; FAST 3, Change over Time—Unit 4, Life on Earth. FAST 3, Change over Time—Unit 4, Life on Earth.

9. The Mathematical World

9A. Numbers • There have been systems for writing numbers other than the Arabic system of place values based on tens. The very old Roman numerals are now used only for dates, clock faces, or ordering chapters in a book. Numbers based on 60 are still used for describing time and angles. • A number line can be extended on the other side of zero to represent *negative numbers*. Negative numbers allow subtraction of a bigger number from a smaller number to make sense, and are often used when something can be measured on either side of some reference point (time, ground level, temperature, budget). • Numbers can be written in different forms, depending on how they are being used. How fractions or decimals based on *measured* quantities should be written depends on how precise an answer is needed. • The operations + and - are inverses of each other—one undoes what the other does; likewise x and ÷. • The expression *a/b* can mean different things; *a* parts of size *1/b* each, *a* divided by *b*, or *a* compared to *b*. • Numbers can be represented by using sequences of only two symbols (such as 1 and 0, on and off); computers work this way. • Computations (as on calculators) can give more digits than make sense or are useful.	FAST 3, Change over Time—Scientific notation.
9B. Symbolic Relationships • An equation containing a variable may be true for just one value of the variable. • Mathematical statements can be used to describe how one quantity changes. Rates of change can be computed from differences in magnitudes and vice versa. • Graphs can show a variety of possible relationships between two variables. As one variable increases uniformly, the other may do one of the following: increase or decrease steadily, increase or decrease faster and faster, get closer and closer to some limiting value, reach some intermediate maximum or minimum, alternately increase and decrease indefinitely, increase or decrease in steps, or do something different from any of these.	FAST 1, The Local Environment—density, heat, population sampling; FAST 2, Matter & Energy in the Biosphere—heat, chemical equations; FAST 3, Change over Time—force, work, energy, gravitation, mechanical equivalent of heat, heat of fusion. FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time
9C. Shapes • Some shapes have special properties: Triangular shapes tend to make structures rigid, and round shapes give the least possible boundary for a given amount of interior area. Shapes can match exactly or have the same shape in different sizes. • Lines can be parallel, perpendicular, or oblique. • Shapes on a sphere like the earth cannot be depicted on a flat surface without some distortion.	FAST 1, The Local Environment—Field Mapping; FAST 3, Change over Time—The Changing Earth.

9C. Shapes (continued) • The graphic display of numbers may help to show patterns such as trends, varying rates of change, gaps, or clusters. Such patterns sometimes can be used to make predictions about the phenomena being graphed. • It takes two numbers to locate a point on a map or any other flat surface. The numbers may be two perpendicular distances from a point, or an angle and a distance from a point. • The scale chosen for a graph or drawing makes a big difference in how useful it is.	FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time FAST 1, The Local Environment—E Unit 4, Field Ecology; FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 5, Continental Drift. FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time
9D. Uncertainty • How probability is estimated depends on what is known about the situation. Estimates can be based on data from similar conditions in the past or on the assumption that all the possibilities are known. • Probabilities are ratios and can be expressed as fractions, percentages, or odds. • The mean, median, and mode tell different things about the middle of a data set. • Comparison of data from two groups should involve comparing both their middles and the spreads around them. • The larger a well-chosen sample is, the more accurately it is likely to represent the whole. But there are many ways of choosing a sample that can make it unrepresentative of the whole. • Events can be described in terms of being more or less likely, impossible, or certain.	FAST 1, The Local Environment; FAST 2, Matter & Energy in the Biosphere; FAST 3, Change over Time—uncertainty in measurement, estimation of measurements. FAST 1, The Local Environment—density, humidity, population sampling; FAST 2, Matter & Energy in the Biosphere—RS Unit 1, Productivity Project; FAST 3, Change over Time.
9E. Reasoning • Some aspects of reasoning have fairly rigid rules for what makes sense; other aspects don't. If people have rules that always hold, and good information about a particular situation, then logic can help them to figure out what is true about it. This kind of reasoning requires care in the use of key words such as *if, and, not, or, all* , and *some*. Reasoning by similarities can suggest ideas but can't prove them one way or the other. • Practical reasoning, such as diagnosing or troubleshooting almost anything, may require many-step, branching logic. Because computers can keep track of complicated logic, as well as a lot of information, they are useful in a lot of problem-solving situations. • Sometimes people invent a general rule to explain how something works by summarizing observations. But people tend to over generalize, imagining general rules on the basis of only a few observations. • People are using incorrect logic when they make a statement such as "If A is true, then B is true; but A isn't true, therefore B isn't true either."	Throughout all three courses in FAST students are constantly engaged in reasoning. They analyze the data from their investigations for patterns and relationships and then use this information to create generalizations and explanations. Explanations in FAST as in science are always tentative and subject to change with new data or new interpretations of old data. In FAST students are engaged in a search for universal explanations which can account for the greatest number of observed phenomena. Students are also engaged in reasoning as they design and carry out their individual and group experiments. Valid experimental designs take time to reason out to be better assured that the interpretation of results is adequately based on evidence. Students are engaged in inventing their own instruments and creating technology projects such as the submarine (FAST 1), the solar constant measuring device (FAST 2), and the astrolabe and sunscope (FAST 3). The test of the adequacy of these inventions is whether they work for the purpose intended. If not, students must apply reasoning skills to adjust, adapt, and improve on their original designs.

9E. Reasoning (continued) • A single example can never prove that something is true, but sometimes a single example can prove that something is not true. • An analogy has some likenesses to but also some differences from the real thing.	In their search for universal explanations, FAST students rely on replication of experimental results in their own investigations and those of their classmates. Introduction and identification of anomalies is central to the FAST instructional system since such anomalies challenge existing ideas, interpretations, and generalizations and force students to carefully examine their current knowledge. Analogies are used throughout FAST investigations. Identifying similarities and differences and creating models is often enhanced by the use of analogy. This is particularly evident in FAST 1 and 2 in the search for a model of heat.

10. Historical Perspectives

10A. Displacing the Earth from the Center of the Universe • The motion of an object is always judged with respect to some other object or point and so the idea of absolute motion or rest is misleading. • Telescopes reveal that there are many more stars in the night sky than are evident to the unaided eye, the surface of the moon has many craters and mountains, the sun has dark spots, and Jupiter and some other planets have their own moons.	FAST 3, Change over Time—Unit 3, The Changing Universe. FAST 3, Change over Time—Unit 3, The Changing Universe.
10B. Uniting the Heavens and the Earth No benchmarks for grades 6–8.	FAST 3, Change over Time—Unit 3, The Changing Universe.
10C. Relating Matter & Energy and Time & Space No benchmarks for grades 6–8.	FAST 3, Change over Time.
10D. Extending Time No benchmarks for grades 6–8.	FAST 3, Change over Time
10E. Moving Continents No benchmarks for grades 68.	FAST 3, Change over Time—Unit 5, Continental Drift

10F. Understanding Fire • From the earliest times until now, people have believed that even though millions of different kinds of material seem to exist in the world, most things must be made up of combinations of just a few basic kinds of things. There has not always been agreement, however, on what those basic kinds of things are. One theory long ago was that the basic substances were earth, water, air, and fire. Scientists now know that these are not the basic substances. But the old theory seemed to explain many observations about the world. • Today, scientists are still working out the details of what the basic kinds of matter are and of how they combine, or can be made to combine, to make other substances. • Experimental and theoretical work done by French scientist Antoine Lavoisier in the decade between the American and French revolution led to the modern science of chemistry. • Lavoiser's work was based on the idea that when materials react with each other many changes can take place but that in every case the total amount of matter afterward is the same as before. He successfully tested the concept of conservation of matter by conducting a series of experiments in which he carefully measured all the substances involved in burning, including the gases used and those given off. • Alchemy was chiefly an effort to change base metals like lead into gold and to produce an elixir that would enable people to live forever. It failed to do that or to create much knowledge of how substances react with each other. The more scientific study of chemistry that began in Lavoisier's time has gone far beyond alchemy in understanding reactions and producing new materials.	FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory. FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory; PS Unit 3, A Model of Matter; FAST 3, Change over Time—Unit 4, Life on Earth. FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory; PS Unit 3, A Model of Matter; FAST 3, Change over Time—Unit 4, Life on Earth.
10G. Splitting the Atom • The accidental discovery that minerals containing uranium darken photographic film, as light does, led to the idea of radioactivity. • In their laboratory in France, Marie Curie and her husband, Pierre Curie, isolated two new elements that caused most of the radioactivity of the uranium mineral. They named one radium because it gave off powerful, invisible rays, and the other polonium in honor of Madame Curie's country of birth. Marie Curie was the first scientist ever to win the Nobel prize in two different fields—in physics shared with her husband, and later in chemistry.	
10H. Explaining the Diversity of Life No benchmarks for grades 6–8.	FAST 3, Change over Time—Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems.

10I. Discovering Germs • Throughout history, people have created explanations for disease. Some have held spiritual causes, but the most persistent biological theory over the centuries was that illness resulted from an imbalance in the body fluids. The introduction of germ theory by Louis Pasteur and others in the 19th century led to the modern belief that many diseases are caused by microorganisms—bacteria, viruses, yeasts, and parasites. • Pasteur wanted to find out what causes milk and wine to spoil. He demonstrated that spoilage and fermentation occur when microorganisms enter from the air, multiply rapidly, and produce waste products. After showing that spoilage could be avoided by keeping germs out or by destroying them with heat, he investigated animal diseases and showed that microorganisms were involved. Other investigations later showed that specific kinds of germs caused specific diseases. • Pasteur found that infection by disease organisms—germs—caused the body to build up an immunity against subsequent infection by the same organism. He then demonstrated that it was possible to produce vaccines that would induce the body to build immunity to a disease without actually causing the disease itself. • Changes in health practices have resulted from the acceptance of the germ theory of disease. Before germ theory, illness was treated by appeals to supernatural powers or by trying to adjust body fluids through induced vomiting, bleeding, or purging. The modern approach emphasizes sanitation, the safe handling of food and water, the pasteurization of milk, quarantine, and aseptic surgical techniques to keep germs out of the body; vaccinations to strengthen the body's immune system against subsequent infection by the same kind of microorganisms; and processes to destroy microorganisms. • In medicine, as in other fields of science, discoveries are sometimes made unexpectedly, even by accident. But knowledge and creative insight are usually required to recognize the meaning of the unexpected.	
10J. Harnessing Power • Until the 1800's, most manufacturing was done in homes, using small, handmade machines that were powered by muscle, wind, or running water. New machinery and steam engines to drive them made it possible to replace craftsmanship with factories, using fuels to replace human and animal labor. In the factory system, workers, materials, and energy could be brought together efficiently. • The invention of the steam engine was at the center of the Industrial Revolution. It converted the chemical energy stored in coal, which was plentiful, into mechanical work. The steam engine was invented to solve the urgent problem of pumping water out of the coal mines. As improved by James Watt, it was soon used to move coal, drive manufacturing machinery, and power locomotives, ships, and even the first automobiles.	FAST 3, Change over Time—Unit 7, Humans in the Environment. FAST 3, Change over Time—Unit 7, Humans in the Environment.

11. Common Themes

11A. Systems • A system can include processes as well as things. • Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts. Such feedback can serve to control what goes on in the system as a whole. • Any system is usually connected to other systems, both internally and externally. Thus a system may be thought of as containing subsystems and as being a subsystem of a larger system.	Systems is a common unifying theme throughout FAST 1, The Local Environment, FAST 2, Matter & Energy in the Biosphere, and FAST 3, Change over Time. FAST 2 and FAST 3 make extensive use of systems analysis diagrams to help organize thinking and make predictions about interactions of matter and energy.
11B. Models • Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or that are too vast to be changed deliberately, or that are potentially dangerous. • Mathematical models can be displayed on a computer and then modified to see what happens. • Different models can be used to represent the same thing. What kind of a model to use and how complex it should be depends on its purpose. The usefulness of a model may be limited if it is too simple or if it is needlessly complicated. Choosing a useful model is one of the instances in which intuition and creativity come into play in science, mathematics, and engineering.	The concept of model is introduced in FAST 1, The Local Environment in investigations of weather and the water cycle in the ecology strand and in investigations of heat energy in physical science. The concept is expanded in the relational study units on air pollution and water resource management. Models becomes a major organizing theme of FAST 2, Matter & Energy in the Biosphere (model of heat, model of light, model of matter, systems analysis models of producers, consumers, and decomposers) and FAST 3, Change over Time (model of heat, models of Earth, cosmological models, models of stellar evolution, models of organisms, molecular models, models of Earth change, models of ecosystems, and models of human interaction with ecosystems).
11C. Constancy and Change • Physical and biological systems tend to change until they become stable and then remain that way unless their surroundings change. • A system may stay the same because nothing is happening or because things are happening but exactly counterbalance one another. • Many systems contain feedback mechanisms that serve to keep changes within specified limits. • Symbolic equations can be used to summarize how the quantity of something changes over time or in response to other changes. • Symmetry (or the lack of it) may determine properties of many objects, from molecules and crystals to organisms and designed structures. • Things that change in cycles, such as the seasons or body temperature, can be described by their cycle length or frequency, what the highest and lowest values are, and when they occur. Different cycles range from many thousands of years down to less than a billionth of a second.	FAST 1, The Local Environment—Unit 4, Field Ecology; FAST 2, Matter & Energy in the Biosphere—E Unit 3, The Cycling of Matter; RS Unit 1, Productivity Project; FAST 3, Change over Time—Unit 2, The Changing Earth; Unit 3, The Changing Universe; Unit 4, Life on Earth; Unit 5, Continental Drift; Unit 6, Changing Ecosystems; Unit 7, Humans in the Environment. FAST 2, Matter & Energy in the Biosphere—PS Unit 2, Evidence for an Atomic Theory; E Unit 1, Primary Production. FAST 2, Matter & Energy in the Biosphere—crystal growing; FAST 3, Change over Time—molecular models. FAST 1, The Local Environment—life cycles, water cycle; FAST 2, Matter & Energy in the Biosphere—cycling of matter & flow of energy; FAST 3, Change over Time—geologic cycles, stellar life cycles, cosmological models, changing ecosystems, biological cycles.

11D. Scale • Properties of systems that depend on volume, such as capacity and weight, change out of proportion to properties that depend on area, such as strength or surface processes. • As the complexity of any system increases, gaining an understanding of it depends increasingly on summaries, such as averages and ranges, and on descriptions of typical examples of that system.	FAST 1, The Local Environment FAST 2, Matter & Energy in the Biosphere FAST 3, Change over Time.

12. Habits of Mind

12A. Values and Attitudes • Know why it is important in science to keep honest, clear, and accurate records. • Know that hypotheses are valuable, even if they turn out not to be true, if they lead to fruitful investigations. • Know that often different explanations can be given for the same evidence, and it is not always possible to tell which one is correct.	As in science, such values and attitudes are developed and established in FAST 1, The Local Environment, FAST 2, Matter & Energy in the Biosphere, and FAST 3, Change over Time. Students develop their own texts out of the investigations they do and the data they collect, analyze, interpret, and draw conclusions from.
12B. Computation and Estimation • Find what percentage one number is of another and figure any percentage of any number. • Use, interpret, and compare numbers in several equivalent forms such integers, fractions, decimals, and percents. • Calculate the circumference and areas of rectangles, triangles, and circles and the volumes of rectangular solids. • Find the mean and median of a set of data. • Estimate distances and travel times from maps and the actual size of objects from scale drawings. • Insert instructions into computer spreadsheet cells to program arithmetic calculations. • Determine what unit (such as seconds, square inches, or dollars per tankful) an answer should be expressed in from the units of the inputs to the calculation, and be able to convert compound units (such as yen per dollar per yen, or miles per hour into feet per second). • Decide what degree of precision is adequate and round off the result of calculator operations to enough significant figures to reasonably reflect those of the inputs. • Express numbers like 199, 1,000, and 1,000,000 as powers of 10. • Estimate probabilities of outcomes in familiar situations, on the basis of history or the number of possible outcomes.	Measurement, computation, and estimation are integral parts of all three courses in FAST. Emphasis is placed on developing laboratory skills of measuring distance, mass, area, volume, temperature, time, rainfall, humidity, vapor pressure, transpiration, energy transfer, rates of change, heat, work, force, specific heat, solar constant, movement of the sun, moon, planets, and constellations, and so on. Students construct and calibrate many of their own instruments such as those for field mapping, measuring the solar constant, force scale, and many others. The CGS challenge game is used to help students improve their estimating skills.
12C. Manipulation and Observation • Use calculators to compare amounts proportionally. • Use computers to store and retrieve information in topical, alphabetical, numerical, and key-word files, and create simple files of their own devising. • Read analog and digital meters on instruments used to make direct measurements of length, volume, weight, elapsed time, rates, and temperature, and choose appropriate units for reporting various magnitudes.	Calculators and computers are used in FAST as available. Computer software is available for student data management, student assessment, and simulations. Students develop all of their basic laboratory measurement skills in FAST.

12C. Manipulation and Observation (continued) • Use cameras and tape recorders for capturing information. • Inspect, disassemble, and reassemble simple mechanical devices and describe what the various parts are for; estimate what the effect that making a change in one part of a system is likely to have on the system as a whole.	FAST students use cameras and tape recorders as they are available for collecting data. FAST students assemble and disassemble laboratory equipment used in their investigations. They invent and calibrate a wide variety of instruments needed in their investigations.
12D. Communication Skills • Organize information in simple tables and graphs and identify relationships they reveal. • Read simple tables and graphs produced by others and describe in words what they show. • Locate information in reference books, back issues of newspapers and magazines, compact disks, and computer databases. • Understand writing that incorporates circle charts, bar and line graphs, two-way data tables, diagrams, and symbols. • Find and describe locations on maps with rectangular and polar coordinates.	In FAST data tables and graphs are used extensively to analyze data and search for patterns and relationships. Students generate data from their own investigations and compare their finding with those of others. Students keep a log of their investigations and findings in their student notebooks which become their textbook. Communication through oral and written scientific reports and student seminars and debates form a central focus in FAST. Just as in science communication is essential to students in constructing their knowledge of science. Library research is first introduced through the use of the FAST classroom library and later extended to the research literature relevant to student investigations that can be found in the library and in computer databases.
12E. Critical-Response Skills • Question claims made by vague attributions (such as "Leading doctors say...") or on statements made by celebrities or others outside the area of their particular expertise. • Compare consumer products and consider reasonable trade-offs among them on the basis of features, performance, durability, and cost. • Be skeptical of arguments based on very small samples of data, biased samples, or samples for which there was no control sample. • Be aware that there may be more than one good way to interpret a given set of findings. • Notice and criticize the reasoning in arguments in which (1) fact and opinion are intermingled or the conclusions do not follow logically from the evidence given, (2) an analogy is not apt, (3) no mention is made of whether the control groups are very much like the experimental group, or (4) all members of a group (such as teenagers or chemists) are implied to have nearly identical characteristics that differ from those of other groups.	The reliance on data generated and collected by students in FAST and the consensus building among class members on the interpretation and generalizations warranted from the data are designed to develop critical response skills. Students are required to base their conclusions on evidence and data, not opinion. They must also defend their conclusions among their peers through oral and written reports, seminars, and general class discussion. FAST 3, Change over Time is designed to leave students with competing theories for the formation of the universe, origin of life, changes in life forms over time, plate tectonics, and other currently competing ideas. Student investigations in FAST are always subjected to tests of valid experimental design including the use of controls, replication, and standards for data collection. Generalizations are based on data and consensus rather than opinion. In this way FAST students develop critical response skills.