Annenberg/CPB
Professional Development Workshop Guide

<u>Science in Focus</u>

Energy

An eight-part professional development workshop
for K-6 science teachers

Produced by the Harvard-Smithsonian Center for Astrophysics

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About the Workshop

Workshop Overview

Everything we do involves energy in some way. Whenever we walk, run, drive our cars, eat, or breathe, we are using energy, transferring it from place to place, or converting it from one form (such as the chemical energy in food) to another (such as the kinetic energy of a moving body). ***Science in Focus: Energy*** provides a step-by-step guide to energy and related concepts. The workshop brings the participant to a thorough, scientifically valid understanding of energy, and to an appreciation of how energy-related ideas are relevant in everyday life. As a result, participants will be able to help their students to understand the science of energy, and to see how energy is related to their common-sense notions of how the world works.

The workshop is composed of eight two-hour sessions, each with a one-hour video program devoted to a single topic. The workshop features interviews with children, who give insight into what typical students might think about the subject. Similar interviews with scientists provide clear and accurate explanations of the children's ideas. Classroom footage shows how these ideas come up in many commonly taught K-6 units, even those that do not overtly concern energy. Animations, graphics, person-on-the-street interviews, and field trips to such sites as a bell tower, a power plant, a playground, and the Boston Marathon add color and excitement, and show living examples of the concepts discussed in the workshop.

After viewing the series, participants will be able to answers such questions as:

- Why do scientists say that energy cannot be created or destroyed, when we know that our cars, air conditioners, machines, etc., all "use up" energy, and that power plants "generate" energy?
- What kinds of food contain a lot of energy? And is it good or bad to eat those foods?
- What do those numbers on my electric bill mean, and what really happens when I plug an appliance into the wall?
- How can we, as a society, reduce our dependence on fossil fuels, either by reducing the amount of energy we use or by developing alternative energy sources?
- What is the principle of *conservation of energy,* and what does it have to do with energy conservation?
- Who came up with the idea of energy in the first place, and why do scientists say it is so important?

Workshop Goals

Concepts

You will:

- develop a better appreciation for the importance of energy as a unifying concept in physics, chemistry, biology, and Earth science.
- develop the ability to recognize the differences between the scientific and the commonly understood, yet sometimes contradictory, meanings of the word *energy.*
- develop an understanding of how the principle of conservation of energy is used to make predictions about energy systems.
- develop the ability to trace energy transfers and conversions.

About the Workshop, cont'd.

Skills

You will learn to:

- recognize how the everyday meaning of the word *energy* differs from the scientific meaning.
- distinguish between several forms of energy (chemical, electrical, heat, etc.).
- apply the principle of conservation of energy.
- trace the origin of the concept of energy back to eighteenth-century investigations of heat.
- distinguish between power and energy.
- define energy in different scientific ways, including as work (W): the product of a force (F) and distance (d) through which the force acts: W = F * d.
- describe various ways in which energy can be converted from one form to another or transferred from one system to another.
- analyze the transfer of energy through a system, seeing how energy is never really "lost," but can be converted to forms that are less useful (such as heat).
- recognize energy systems and use them to make predictions about energy.
- understand how a small amount of energy can trigger the release of a much greater amount of stored energy.
- trace the interplay between kinetic and potential energy in cycles, such as the motion of a swinging pendulum.
- recognize energy when it is stored as potential energy in various ways (mechanical, elastic, chemical...).
- trace the energy we receive from food back to sunlight captured by photosynthesis.
- describe how heat can be converted to work.
- define heat as the random movement of the atoms or molecules that compose a substance.
- explain how friction acts to convert kinetic energy into heat.

In terms of energy and society, you will be able to:

- understand sources of energy for our industries, homes, and transportation systems.
- recognize that fossil fuel resources are finite and that there are environmental, social, and health costs associated with their use.
- demonstrate several ways to conserve energy.
- describe several renewable energy sources.
- point out the difference between "conservation of energy" and "energy conservation."

You will gain a better understanding of these fundamental ideas:

- conservation of energy; and
- the tendency of energy systems to move from ordered to disordered states.

About the Workshop, cont'd.

Key Terms

Calorie	Conservation of energy	Efficiency
Energy	Energy conservation	Energy cycle
Energy system	Fossil fuels	Force
Forms of energy (Chemical, Heat, Light, Mechanical, Nuclear, Potential, Sound)		
Friction	Heat	Heat engine
Kilowatt hour	Kinetic energy	Photosynthesis
Potential energy	Renewable energy sources	Respiration
Temperature	Watt	Work

Workshop Descriptions

Understanding the concept of energy is crucial to the comprehension of many ideas in physical science, Earth and space science, and life science. The video programs, print guide, and Web site of this workshop for elementary school teachers provide a solid foundation, enabling you to distinguish between the way energy is commonly understood and its meaning in science. Examine energy's role in motion, machines, food, the human body, and the universe as a whole. Learn how energy can be converted from one form to another and transferred over space and time. And explore the notion of *conservation of energy*—the idea that energy can neither be created nor destroyed. Return to the classroom with a new focus on the important concept of energy.

Workshop 1. What Is Energy?

Interviews about energy with children, scientists, and people on the street reveal the wide range of concepts that teachers encounter. In this session, you will look at the differences between the everyday language of energy and the scientific concept, see highlights of its history, and learn its importance in our understanding of the world.

Workshop 2. Force and Work

Scientists define energy as the ability to do work. In this session, see how work is defined in physics and examine how energy and work are related.

Workshop 3. Transfer and Conversion of Energy

Change happens when energy is transferred or converted. In this session, examine conversion between potential and kinetic energy. Through examples, see how events that involve a small amount of energy can trigger much larger events.

Workshop 4. Energy in Cycles

Energy can be seen in cycles every day, from the bouncing of balls to the swinging of pendulums. In this session, further explore the relationship between kinetic and potential energy to understand how cycles begin and are sustained, and why they decay.

Workshop 5. Energy in Food

All life forms use energy. In this session, explore the transfer and conversion of the potential energy in food, and see how that energy is stored. Through animations, witness photosynthesis, the process by which plant cells capture the ultimate energy source for all food—sunlight.

About the Workshop, cont'd.

Workshop 6. Energy and Systems

Physicists use the concept of a system to trace and quantify the flow of energy. In this program, take a close look at a number of energy systems and see how this concept is closely linked to the principle of conservation of energy.

Workshop 7. Heat, Work, and Efficiency

A machine's energy output cannot be greater than its input. In this session, look at the energy that goes into useful work, examine how some always ends up as heat, and see why systems are never 100% efficient.

Workshop 8. Understanding Energy

Energy lights our homes, fuels our transportation systems, and much more, but affordable energy is in limited supply. In this session, look at the global impact of these limits and see how being smart about using energy will become more important in our daily lives.

Classroom Clips

Workshop 1

Grade Level	Teacher's Name	School	Name of Activity
Gr. 5	Kalpana Guttman	Burr Elementary School, Newton, MA	**Food Webs**
As part of an Owl Pellets unit, in which students dissect owl pellets and reconstruct the owl's diet from their findings, these fifth-grade students examine food chains and build a food web for a forest ecosystem. Kalpana Guttman outlines how she has incorporated the concept of energy in her science lessons throughout the year.			
Gr. 5/6	Alice Garcia	City View Discovery School, Worcester, MA	**Circuits and Pathways**
Alice Garcia's fifth- and sixth-grade bilingual students build electrical circuits and make discoveries about energy conversions.			
Gr. 3	Michelle Paul	Frank M. Silvia School, Fall River, MA	**Sound**
Michelle Paul's third-grade class participates in an inquiry-based unit on sound. The children explore how sound travels through solids, liquids, and gases using the FOSS "Physics of Sound" module.			
Gr. 4	Janet Smithers	Harwich Elementary School, Harwich, MA	**Magnetism**
Janet Smithers's fourth-grade students explore the strength of magnetic force as they try to break the force of attraction by countering it with the force of gravity.			
Gr. 1	Joanne Aguiar	Laurel Lake School, Fall River, MA	**Balls and Ramps**
Joanne Aguiar's first-grade students roll balls down ramps of varying heights and compare the resulting speed of the balls.			
Gr. 3	Mary Mahoney	Washington Community Magnet School, Lynn, MA	**Food and Nutrition**
Cheryl Procton, a nutritionist from the University of Massachusetts Cooperative Extension, visits second-graders at the Washington Community Magnet School, in Lynn, Massachusetts. Ms. Procton elicits students' ideas about energy users and energy sources as part of a unit on food and nutrition.			
Gr. 7	Roland Stern	Wayland Middle School, Wayland, MA	**Solar Cars**
Roland Stern's seventh-grade class builds and races solar cars and battery-operated cars.			

About the Workshop, cont'd.

Workshop 2

Grade Level	Teacher's Name	School	Name of Activity
Gr. 5	Barbara Mitchell	Armstrong School, Westborough, MA	**Rubber Band Cars**

Barbara Mitchell's students explore the motion of rubber band-powered cars, relating the number of twists in the rubber band to the distance and speed they travel.

Gr. 1	Joanne Aguiar	Laurel Lake School, Fall River, MA	**Balls and Ramps**

Joanne Aguiar's first-grade students roll balls down ramps of varying heights and compare the resulting speed of the balls. Based on an activity developed at the San Francisco Exploratorium: http://www.exploratorium.edu/baseball/bouncing_balls.html.

Gr. 4	Beth Carney	Norris Road Elementary School, Tyngsboro, MA	**Water Power**

Beth Carney's students go on a field trip to the Tsongas Industrial History Center in Lowell, Massachusetts, where they participate in workshops to determine which type of water wheel provides the most power to run textile machines. For more information, see http://www.uml.edu/Tsongas.

Workshop 3

Grade Level	Teacher's Name	School	Name of Activity
Gr. 6	Roland Stern	Wayland Middle School, Wayland, MA	**Solar Cars**

These sixth-graders build and race solar cars and battery-operated cars.

Gr. 3	Michelle Paul	Frank M. Silvia Elementary School, Fall River, MA	**Sound**

Michelle Paul's third-grade class participates in an inquiry-based unit on sound, using the FOSS "Physics of Sound" module. The children explore how sound travels through solids, liquids, and gases by testing devices such as a string telephone.

Gr. K/1	Janice Beattie	Chatham Elementary School, Chatham, MA	**The Domino Theory**

Janice Beattie's K/1 students build domino chains and consider and discuss what starts the chain reaction and how much energy is needed to start it.

Workshop 4

Grade Level	Teacher's Name	School	Name of Activity
Gr. 4	Marquita Jackson-Minot	Hennigan School, Boston, MA	**Pendulums**

Marquita Jackson-Minot's fourth-grade students are in the exploration phase of a unit about time. They consider what factors might influence the rate of a pendulum's swing by comparing a variety of pendulums in their classroom. From Project ARIES: http://cfa-www.harvard.edu/cfa/sed/aries.html.

Gr. 1	Ingrid Allardi	Potter Road School, Framingham, MA	**Musical Instruments**

Ingrid Allardi's first-graders are in the middle of a unit about sound. They use Geoboards and rubber bands to make sounds, and compare how different length and tension of the bands affect the pitch of their instruments.

Gr. 7	Dr. Robert Tai, Jim Chin	Day Middle School, Newton, MA	**Thought Experiment**

Robert Tai is a guest teacher in Jim Chin's seventh-grade class at Day Middle School in Newton, Massachusetts. He asks students to imagine a world in which there is no friction. Their discussion about a ball rolling on a hill reveals a variety of different ideas about momentum, friction, gravity, and energy.

Gr. K – 4	Adam Corbeil, Gretchen Iversen	Graham & Parks SACC Program, Cambridge, MA	**Resonant Pendulum**

Students of different ages in an after-school program try to meet a challenge: cause a heavy pendulum to start swinging by touching it only with tiny, weak magnets tied to strings. Originally created by the San Francisco Exploratorium, "Science Snacks" collection. For more information see http://www.exploratorium.edu/snacks/resonant_pendulum.html.

About the Workshop, cont'd.

Workshop 5

Grade Level	Teacher's Name	School	Name of Activity
Gr. 3/4	Sue Mesiter, Garden Club Coordinator	Chatham Elementary School, Chatham, MA	**Garden**
These students get hands-on experience working with the Chatham Garden Club where they learn about what plants need to grow as they plant and tend their own school garden.			
Gr. 2	Diane Littlefield	Chatham Elementary School, Chatham, MA	**Seeds**
As part of a unit about how seeds travel, these second-graders take a close look at seeds and predict what is needed for a plant to grow.			
Gr. 2	Mary Mahoney	Washington Community Magnet School, Lynn, MA	**Food and Nutrition**
We revisit in more detail an activity briefly featured in Workshop 1.			

Workshop 6

Grade Level	Teacher's Name	School	Name of Activity
Gr. 5	Leslie Kramer	Haggerty Elementary School, Cambridge, MA	**Pendulums**
Near the end of a unit studying pendulums, Leslie Kramer takes her students to the playground for a group interview, where they describe what happens when a pendulum's motion diminishes and stops.			
Gr. 5	Kalpana Guttman	Burr Elementary School, Newton, MA	**Food Webs**
We revisit in more detail an activity briefly featured in Workshop 1.			
____	Barbara Lee	MassPEP (Massachusetts Pre-Engineering Program), Boston, MA	**Solar Houses**
MassPEP offers enrichment engineering and science projects geared toward non-science students. Barbara Lee, a teacher from Hilo, Hawaii, is piloting an activity from the Solar House unit of Project DESIGNS (Doable Engineering Science Investigations Geared for Non-Science Students), a middle school engineering program: http://cfa-www.harvard.edu/cfa/sed/projects/designsinfo.html. This session was videotaped at the Camp Tech summer program at Wentworth Institute of Technology, in Boston, Massachusetts. More information is available at http://www.masspepinc.org.			
Gr. 6	Dotty Herd	Ten Mile Elementary School, Ten Mile, TN	**Hydroelectric Power**
Dotty Herd's class participates in a unit on hydroelectric power. Students build models of dams and turbines and share their findings with the class. Then they take a field trip to one of the Tennessee Valley Authority's education centers, where TVA staff lead them in discussions about hydroelectric power generation and environmental issues.			

Workshop 7

Grade Level	Teacher's Name	School	Name of Activity
Gr. 3-4	Pilar Fabery	Burr Elementary School, Newton, MA	**Hot and Cold Demonstrations**
Pilar Fabery conducts a number of guided explorations about states of matter using ice, water, and steam.			
Gr. 3-4	Pilar Fabery	University of Massachusetts-Lowell, Demonstration School, Lowell, MA	**States of Matter**
Pilar Fabery helps students look at the differences between solids, liquids, and gases.			
Gr. 3	Jean Huff	Burr Elementary School, Newton, MA	**Molecules**
Jean Huff's third-graders demonstrate their knowledge of how temperature affects molecules by pretending to be molecules of ice, water, and steam.			
Gr. 7	Karen Spaulding	The Morse School, Cambridge, MA	**Ice Cream Makers**
Karen Spaulding's seventh-graders investigate and gather data about heat transfer through different materials as one step in designing an ice cream maker.			

About the Workshop, cont'd.

Workshop 7, cont'd.

Grade Level	Teacher's Name	School	Name of Activity
Gr. 6	Robert Peterson, Sixth-Grade Science Coordinator; Tom Poland, Watt Watchers Instructor	Bethany Community School, Bethany, CT	**Watt Watchers: Light Bulbs**

Tom Poland, of Wilson Educational Services, Inc., leads an activity for sixth-graders at the Bethany Community School in Bethany, Connecticut. In an activity from Watt Watchers, a free program sponsored by the U.S. Department of Energy, students compare the efficiency and the lifetime cost of different light bulbs. They learn that standard incandescent bulbs produce much more waste heat per unit of brightness than fluorescent bulbs. More information on Watt Watchers is available at http://p2.utep.edu/watts.

Workshop 8

Grade Level	Teacher's Name	School	Name of Activity
Gr. 4	Judith Hurvitz, Mary Salamone	Spruance School, Philadelphia, PA	**Green Schools: Energy Pathways Activity, Energy Survey, Solar Tea Party**

Spruance School participates in a nationwide program called Green Schools, sponsored by the Alliance To Save Energy. In this service learning program, fourth-grade teachers Judy Hurvitz and Mary Salamone join with the principal and the head custodian to further energy conservation and energy education at their school. Activities depicted include journal writing, charting energy usage in industry, a hands-on oatmeal analogy as an example of the inefficiencies of transfer, an energy survey, and building solar ovens. More information is available at http://www.ase.org/greenschools.

Grade Level	Teacher's Name	School	Name of Activity
Gr. 6	Robert Schongalla, Head of Science Program; Richard Danahy, Science Teacher	Sant Bani School, Sanbornton, NH	**Solar Tour**

Sixth-graders from the Sant Bani School are on a field trip to the Society for the Protection of New Hampshire Forests, where they tour a solar-heated house and learn about renewable energy sources. More information is available at http://www.spnhf.org/who/intro.html.

Workshop Components

On-Site Activities

Weekly workshop sessions may be scheduled around live broadcasts, in which case you will want to begin at least 30 minutes before the scheduled broadcast. You may prefer to pre-record the programs on videocassette, and schedule the sessions at a time that is more convenient for all participants. Sessions should be scheduled for a minimum of two hours.

This guide provides activities and discussion topics for pre-and post-viewing investigations that complement weekly programs. See Helpful Hints for Facilitators for information on preparing for your workshop sessions.

Getting Ready

In preparation for watching the program, you will engage in 30 minutes of investigation through discussion and activity.

Watch the Video

Then you will watch 60 minutes of video with classroom footage, commentary, science demonstrations, and more.

Going Further

Wrap up the workshop with an additional 30 minutes of investigation through discussion and activity.

For Next Time

Homework Assignment

You will be assigned exercises and activities that tie into the last workshop or prepare you for the next one.

Workshop Journal

A critical part of taking steps toward change is documenting your own learning along the way. This is a deliberate process that calls for reflecting upon your own understandings before, during, and after key experiences, and documenting how these understandings change. While there are numerous ways to document learning, we suggest using a journal. As the workshops progress, pay particular attention to changes in your thinking and the implications of these changes, and record them in your journal.

Workshop Web Site: http://www.learner.org/channel/workshops/energy/

Go online for additional activities, resources, and discussion.

Channel-TalkEnergy

You can communicate with other workshop participants via email. To subscribe to the workshop email discussion list, Channel-TalkEnergy, visit:

http://www.learner.org/mailman/listinfo/channel-talkenergy.

Helpful Hints for Facilitators

Successful Workshop Sessions

These guidelines will help you conduct successful workshop sessions, particularly the Getting Ready and Going Further segments. These 30-minute, pre- and post-video group discussions will help participants better understand the video programs and enhance the workshop experience.

Designate Responsibilities

Each week, someone should be responsible for facilitating the workshop sessions. This may be a professional facilitator or a volunteer from among the participants, or you may choose to divide and rotate duties among several participants.

Prepare for the Session and Bring the Necessary Materials

The facilitator should review the entire session in this guide prior to arriving for the session, as well as reviewing the Materials Needed for that session. The facilitator will be responsible for bringing enough materials for the participants. If you are viewing the video programs on videocassette, the facilitator may want to preview the programs.

Distribute This Guide

You may want to photocopy this guide for all participants so they may follow along, refer back to ideas covered in the session, or have their homework assignments handy. Or, you may direct them to the workshop Web site at **www.learner.org/channel/workshops/energy/** to print the guide themselves (direct them to "Support Materials"). Either way, you will want participants to have the guide prior to the first session, so they will come prepared.

Keep an Eye on the Time

We have suggested the amount of time you should spend on each question or activity. While these times are merely guidelines, you should keep an eye on the clock, particularly if you are watching a live broadcast. You may want to set a kitchen timer before you begin Getting Ready to ensure that you won't miss the beginning of the video. If you are watching the workshops on videotape, you will have more flexibility if your discussions run longer.

Record Your Discussions

We recommend that someone take notes during each discussion, or even better, that you tape-record the discussions. The notes or audiotapes can serve as make-up materials in case anyone misses a workshop.

Share Your Discussions on the Web

The workshop sessions serve as a starting point to share and think about the workshop ideas. Encourage participants to continue their discussions with participants from other sites on Channel-TalkEnergy at the workshop Web site.

About the Contributors

Content Advisors

Paul Hickman worked as an engineer and taught high school physics in Cold Spring Harbor, New York and Belmont, Massachusetts. He is the director of Northeastern University's Center for the Enhancement of Science and Mathematics Education (CESAME) and helps teachers to advance K-12 educational reform. He received the Presidential Award for Excellence in Science Teaching, the Tandy Technology Scholars Award, and the American Association of Physics Teachers' Award for Excellence in Pre-College Physics Education. Hickman has been involved with several national programs to improve science teaching and learning, has written for numerous professional journals, and has given talks and workshops for teachers nationwide. He received his B.S. in physics from Manhattan College and his M.S. from Long Island University.

Jennifer Bond Hickman, Ed.D., taught physics and astronomy at the Pomfret School in Connecticut, at Phillips Academy in Andover, Massachusetts, and most recently at Boston University Academy, where she also served as head of school. Dr. Hickman has served on the boards of several physics and astronomy organizations and is currently on the board of Boston's Hayden Planetarium. She has worked on numerous national curriculum development projects in science and has given talks and workshops around the country. Dr. Hickman is a recipient of the Presidential Award for Excellence in Science Teaching and the Tandy Technology Scholars Award, and is the author of *Problem-Solving Exercises in Physics.* She received her B.A. in physics and astronomy from Wellesley College, her M.S. from Worcester Polytechnic Institute, and her Ed.D. and M.B.A. from Boston University.

Ari W. Epstein, Ph.D. is a scientist and educator who has broad experience communicating science to the public in a variety of media. From 1999 to 2001, he was editor of *Scientific American Explorations,* a new science magazine for families. He has also worked as a visiting assistant professor in the Department of Physics and Astronomy at Bowdoin College (1996-1999), as a postdoctoral associate at MIT (1995-1996), and as a member of the Board of Editors of *Scientific American* magazine (1984-1988). Since 1995, Epstein has been a visiting scholar at the New England Aquarium, where he has led the development teams for several special interactive exhibits, assisted in the development of a variety of other programs and exhibits, and served as a content consultant and on-camera guest for the *High Seas* and *World of Water* television series, broadcast live to elementary schools across the U.S. Epstein holds a Ph.D. in physical oceanography awarded jointly by the Massachusetts Institute of Technology (MIT) and the Woods Hole Oceanographic Institution (WHOI), and an A.B. in history and science (with an emphasis on the history and philosophy of modern physics) from Harvard College. He is also an alumnus of Sea Semester, a three-month, intensive program in oceanography and seamanship.

Host

Charles A. Whitney, Ph.D., is professor *emeritus* of astronomy at Harvard University and a retired senior scientist at the Smithsonian Astrophysical Observatory. He received an S.B. in physics from MIT in 1951 and a Ph.D. in astrophysics from Harvard in 1956. During the early Sputnik days, he served as chief of computations of the Satellite Tracking Program, Center for Astrophysics. His research during the next two decades focused on the theory and observation of stellar variations and the structure of stellar atmospheres. One of his books, *Discovery of Our Galaxy,* was nominated for the National Book Award in 1962. In 1971, he received a Solomon R. Guggenheim Fellowship for study in the history of astronomy.

Professor Whitney has written on the astronomy of Vincent van Gogh's skyscapes, and has been active in developing and evaluating software for instruction in physics and astronomy. He served on the National Scientific Advisory Board of Children's Television Workshop Public Television series, *3-2-1 Contact,* and on the Science Advisory Committee of Project STAR. He is editor of the *Journal of the American Association of Variable Star Observers.*

About the Contributors, cont'd.

Scientists

Sallie Baliunas, Ph.D. is an astrophysicist at the Harvard-Smithsonian Center for Astrophysics. She is deputy director and director of science programs at Mount Wilson Observatory; she also serves as senior scientist at the George C. Marshall Institute in Washington, D.C., and chairs the Institute's Science Advisory Board. She is also adjunct professor at Tennessee State University.

Dr. Baliunas's research interests include solar variability and other factors in climate change, magnetohydrodynamics of the sun and sun-like stars, exoplanets, and the use of laser electro-optics to correct turbulence in the Earth's atmosphere that blurs astronomical images. She has written over 200 scientific research articles and is a contributing editor to the *World Climate Report* and an editor for *New Astronomy.* Her awards include the Newton-Lacy-Pierce Prize of the American Astronomical Society, the Petr Beckmann Award for Scientific Freedom, and the Bok Prize from Harvard University.

Dr. Baliunas received her Ph.D. in astrophysics from Harvard University. In 1991, she was profiled by *Discover* magazine as one of America's outstanding women scientists. In addition to appearing in *Science in Focus: Force and Motion,* Dr. Baliunas is the science advisor for *Gene Roddenberry's Earth: Final Conflict,* the sci-fi television series launched in 1997.

William G. Gardner, Ph.D. is an expert in acoustics and sound engineering. He received a B.S. in computer science and engineering from MIT in 1982, and M.S. and Ph.D. degrees in media arts and sciences from MIT in 1992 and 1997. From 1984 to 1990, he worked at Kurzweil Music Systems, developing software and signal-processing algorithms for electronic musical instruments. As a graduate student at the MIT Media Lab, he researched spatial audio, reverberation, sound synthesis, real-time signal processing, and psychoacoustics, and completed a dissertation on the topic of 3-D audio using loudspeakers. He was awarded a Motorola Fellowship at the Media Lab, and was recipient of the 1997 Audio Engineering Society Publications Award.

In 1997, Dr. Gardner founded Wave Arts, Inc. (Arlington, Massachusetts) a company whose objective is to develop and sell audio-processing software and related technology. He is a member of the Audio Engineering Society and the Acoustical Society of America.

Les Kaufman, Ph.D. is an evolutionary ecologist at Boston University, where he is associate professor and undergraduate coordinator for the B.U. Marine Program. In his own research, Dr. Kaufman studies how biological diversity evolves, the ecology of how species coexist, and the ways in which people's activities harm or eliminate living species. He likes to do basic research that has direct applications to environmental conservation.

Dr. Kaufman is particularly fascinated with fish species in the wild, calling for an odd combination of skills in ecology, mathematics, physics, scuba diving, and wilderness survival. His current projects deal with fish communities and fisheries restoration in East African great lakes, the Gulf of Maine, Caribbean coral reefs, and California kelp reefs. In 1990, he was named Pew Scholar in Conservation and the Environment for this work. Dr. Kaufman is also an amateur astronomer and teaches astronomy as a hobby.

He has been active in public television and informal science education for more than 20 years, including an 11-year stint at The New England Aquarium in Boston, first as curator of education and later as director of research. He continues with the Aquarium as a research scholar.

About the Contributors, cont'd.

Philip Morrison, Ph.D. is a theoretical astrophysicist who has served on the physics faculties of Cornell University (1946-1964) and the Massachusetts Institute of Technology (1964-present) where he is now institute professor, *emeritus*. He received his Ph.D. in theoretical physics in 1940 from the University of California, Berkeley, as a student of J. Robert Oppenheimer, and during World War II he worked on the Manhattan Project. He has numerous research publications in physics and astronomy.

Dr. Morrison has a special interest in the understanding, both formal and informal, of science. He is the author of physics textbooks for high school, college, and graduate students, and, with his wife Phylis, has written book reviews and columns for *Scientific American* since 1964. He has appeared frequently on the BBC (beginning with the 1961 show, *Fabric of the Atom*), *Nova,* and the acclaimed PBS miniseries, *The Ring of Truth,* as well as on commercial television. Dr. Morrison has also co-authored books on United States military policy and on world problems of the twenty-first century, and has written and spoken widely in favor of nuclear disarmament. He has taught overseas in the United Kingdom, West and South Africa, and India.

Jaci VanHeest, Ph.D. has contributed a wide variety of research to sports science, including studies of elite child athletes; training and over-training in female athletes; the cellular mechanisms of obesity, nutrition, and body weight regulation; and exercise physiology. Dr. VanHeest is assistant professor in the department of kinesiology at the University of Connecticut and has taught and researched at the University of Colorado Health Sciences Center, the University of Cincinnati, and the University of Toronto. Other primary areas of her research include hormonal and metabolic factors increasing children's risk for obesity, the role of pregnancy as a risk factor for obesity, and the metabolic impact of exercise during pregnancy.

Dr. VanHeest received her M.S. and Ph.D. degrees from Michigan State University in exercise physiology/exercise endocrinology. She was director of exercise physiology at the International Center for Aquatics Research, where she saw her role as "using science to help athletes win medals." She also served as the director of physiology for USA Swimming at the Olympic Training Center in Colorado Springs.

Peter Weyand, Ph.D. is a physiologist and biomechanist who specializes in animal locomotion, particularly in relating muscle function to metabolic energy expenditure and performance. An expert in the science of running, his interests involve muscles and movement, making energy a central theme throughout his research career. Dr. Weyand is the research director at Harvard University's Concord Field Station, a large animal facility specializing in animal locomotion, and a senior research fellow at the U.S. Army's Research Institute for Environmental Medicine. He teaches an undergraduate biology class at Harvard on "Muscles, Metabolism, and Movement" (reluctantly changed from its former title, "See Spot Run.") He is the recipient of Harvard's Joseph E. Levenson Award for excellence in undergraduate teaching.

Dr. Weyand received his Ph.D. in exercise physiology from the University of Georgia in 1992. He began running competitively at age 16, and has run about 60,000 lifetime miles, expending about 6,000,000 kilocalories of chemical energy. When he's not running animals on treadmills, he spends a lot of time encouraging people to exercise, usually vigorously.

Standards

Note: Each standard is accompanied by one example—though there may be others—from a program in the ***Science in Focus: Energy*** workshop.

National Science Education Standards (National Research Council)

http://bob.nap.edu/readingroom/books/nses/html/

K-4 Standards

K-4 Standards: Physical Science: http://bob.nap.edu/readingroom/books/nses/html/6c.html#ps

Materials can exist in different states—solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling.

> **Example:** Students simulating motion of water molecules in various states (Workshop 7: Heat, Work, and Efficiency)
>
> **Content Standards:** K-4: Physical Science: Properties of Objects and Materials

Sound is produced by vibrating objects. The pitch of the sound can be varied by changing the rate of vibration.

> **Example:** Students experimenting with sounds generated by elastic bands (Workshop 4: Energy in Cycles)
>
> **Content Standards:** K-4: Physical Science: Position and Motion of Objects

Heat can be produced in many ways, such as burning, rubbing, or mixing one substance with another. Heat can move from one object to another by conduction.

> **Example:** Explanation, in terms of molecular motion, of heat production and conduction (Workshop 7: Heat, Work, and Efficiency)
>
> **Content Standards:** K-4: Physical Science: Light, Heat, Electricity, and Magnetism

Electricity in circuits can produce light, heat, sound, and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass.

> **Example:** Scientists producing light, sound, and heat with a hand-cranked electrical generator (Workshop 3: Transfer and Conversion of Energy)
>
> **Content Standards:** K-4: Physical Science: Light, Heat, Electricity, and Magnetism

K-4 Standards: Life Science: http://bob.nap.edu/readingroom/books/nses/html/6c.html#ls

All animals depend on plants. Some animals eat plants for food. Other animals eat animals that eat the plants.

> **Example:** Description of energy pathways in food (Workshop 5: Energy in Food)
>
> **Content Standards:** K-4: Life Science: Organisms and Their Environments

Humans depend on their natural and constructed environments. Humans change environments in ways that can be either beneficial or detrimental for themselves and other organisms.

> **Example:** Environmental changes due to use of fossil fuels (Workshop 8: Understanding Energy)
>
> **Content Standards:** K-4: Life Science: Organisms and Their Environments

Standards, cont'd.

K-4 Standards: Science and Technology: http://bob.nap.edu/readingroom/books/nses/html/6c.html#st

People have always had questions about their world. Science is one way of answering questions and explaining the natural world.

Example: Exploration of naive ideas and scientific explanations throughout workshop

Content Standards: K-4: Science and Technology: Understanding About Science and Technology

People have always had problems and invented tools and techniques (ways of doing something) to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.

Example: Use of systems-related thinking in designing energy-efficient, low-emission automobiles to replace inefficient, polluting technology (Workshop 6: Energy and Systems)

Content Standards: K-4: Science and Technology: Understanding About Science and Technology

K-4 Standards: Science in Personal and Social Perspectives: http://bob.nap.edu/readingroom/books/nses/html/6c.html#sp

The supply of many resources is limited. If used, resources can be extended through recycling and decreased use.

Example: Discussion of limits on availability of fossil fuels and ways to decrease energy usage in general (Workshop 8: Understanding Energy)

Content Standards: K-4: Science in Personal and Social Perspectives: Types of Resources

K-4 Standards: History and Nature of Science: http://bob.nap.edu/readingroom/books/nses/html/6c.html#hn

Many people choose science as a career and devote their entire lives to studying it. Many people derive great pleasure from doing science.

Example: Interviews with scientists throughout workshop

Content Standards: K-4: History and Nature of Science: Science as a Human Endeavor

5-8 Standards

5-8 Standards: Science as Inquiry: http://bob.nap.edu/readingroom/books/nses/html/6d.html#si

Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations.

Example: Overturning of caloric theory of heat (Workshop 1: What Is Energy?)

Content Standards: 5-8: Science as Inquiry: Understandings About Scientific Inquiry

5-8 Standards: Physical Science: http://bob.nap.edu/readingroom/books/nses/html/6d.html#ps

Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

Example: Among the key ideas covered throughout the workshop; particularly emphasized in Workshop 3: Transfer and Conversion of Energy

Content Standards: 5-8: Physical Science: Transfer of Energy

Standards, cont'd.

Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

Example: Explanation, in terms of molecular motion, of heat conduction (Workshop 7: Heat, Work, and Efficiency)

Content Standards: 5-8: Physical Science: Transfer of Energy

Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

Example: Descriptions of various methods for transferring energy (Workshop 3: Transfer and Conversion of Energy)

Content Standards: 5-8: Physical Science: Transfer of Energy

5-8 Standards: Life Science: http://bob.nap.edu/readingroom/books/nses/html/6d.html#ls

For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.

Example: Description of energy pathways in ecosystems (Workshop 5: Energy in Food)

Content Standards: 5-8: Life Science: Populations and Ecosystems

5-8 Standards: Earth and Space Science: http://bob.nap.edu/readingroom/books/nses/html/6d.html#es

Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate, because water in the oceans holds a large amount of heat.

Example: Discussion of how transfer of heat energy to the atmosphere drives hurricanes (Workshop 6: Energy and Systems)

Content Standards: 5-8: Earth and Space Science: Structure of the Earth System

5-8 Standards: Science and Technology: http://bob.nap.edu/readingroom/books/nses/html/6d.html#st

Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations. Technological solutions are temporary; technologies exist within nature and so they cannot contravene physical or biological principles; technological solutions have side effects; and technologies cost, carry risks, and provide benefits.

Example: Student project: designing shelters for warm climates, with emphasis on using scientific knowledge about energy to find technological ways to keep the shelters cool (Workshop 6: Energy and Systems)

Content Standards: 5-8: Science and Technology: Understandings About Science and Technology

Standards, cont'd.

5-8 Standards: Science in Personal and Social Perspectives: http://bob.nap.edu/readingroom/books/nses/html/6d.html#sp

Societal challenges often inspire questions for scientific research, and social priorities often influence research priorities through the availability of funding for research.

Example: Discussion of research into alternative sources of energy, as a way of addressing possible shortages of conventional forms of energy and the costs (economic, environmental, and societal) of current energy sources (Workshop 8: Understanding Energy)

Content Standards: 5-8: Science in Personal and Social Perspectives: Science and Technology in Society

Scientists and engineers work in many different settings, including colleges and universities, businesses and industries, specific research institutes, and government agencies.

Example: Diversity in background and occupation of scientists and engineers interviewed throughout the workshop

Content Standards: 5-8: Science in Personal and Social Perspectives: Science and Technology in Society

5-8 Standards: History and Nature of Science: http://bob.nap.edu/readingroom/books/nses/html/6d.html#hn

Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. Those ideas are not likely to change greatly in the future. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.

Example: Discussion of proposed perpetual-motion machines, and the observation that it has been impossible to design one that works, as evidence for scientific theories about energy and entropy (Workshop 7: Heat, Work, and Efficiency)

Content Standards: 5-8: History and Nature of Science: Nature of Science

In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered. Different scientists might publish conflicting experimental results or might draw different conclusions from the same data. Ideally, scientists acknowledge such conflict and work toward finding evidence that will resolve their disagreement.

Example: Historical development of scientific theories concerning heat and energy (Workshop 1: What Is Energy?)

Content Standards: 5-8: History and Nature of Science: Nature of Science

It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. Although scientists may disagree about explanations of phenomena, about interpretations of data, or about the value of rival theories, they do agree that questioning, response to criticism, and open communication are integral to the process of science. As scientific knowledge evolves, major disagreements are eventually resolved through such interactions between scientists.

Example: Challenges to, and ultimate replacement of, caloric theory of heat (Workshop 1: What Is Energy?)

Standards, cont'd.

Content Standards: 5-8: History and Nature of Science: Nature of Science

Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

Example: Description of the social, professional, and political backgrounds of various eighteenth- and nineteenth-century physicists, and discussion of how their backgrounds helped shape their scientific skills and outlooks (Workshop 1: What Is Energy?)

Content Standards: 5-8: History and Nature of Science: History of Science

Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted.

Example: Development of the concept of energy itself; early steps and later successes (Workshop 1: What Is Energy?)

Content Standards: 5-8: History and Nature of Science: History of Science

9-12 Standards

9-12 Standards: Physical Science: http://bob.nap.edu/readingroom/books/nses/html/6e.html#ps

Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids, the structure is nearly rigid; in liquids, molecules or atoms move around each other but do not move apart; and in gases, molecules or atoms move almost independently of each other and are mostly far apart.

Example: Discussion of how heat is related to motions of individual molecules in solids, liquids, and gases (Workshop 7: Heat, Work, and Efficiency)

Content Standards: 9-12: Physical Science: Structure and Properties of Matter

Chemical reactions may release or consume energy. Some reactions, such as the burning of fossil fuels, release large amounts of energy by losing heat and emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.

Example: Discussion of energy sources, such as fossil fuels, in terms of stored chemical potential energy (Workshop 8: Understanding Energy)

Content Standards: 9-12: Physical Science: Chemical Reactions

The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.

Example: Discussion of energy transfers, the conservation of energy during such transfers, and the loss of energy to "waste" heat during transfers (Workshop 3: Transfer and Conversion of Energy)

Content Standards: 9-12: Physical Science: Conservation of Energy and the Increase in Disorder

All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.

Example: Discussion of various form of energy (Workshop 3: Transfer and Conversion of Energy)

Standards, cont'd.

Content Standards: 9-12: Physical Science: Conservation of Energy and the Increase in Disorder

Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion.

Example: Discussion of the nature of heat (Workshop 7: Heat, Work, and Efficiency)

Content Standards: 9-12: Physical Science: Conservation of Energy and the Increase in Disorder

Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.

Example: Discussion of tendency toward disorder and spread of energy (Workshop 7: Heat, Work, and Efficiency)

Content Standards: 9-12: Physical Science: Conservation of Energy and the Increase in Disorder

9-12 Standards: Life Science: http://bob.nap.edu/readingroom/books/nses/html/6e.html#ls

Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen to the environment. This process of photosynthesis provides a vital connection between the Sun and the energy needs of living systems.

Example: Discussion of the Sun as the ultimate source of energy in food (Workshop 5: Energy in Food)

Content Standards: 9-12: Life Science: The Cell

Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers.

Example: Discussion of food chains in ecosystems (Workshop 6: Energy and Systems)

Content Standards: 9-12: Life Science: The Interdependence of Organisms

The energy for life primarily derives from the Sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes.

Example: Discussion of role of plants in collecting solar energy, which is ultimately the energy source for other organisms (Workshop 5: Energy in Food)

Content Standards: 9-12: Life Science: Matter, Energy, and Organization in Living Systems

9-12 Standards: Science in Personal and Social Perspectives: http://bob.nap.edu/readingroom/books/nses/html/6e.html#sp

The Earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.

Example: Discussion of renewable and non-renewable energy resources, and limitations on the availability of energy (Workshop 8: Understanding Energy)

Content Standards: 9-12: Science in Personal and Social Perspectives: Natural Resources

Standards, cont'd.

American Association for the Advancement of Science (AAAS) Project 2061 Benchmarks

http://www.project2061.org/tools/benchol/bolframe.htm

By the end of second grade, students should know that:

The sun warms the land, air, and water.

Example: Discussion of hurricanes' driving forces (Workshop 6: Energy and Systems)

Benchmark: The Physical Setting: 4E Energy Transformations: K-2

The way to change how something is moving is to give it a push or a pull.

Example: Definition of "force" (Workshop 2: Force and Work)

Benchmark: The Physical Setting: 4F Motion: K-2

Things that make sound vibrate.

Example: Generation of sound by vibrating objects used as an example of an energy cycle (Workshop 4: Energy in Cycles)

Benchmark: The Physical Setting: 4F Motion: K-2

Animals eat plants or other animals for food and may also use plants (or even other animals) for shelter and nesting.

Example: Discussion of energy in food webs (Workshop 6: Energy and Systems)

Benchmark: The Living Environment: 5D Interdependence of Life: K-2

Several steps are usually involved in making things.

Example: Tracing the energy pathways of the steps involved in a number of manufacturing processes (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8B Materials and Manufacturing: K-2

People can save money by turning off machines when they are not using them.

Example: Schoolchildren as school-wide energy monitors (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: K-2

People burn fuels such as wood, oil, coal, or natural gas, or use electricity to cook their food and warm their houses.

Example: Discussion of sources and uses of energy (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: K-2

Standards, cont'd.

Things change in some ways and stay the same in some ways.

Example: When you convert energy from one form to another, the amount of energy stays the same, even though its form changes (Workshop 3: Transfer and Conversion of Energy)

Benchmark: Common Themes: 11C Constancy and Change: K-2

People can keep track of some things, seeing where they come from and where they go.

Example: Use of systems-oriented thinking to trace the flow of energy into and out of a system (Workshop 6: Energy and Systems)

Benchmark: Common Themes: 11C Constancy and Change: K-2

By the end of fifth grade, students should know that:

Doing science involves many different kinds of work and engages men and women of all ages and backgrounds.

Example: Varied ages, backgrounds, and specialties of scientists interviewed throughout the workshop

Benchmark: The Nature of Science: 1C The Scientific Enterprise: 3-5

When liquid water disappears, it turns into a gas (vapor) in the air and can reappear as a liquid when cooled, or as a solid if cooled below the freezing point of water. Clouds and fog are made of tiny droplets of water.

Example: Students enacting their ideas of how water molecules behave when going from solid to liquid to gaseous state (Workshop 7: Heat, Work, and Efficiency)

Benchmark: The Physical Setting: 4B The Earth: 3-5

Heating and cooling cause changes in the properties of materials. Many kinds of changes occur faster under hotter conditions.

Example: Students testing the rate at which ice cubes melt in water of different temperatures (Workshop 7: Heat, Work, and Efficiency)

Benchmark: The Physical Setting: 4D The Structure of Matter: 3-5

Things that give off light often also give off heat. Heat is produced by mechanical and electrical machines, and any time one thing rubs against something else.

Example: Discussion of "waste" heat given off by various energy conversions, such as conversion of electrical energy into light, and by various physical processes, such as friction (Workshop 7: Heat, Work, and Efficiency)

Benchmark: The Physical Setting: 4E Energy Transformations: 3-5

When warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are all at the same temperature.

Example: Discussion of mechanisms through which warm things cool down and cold things warm up (Workshop 7: Heat, Work, and Efficiency)

Benchmark: The Physical Setting: 4E Energy Transformations: 3-5

Standards, cont'd.

A warmer object can warm a cooler one by contact or at a distance. Some materials conduct heat much better than others. Poor conductors can reduce heat loss.

Example: Students testing the insulating power of various materials (Workshop 7: Heat, Work, and Efficiency)

Benchmark: The Physical Setting: 4E Energy Transformations: 3-5

Almost all kinds of animals' food can be traced back to plants.

Example: Discussion of photosynthesis as starting point of food chain (Workshop 5: Energy in Food)

Benchmark: The Living Environment: 5E Flow of Matter and Energy: 3-5

Some source of "energy" is needed for all organisms to stay alive and grow.

Example: Description of food as a source of energy (Workshop 5: Energy in Food)

Benchmark: The Living Environment: 5E Flow of Matter and Energy: 3-5

In making decisions, it helps to take time to consider the benefits and drawbacks of alternatives.

Example: Discussion of benefits and drawbacks of various energy sources, as background for discussion of how people may choose which energy sources to rely on (Workshop 8: Understanding Energy)

Benchmark: Human Society: 7D Social Trade-Offs: 3-5

Moving air and water can be used to run machines.

Example: Description of alternative energy sources, including wind and hydro power (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 3-5

The Sun is the main source of energy for people and they use it in various ways. The energy in fossil fuels, such as oil and coal, comes from the Sun indirectly, because the fuels come from plants that grew long ago.

Example: Description of origin of fossil fuels (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 3-5

Some energy sources cost less than others and some cause less pollution than others.

Example: Description of drawbacks and advantages of various energy sources (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 3-5

People try to conserve energy in order to slow down the depletion of energy resources and/or to save money.

Example: Discussion of ways to conserve energy and reasons for doing so (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 3-5

Standards, cont'd.

By the end of eighth grade, students should know that:

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 the ocean floor.

Example: Varied careers, employers, and specialties of scientists interviewed throughout the workshop

Benchmark: The Nature of Science: 1C The Scientific Enterprise: 6-8

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.

Example: Field trip to solar house and discussion of benefits—economic, aesthetic, and social—of energy-efficient design techniques (Workshop 8: Understanding Energy)

Benchmark: The Nature of Technology: 3A Technology and Science: 6-8

Heat energy carried by ocean currents has a strong influence on climate around the world.

Example: Explanation of how heat from the ocean helps to create and sustain hurricanes, which in turn affect global climate (Workshop 6: Energy and Systems)

Benchmark: The Physical Setting: 4B The Earth: 6-8

Atoms and molecules are perpetually in motion. Increased temperature means greater average energy, 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, 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 and are free of one another except during occasional collisions.

Example: Description of relationship between heat and molecular motion (Workshop 7: Heat, Work, and Efficiency)

Benchmark: The Physical Setting: 4D The Structure of Matter: 6-8

Energy cannot be created or destroyed, but only changed from one form into another.

Example: Principle that energy is conserved during conversions from one form to another (Workshop 3: Transfer and Conversion of Energy)

Benchmark: The Physical Setting: 4E Energy Transformations: 6-8

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.

Example: Discussion of energy transformations and associated "waste" heat (Workshop 3: Transfer and Conversion of Energy)

Benchmark: The Physical Setting: 4E Energy Transformations: 6-8

Standards, cont'd.

Energy appears in different forms. Heat energy is in the disorderly motion of molecules; chemical energy is in the arrangement of atoms; mechanical energy is in moving bodies or in elastically distorted shapes; gravitational energy is in the separation of mutually attracting masses.

Example: Description of various forms of energy (Workshop 3: Transfer and Conversion of Energy)

Benchmark: The Physical Setting: 4E Energy Transformations: 6-8

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.

Example: Description of food webs and their cyclic nature (Workshop 5: Energy in Food)

Benchmark: The Living Environment: 5A Diversity of Life: 6-8

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.

Example: Explanation of origin and pathways of energy in food (Workshop 5: Energy in Food)

Benchmark: The Living Environment: 5E Flow of Matter and Energy: 6-8

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.

Example: Discussion of energy conversions and associated "waste" heat (Workshop 3: Transfer and Conversion of Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 6-8

Different ways of obtaining, transforming, and distributing energy have different environmental consequences.

Example: Discussion of environmental (and other) costs and benefits of various energy sources (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 6-8

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.

Example: Description of production and distribution of electrical power (Workshop 6: Energy and Systems)

Benchmark: The Designed World: 8C Energy Sources and Use: 6-8

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.

Example: Discussion of renewable and nonrenewable energy sources (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 6-8

Standards, cont'd.

The invention of the steam engine was at the center of the Industrial Revolution. It converted the chemical energy stored in wood and coal, which were plentiful, into mechanical work. The steam engine was invented to solve the urgent problem of pumping water out of 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.

Example: Description of role played by Industrial Revolution in changing the ways in which people used energy and the energy sources they relied on (Workshop 8: Understanding Energy)

Benchmark: Historical Perspectives: 10J Harnessing Power: 6-8

By the end of twelfth grade, students should know that:

Mathematics provides a precise language for science and technology—to describe objects and events, to characterize relationships between variables, and to argue logically.

Example: Definitions, at appropriate moments throughout the workshop, of various physical quantities (such as work, power, efficiency, etc.) in precise mathematical terms, rather than purely qualitative language

Benchmark: The Nature of Mathematics: 2B Mathematics, Science, and Technology: 9-12

Whenever the amount of energy in one place or form diminishes, the amount in other places or forms increases by the same amount.

Example: Principle of conservation of energy, a key theme of the entire workshop

Benchmark: The Physical Setting: 4E Energy Transformations: 9-12

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.

Example: Discussion of the universal tendency toward disorder and the nature of heat (Workshop 7: Heat, Work, and Efficiency)

Benchmark: The Physical Setting: 4E Energy Transformations: 9-12

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.

Example: Description of generation of "waste" heat during energy conversions (Workshop 3: Transfer and Conversion of Energy)

Benchmark: The Physical Setting: 4E Energy Transformations: 9-12

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 of 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.

Example: Description of origin of fossil fuels, and their role as a storage medium for ancient solar energy (Workshop 8: Understanding Energy)

Benchmark: The Living Environment: 5E Flow of Matter and Energy: 9-12

Standards, cont'd.

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.

Example: Explanation of pathways of energy through food webs (Workshop 5: Energy in Food)

Benchmark: The Living Environment: 5E Flow of Matter and Energy: 9-12

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.

Example: Discussion of role played by societal values and priorities in choosing which energy sources to exploit (Workshop 8: Understanding Energy)

Benchmark: Human Society: 7D Social Trade-Offs: 9-12

At present, all fuels have advantages and disadvantages so that society must consider the tradeoffs among them.

Example: Description of advantages and disadvantages of various energy sources (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 9-12

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.

Example: Discussion of non-economic costs of various energy sources (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 9-12

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.

Example: Description of the role of the Industrial Revolution in changing people's use of energy, and the environmental and social consequences of increased dependence on energy (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 9-12

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 tradeoffs of economic costs and social values.

Example: Descriptions of techniques (personal and societal) for reducing energy usage (Workshop 8: Understanding Energy)

Benchmark: The Designed World: 8C Energy Sources and Use: 9-12

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.

Example: Explanation of how systems-oriented thinking is useful in designing more energy-efficient products (Workshop 6: Energy and Systems)

Benchmark: Common Themes: 11A Systems: 9-12

Workshop 1
What Is Energy?

Interviews with children, scientists, and people on the street reveal that many of us share common-sense ideas about the subject of energy, leading to statements such as, "sunny days give me energy" or "energy is a source of life." This program explores some of the differences and similarities between the everyday and the scientific language of energy, recognizing that many everyday concepts are useful launching points for getting to know more about energy. The program traces the development of these ideas through interviews with scientists and with children, aged 10 and 11.

After a brief tour of the history of the scientific concept of energy, this session defines different forms of energy and discusses how central the idea of energy is to a scientific understanding of the world. Finally it shows how the "Big Idea" of energy is embedded in the K-6 curriculum with views of elementary classrooms in which students and teachers are engaged in activities related to energy, even when the word *energy* is never explicitly mentioned.

On-Site Activities

Getting Ready (30 minutes)

What Is Energy?

1. During the next few weeks, you will be studying the concept of energy. Before we begin, how would you define energy?

Write out your definition of the word *energy* on a sheet of paper and hand it to your workshop facilitator. It will be returned to you at the end of Workshop 8.

2. Write down your responses to the following questions. Then share them with a partner and make a combined list to share with others in the group.

   a. If you asked your students to define the word *energy,* what do you think they would say?

   b. If you asked one of your teaching colleagues to define the word *energy,* what would he or she say?

3. Discuss the key ideas in these shared responses. What are some similarities and differences between the students' definitions and the teachers' definitions?

Watch the Video (60 minutes)

As you watch the video, consider the following questions and answers:

1. What is energy?	***Energy is the ability to do work.***
2. What are some forms of energy?	***Forms of energy include light, sound, heat, mechanical, and chemical.***
3. Where does energy come from?	***The Sun is the source of almost all energy on Earth that we use.***
4. How did scientists develop the concept of energy?	***Scientists arrived at the idea of energy by investigating heat.***

Going Further (30 minutes)

Making Meaning

In this program, several different metaphors for energy were introduced. Discuss with a group which of the metaphors was easiest for you to understand? Why?

Lights, Camera, Energy!

With a partner, discuss the following: You have been hired to design a video series based on the concept of energy. As you are outlining the plans for your work, be sure to consider the following list of questions.

1. What topics will you cover in the series?
2. What activities or demonstrations will you do to illustrate the concept of energy?
3. What real-life examples will you provide to help the audience better understand energy?

Share your ideas with the group and then look for them as you watch this video series.

For Next Time

Homework Assignment

Later in the workshop, you are going to need some information that you will begin collecting now. Each time you go to the gas station for the next few weeks, please record the following data in the table below. You will discuss it during the Getting Ready for Workshop 7.

If you have two cars in your family, please collect separate data for each car. Record the make, model, year, and engine size (4-, 6-, or 8-cylinder) below.

CAR 1:

Make ______________________ Year ___________________

Model ______________________ Engine size _____________

Miles driven since last fill-up	Total gallons on this fill-up	Miles/gallon	Miles driven since last fill-up	Total gallons on this fill-up	Miles/gallon

CAR 2:

Make ______________________ Year ___________________

Model ______________________ Engine size _____________

Miles driven since last fill-up	Total gallons on this fill-up	Miles/gallon	Miles driven since last fill-up	Total gallons on this fill-up	Miles/gallon

Reading

Read the article by Mary Kay Hemenway titled “Our Star the Sun,” found in the Appendix of this guide. Identify three facts about the Sun that relate to energy.

Materials Needed for Next Time

The Going Further section for Workshop 2 requires a ruler and a stopwatch.

Notes

Workshop 2
Force and Work

Force and work play an important role in a scientist's definition of energy. In this session, the everyday meanings of these words are contrasted with their scientific definitions. Viewers will explore how energy is related to work, which physicists calculate as the force applied to an object multiplied by the distance the object travels under the influence of that force (work = force x distance). As an example, an archer does work when he draws back his bow-string, and that work stores potential energy in the string and bow. The potential energy is then transformed into the kinetic energy of the arrow's motion. During extended interviews with children, the program shows how young people may begin to think about these ideas while exploring the behavior of balls and waterwheels.

The second half of the program looks closely at the concept of power, defined as the rate at which energy is expended or stored (power = energy / time). The relationship between power, time, and energy is explored through everyday examples such as light bulbs and electric bills. The program documents a number of classroom activities as well as a visit by a fourth-grade class to the historic textile mills in Lowell, Massachusetts, where the students have first-hand experiences with the energy of falling water.

On-Site Activities

Getting Ready (30 minutes)

The Sun and Energy

You read the article "Our Star the Sun" and identified three facts about the Sun that relate to energy. Have each member of the group take turns offering one of the facts you identified and continue until all items are mentioned.

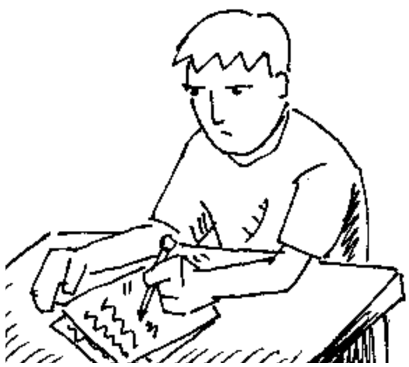
Shared Language

The terms force, work, and power are used in different contexts. Write a sentence using each of these words. Do you think you are using the word in the scientific sense, the everyday sense, or are they the same?

Physics Workout?

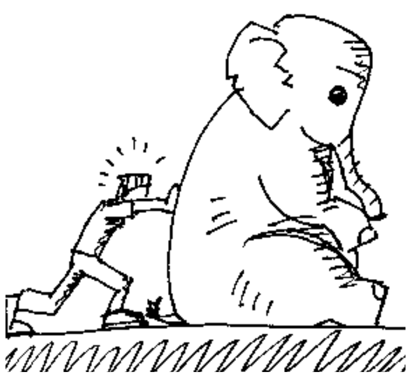
1. Rank the following pictures in order from the one showing the greatest amount of work to the one showing the least amount of work.

2. Discuss the reason for your selections with a partner and then share your ideas with the entire group.

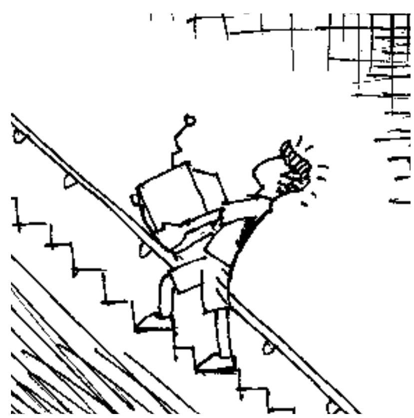


Picture 1: Student writing a paper

Picture 2: Student throwing a baseball



Picture 3: Student pushing a sitting elephant that is not moving



Picture 4: Student carrying a large TV up a flight of stairs

On-Site Activities, cont'd.

Picture 5: Student typing at a computer

Watch the Video (60 minutes)

As you watch the video, consider the following questions and answers:

1. What are forces and what do they do? — ***A force is a push or a pull. Forces can transmit energy from one object to another.***
2. What is work? — ***Work equals the force on an object multiplied by the distance the object moves while the force is being exerted.***
3. How are work and energy related? — ***Work is a way of transferring energy from one system to another or converting energy from one form to another.***
4. What is power? — ***Power is the rate at which energy is transferred from one system to another or converted from one form to another.***

Going Further (30 minutes)

How Powerful Are You?

In this activity, you will determine how much power you generate when you ascend a flight of stairs. Do you think you can put out as much power as a 100-watt light bulb? More? Less? Write down your answer and let's find out!

Materials: 1 ruler, 1 stopwatch

1. Find a staircase that is not currently in use. With a ruler, measure the height of one stair and multiply by the number of stairs to determine the height of the staircase in inches.

   Height of staircase (in inches) ________________

   Your weight (in pounds) ________________

By multiplying your weight by the height of the stairs, you can determine how much work you do in order to climb the stairs. How fast you do the work is your power output.

On-Site Activities, cont'd.

2. Have a member of your group stand at the top of the stairs and time each member as he or she runs up the stairs. (If you do not wish to run, feel free to walk—you will still be able to do the calculation, you just won't be the most powerful one in the group.)

Your time to go up the stairs (in seconds) ________________

3. To calculate how much power you generate while climbing the stairs, you will divide the work you do by the time it takes you to do it. The formula shown below includes a conversion factor of 0.113 that changes your answer into watts.

$$\text{power} = \frac{\text{weight x distance x 0.113}}{\text{time}} \quad \text{or} \quad \text{power} = \frac{\text{work}}{\text{time}}$$

4. How many watts of power did you generate while going up the stairs?

5. How many 100-watt light bulbs could you light with this amount of power? How does this compare with your estimate?

6. Would the number be the same if the stairs were steeper? Why or why not?

For Next Time

Homework Assignment

Predict which member of your family will be the most powerful. Do you think it will be the person who weighs the most? Weighs the least? Is the fastest? Is the slowest? Is the tallest? Is the shortest? Do the activity at home with your family members to find out.

Reading

Read Chapter 3: "Children's Ideas on Energy" from Joan Solomon's book *Getting To Know About Energy,* found in the Appendix of this guide. Be prepared to discuss some of the ideas that you have seen your students express in class. Were they confusing the everyday and scientific meanings of words or did they not understand the concepts involved?

Workshop 3
Transfer and Conversion of Energy

There are several kinds of energy, for example: motion, heat, light, electricity, and sound, as well as various forms of potential energy, including gravitational, elastic, and chemical. These kinds of energy can be converted from one to another, which is demonstrated in a classroom activity in which students test solar powered cars.

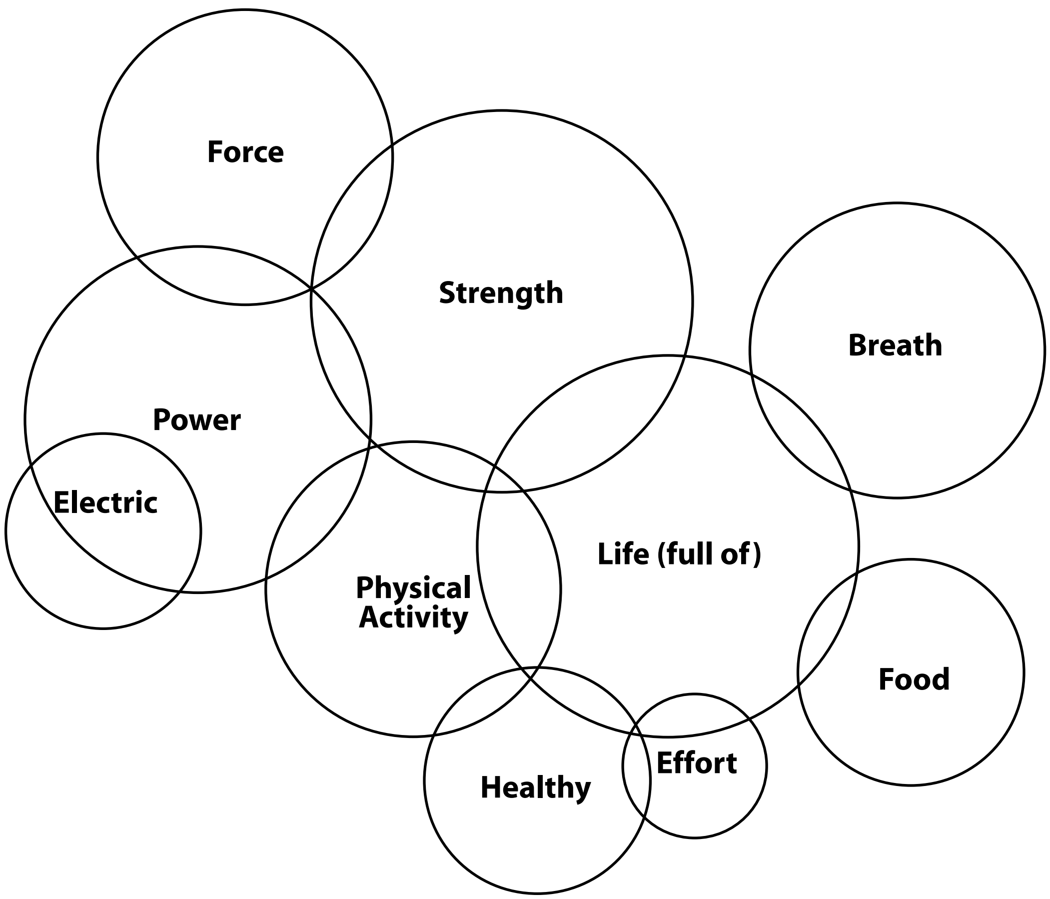
The program explores the principle of *conservation of energy,* which holds that when change happens in the physical world, so that energy is transferred or converted, the total quantity of energy remains constant throughout the process, even if the systems under study change considerably. Through a variety of analogies, different kinds of energy are shown to be equivalent. The second half of the program discusses energy "triggers"—events in which the application of a small amount of energy releases a much larger amount of stored potential energy. Classroom activities and interviews with children and scientists show this concept in action.

On-Site Activities

Getting Ready (30 minutes)

Children's Ideas

Your homework was to read "Children's Ideas on Energy," the third chapter from Joan Solomon's book, *Getting To Know About Energy,* and to be ready to discuss ideas about energy that your students have expressed in class. With a partner, categorize those ideas in the chart below and discuss your findings.



Forms of Energy

Energy can come in many different forms and from a variety of sources. In this workshop, we will categorize energy into several different forms that can be transformed from one to another.

1. Based on what you know about energy from everyday life, see if you can come up with several forms of energy. Be sure to note that we are looking for *forms* of energy, not *sources* of energy.

2. Once you have your list created, discuss it with two or three partners and see if you can agree on a list of energy forms.

3. Share your list with the entire group.

On-Site Activities, cont'd.

Watch the Video (60 minutes)

As you watch the video, consider the following questions and answers:

1. What are some of the forms that energy can take? ***Kinetic, Electromagnetic Radiation, Heat, Electrical Sound, Potential, Nuclear***
2. What happens when energy is converted from one form to another? ***When we convert energy to a different form, the total amount of energy before and after is the same.***
3. How can an object or system gain or lose energy? ***Objects gain or lose energy by transferring energy to or from other objects or systems.***
4. How can energy be stored and then released at a later time? ***Energy can be stored by converting it into some form of potential energy, and it can be released by a small amount of additional energy.***

Going Further (30 minutes)

Energy Transformations

We can trace the path of energy as it changes from one form to another. For example, when you turn on a light, electrical energy is transformed into light and heat.

1. Listed below are some common activities. With a partner, discuss the energy transformations that occur in each of the following activities.

You turn on a flashlight	You strike a match	You hit a nail with a hammer
You ride a bicycle	You turn on a radio	You shoot an arrow with a bow

2. What kind of object would undergo the following energy transformation?

chemical to electrical to mechanical	mechanical to heat
chemical to light and sound	mechanical to sound and electricity

3. Think of a complicated device that transforms energy from one kind to another. Describe your device and list the energy transformations that occur. Try to include at least three or four transformations.

For Next Time

Homework Assignment

1. Describe an energy transformation that occurs in real life:
    a. over the course of one day.
    b. over 100 years.
    c. over thousands of years.
2. Find a toy (or toys) that you can bring with you to the next workshop session and be prepared to describe the energy transformations that occur when you use the toy(s).

Materials Needed for Next Time

Bring the toys described above to class.

Workshop 4

Energy in Cycles

Energy plays a crucial role in cycles that we see around us every day, from the bouncing of a ball to the vibration of a guitar string to the motion of a person running or walking. But how can these cycles be understood in the language of physics? It turns out that all of these phenomena, and many others, are examples of the periodic conversion of kinetic to potential energy and back again within a system.

A pendulum is one well-known example of an energy cycle, and this workshop session looks closely at its motion to see how it relates to other systems that involve energy cycles, such as springs, guitar strings, and U-shaped ramps. Students explore both how energy cycles diminish when energy is dissipated by friction and how they can add energy to a cycle to keep it going. Their thinking is compared to scientists' views. The ideas discussed are examined in a variety of contexts, including interviews on playgrounds, a visit to a bell tower, and an interview with the curator of a collection of antique pendulum clocks.

On-Site Activities

Getting Ready (30 minutes)

The Ups and Downs of Energy Conservation

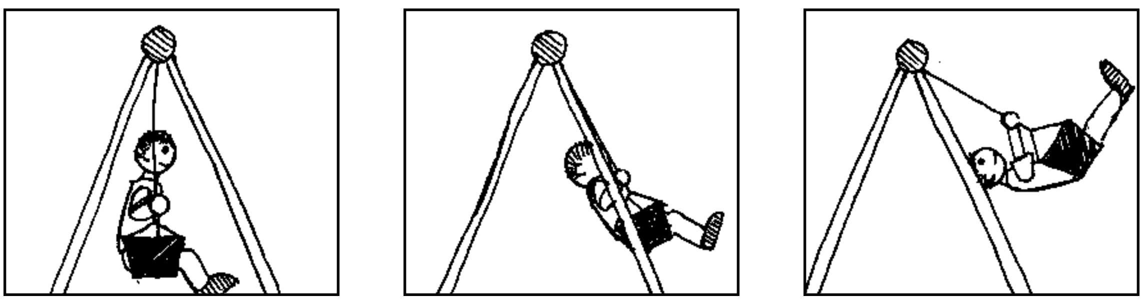
1. Discuss the energy transformations in the toys that you were asked to bring to the session. Which has the most transformations? The fewest?

2. An object gains kinetic energy (KE) when its speed increases and gains gravitational potential energy (PE) when its distance above the ground increases (and its speed decreases). In the following pictures:

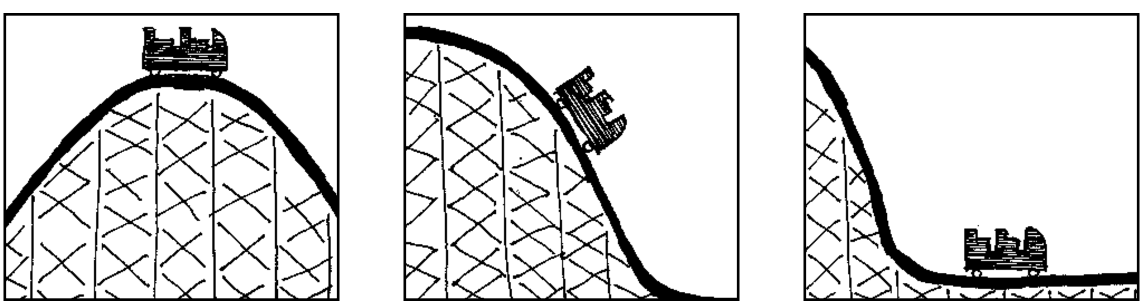
   a. label the spot or spots where the kinetic energy is the greatest.

   b. label the spot or spots where the gravitational potential energy is the greatest.

Discuss your answers with the rest of the group.

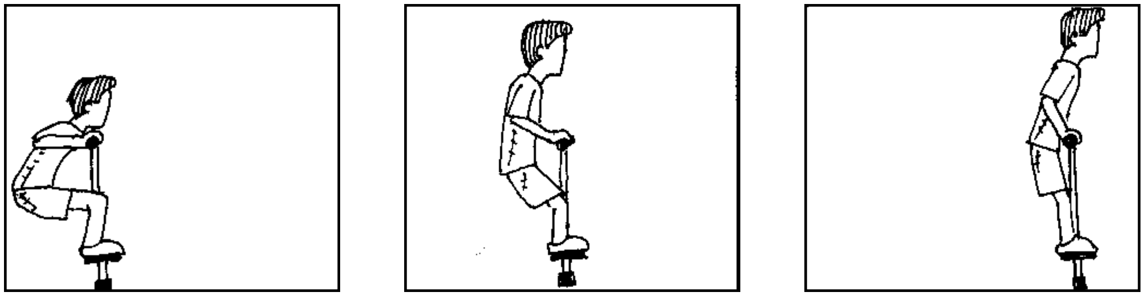


Child on a swing



Roller coaster

On-Site Activities, cont'd.



Boy on a pogo stick

Watch the Video (60 minutes)

As you watch the video, consider the following questions and answers:

1. What happens to energy when an object swings, bounces, or oscillates?
   When an object swings, bounces, or oscillates back and forth, energy is repeatedly converted from potential to kinetic energy and back again.
2. What are some everyday examples of energy cycles? ***Examples of energy cycles include pendulums, bouncing balls, springs, vibrating strings, and people running and walking.***
3. Why do most energy cycles diminish over time? ***In each cycle, some of the energy leaves the system as heat, sound, or other forms of energy. The total amount of energy remains the same, but some of it is no longer available to sustain the cycle.***
4. How can we add energy to maintain a cycle? ***Energy impulses have to be timed—and forces applied in the right direction—so that they add to the total energy in the cycle instead of reducing it.***

Going Further (30 minutes)

Energy Goes Along for the Ride

1. Break up into two groups. One group should discuss how to construct an amusement park ride that *minimizes* changes in gravitational potential energy, but is still fun. The other group should discuss how they would construct an amusement park ride that *maximizes* changes in gravitational potential energy to provide a safe, fun ride for its passengers.

2. After you have decided upon your designs, get together to compare the two rides.

   a. What things are the same?

   b. What things are different?

   c. What kind of ride would you prefer? Why?

For Next Time

Homework Assignment

In the next session, we will be looking at how our bodies use the energy content in food to allow us to carry out our daily lives.

Here is a list of several food items. Assume that there is an equal amount of each item.

Apple

Potato

Slice of pizza

Serving of broccoli

Candy apple

Hamburger

Bag of candy

1. On a sheet of paper, rank the food items from those with the most energy to those with the least. Make sure that you have good reasons for your choices.

2. On the back of the paper, rank the items again, this time order them from most nutritious to least nutritious. Why did you decide on this order?

Materials Needed for Next Time

Bring your food/energy list described above to the next workshop session.

Workshop 5
Energy in Food

Interviews with children, scientists, and people on the street present the wide range of ideas concerning food and energy that teachers encounter in learners. Simple explanations through demonstrations and real-world examples explore how chemical potential energy is stored in food and then in our bodies, and how it is converted into kinetic energy when it is needed.

This program presents the scientific definition of *calorie,* a word often heard in connection with food, and shows that the process of "burning calories" is not so different from what happens when a fire burns. The program also explores photosynthesis, the process by which plant cells capture and use the energy of sunlight.

On-Site Activities

Getting Ready (30 minutes)

Developing a Common Understanding

Before you discuss the homework you did for the last session, take a few minutes to write down the definition you used for "energy content" and "nutritional value" when you ranked the food items. Save these for the discussion at the end of the following activity.

There Is More to Nutrition Than Calories

For your homework, you were asked to evaluate the following list of food items for energy content and nutritional value.

Apple

Potato

Slice of pizza

Serving of broccoli

Candy apple

Hamburger

Bag of candy

1. With a partner, discuss the rationale for your order, and try to come to consensus on your rankings.
2. As a group, develop one set of rankings that represent the judgement of all the participants. (Make sure that you all agree on the definitions of "energy content" and "nutritional value" that you wrote at the beginning of the session.)
3. Finally, consider two more items, a glass of water and a glass of soda. Where would they fall on your consensus lists both for energy content and nutritional value?

Watch the Video (60 minutes)

As you watch the video, consider the following questions and answers:

1. Where do we get energy?

   All of our energy for life comes from food.

2. How do we get energy from food?

   Digestion breaks food down to nutrient molecules. Nutrient molecules then move to all the cells in the body. The process of respiration releases all the energy stored in these molecules.

3. Which foods give us the most energy?

   Foods high in fat contain the most energy.

4. Where does food get energy?

   The Sun is the original source of all the energy in our food.

On-Site Activities, cont'd.

Going Further (30 minutes)

How High a Staircase Can You Climb?

1. If all the energy in the food you consume could be transformed into useful work, how high a staircase could you climb? If that energy went directly into carrying you up the stairs, then the work you do while climbing the stairs equals the energy in the food eaten.

2. To make the calculation, you will need two pieces of information: your weight (in pounds) and the total calories you need for your body size and activity level. Select your appropriate calorie intake and enter it below along with your approximate weight.

Calorie Intake:

Most women, some older adults: about 1,600 calories

Active women, most men: about 2,200 calories

Active men: about 2,800 calories

Your weight (in pounds) ________________

Total calories required ________________

3. To do your calculation, you will use the equation work = force x distance, where the work you do comes from the food energy you take in. The force is simply your weight in pounds and the distance is the height of the stairs. A conversion factor has been put into the equation so you can calculate the height in feet.

$$\frac{\text{(calories consumed) x (3088)}}{\text{your weight}} = \text{height of the stairs (in feet)}$$

How high a flight of stairs could you climb that day (in feet)? ________________

4. If these stairs went up a building that was 10 feet per story, how many stories would you be able to climb that day? ________________

5. Discuss your results with your group. Is this is a realistic number?

6. How does this height compare to Mount Everest or other well-known mountains?

Mt. Everest	29,035 ft.	8,850 m.
Mt. McKinley	20,320 ft.	6,194 m.
Mt. Kilimanjaro	19,563 ft.	5,963 m.

7. If you don't actually do the equivalent of climbing a tall mountain each day, where does your excess energy go? Discuss your answer with others in your group.

For Next Time

Homework Assignment

The Power of Household Appliances

1. Choose one room in your house that contains at least five electrical appliances. Make a list of all the appliances in the room and record the watts of power generated by each appliance. You can get the number of watts from the back of the appliance. If the power is not listed on the appliance, write down the current (in amps) that is on the back of the appliance and convert this into watts.

To convert amps to watts, multiply the number of amps by 120—the number of volts used by most appliances. Large appliances like ovens or air conditioners might use 220 volts but if you are unsure, use 120.

2. Record the amount of time that the appliance is on in a 24-hour period. Be sure to record this in hours, not minutes (e.g. record 0.5 h rather than 30 min.).

Appliance	Power (in W)	Total time in use (in h)

Materials Needed for Next Time

Bring your household appliances list to the next workshop session.

Workshop 6

Energy and Systems

Students sometimes say that energy "disappears," "dies out," or "slips away," because they don't think carefully about the physical boundaries of the objects they are observing and the energy that passes through those boundaries. Scientists, on the other hand, think in terms of systems—collections of objects within a clearly defined boundary. By keeping track of how energy passes through the boundary, they are able to trace and quantify the flow of energy, and to identify places where energy is "leaking" in or out. In this session, viewers examine different systems, including bomb calorimeters, electric power plants, and insulated winter clothing. Finally, the program looks at cases in which a systems-oriented approach helps in analyzing real-world problems, such as predicting the destructive power of a hurricane or planning the water flow of a hydroelectric dam.

On-Site Activities

Getting Ready (30 minutes)

Home Energy Audit

1. Use your appliance list to determine how much energy was used during a 24-hour period in the room you selected. To do so, you will first need to convert watts to kilowatts (kW) (divide the number of watts for each appliance by 1,000) and then put your answer in the column labeled "Power (in kW)".

2. Calculate the energy used by each appliance in kilowatt hours (kWh). To do this, multiply the power (in kW) by the time (in h). Record your answer in the last column.

Appliance	Power (in W)	Power (in kW)	Total time (in h)	Energy (in kWh)

3. Which appliance used the most energy in the 24-hour period? Why do you think this was so? Share your results with the group.

4. If each appliance were on for only one hour a day, which one would use the most energy? Why do you think this is so? Discuss your ideas with the group.

Watch the Video (60 minutes)

As you watch the video, consider the following questions and answers:

1. How can we reconcile the principle of conservation of energy with everyday experience?

We can account for energy in terms of systems. Any "missing" energy can be accounted for by looking for energy conversions and transfers out of the system, even if they are not obvious at first.

2. What is a system?

A system is an object or objects around which we can draw an imaginary boundary to keep track of inputs, outputs, and internal changes.

3. How can systems be useful in thinking about energy?

Systems enable us to make predictions, take better measurements, and improve our energy efficiency.

4. What are some practical applications of energy systems?

Systems are critical in helping us understand energy flow in terms of inputs, outputs, and internal change—even with phenomena not usually thought of in terms of energy.

On-Site Activities, cont'd.

Going Further (30 minutes)

Paying the Price

1. Now that you have calculated the energy used in your room in a 24-hour period, it is time to find out how much it costs to run the appliances. Energy costs vary from region to region, depending on the availability of energy sources in your area. We will assume an average energy cost of $0.10 per kWh. Multiply your total energy (in kWh) by $0.10 to find out how much it would cost to run your room for one day.

   Your energy cost for one day ________________

2. Multiply this number by 365 to find out the cost of running this room for one year.

   Your energy cost for one year ________________

3. Estimate how much you spend to run your entire house for one day.

4. Estimate how much you spend to run your entire house for one year.

5. Compare your results with the group and discuss the ways you could reduce the amount of energy you use each day. How much energy could you save each year with this amount of conservation?

For Next Time

Homework Assignment

1. Find a copy of your energy bill from your electric company. What is your actual cost per kWh of energy used?

2. According to your bill, at what time of year is your energy use the highest? At what time is it the lowest?

3. What energy-users in your house do you think contribute the most to the high cost?

4. Go outside and find your electric meter. Read what it says one day and then read what it says at the same time the following day. How much energy does your meter indicate that you actually use in one day?

For further study: If you have oil or gas heat, take a look at your fuel bill and determine what you pay per day. Remember, oil and gas are also sources of energy for many homes.

Materials Needed for Next Time

Bring along the mileage sheet you have been keeping for your car.

Notes

Workshop 7
Heat, Work, and Efficiency

During any process that uses energy—and that means just about any physical process at all—some of the energy is converted to heat. Conversely, sometimes we start with heat and need to convert some of it to mechanical work. Why can't we harness all of the energy we put into a system to do useful work? It turns out that it's not just friction or waste: there is a fundamental physical limit to how efficient any engine can be. This program examines the central relationship between heat, work, and efficiency.

In addition, the program looks at what heat actually is and why warm objects cool down and cold objects heat up. The program then explores how the energy involved in orderly motion—such as the motion of a pendulum—tends to be converted into the disorderly motion of atoms and molecules—in other words, into heat.

On-Site Activities

Getting Ready (30 minutes)

Is Your Car a Gas-Guzzler?

1. Using the automobile mileage data you started collecting as homework for Workshop 1, record on a blackboard or an overhead transparency the total miles per gallon for each vehicle in the group.

2. Compare the mileage for different cars. Which car was the most fuel-efficient? Which was the least fuel-efficient?

3. What do the fuel-efficient cars have in common?

4. What do the less fuel-efficient cars have in common?

What Are Your Options?

1. In an earlier program we saw a hybrid (gas- and electric-powered) car. There are several models now available and they are about twice as efficient as conventional vehicles but they cost considerably more to purchase and maintain. Think a minute about the following question and then take a vote.

   If you were ready to purchase a new car, would you purchase one of these more efficient vehicles? What factors would influence your decision?

2. High-efficiency fluorescent light bulbs have been available for many years. They give the same amount of light as conventional bulbs, but last eight times longer and use one quarter the electricity. Think a minute about the following question and then take a vote.

   If you needed some new light bulbs, would you purchase these more efficient ones? What factors would influence your decision?

3. "Energy Star" home appliances use 20% to 40% less electricity than older or less-efficient models, but cost more. Think a minute about the following question and then take a vote.

   If you had to replace a home appliance, would you purchase one of the more efficient ones? What factors would influence your decision?

Watch the Video (60 minutes)

As you watch the video, consider the following questions and answers:

1. How can we get work from heat?

   We get work from heat by using a temperature difference between two parts of a system, usually by expanding and contracting a gas.

2. Why do hot things cool down and cold things warm up?

   Molecules in hot places transfer their kinetic energy by randomly bumping and jostling slower-moving molecules.

3. What factor limits a system's efficiency in getting work from heat?

   The key factor is the temperature difference between the system's heat source and the heat sink. The greater the temperature difference, the higher the possible efficiency.

4. How are heat, work, and friction related?

   Friction converts the ordered energy of mechanical motion into the disordered—and less useful—energy of heat.

On-Site Activities, cont'd.

Going Further (30 minutes)

Where Do You Get All That Energy?

We have already discussed the seven different kinds of energy. Now we will take a critical look at where we get that energy.

1. Make a list of all the different sources of energy you know. Share your list with the group, recording all of the suggestions on the blackboard or an overhead transparency.
2. Label each item in your group list:
   a. **C** for a *convenient* energy source or **D** for those that are more *difficult* to use
   b. **E** for an *expensive* source or **I** for *inexpensive* source
   c. **F** for sources *friendly* to the environment or **P** for those that *pollute* the environment
   d. **R** for sources that will eventually *run out* and **L** for those that will *last* indefinitely
3. Are any of the energy sources inexpensive, convenient, non-polluting, and long-lasting?

For Next Time

Homework Assignment

Reading

Read the articles "Classroom Catapults" by Diane D. Villano and "Learning From Your Mistakes" by Pamela J. Galus, found in the Appendix of this guide, and be prepared to discuss the following:

1. Describe something that you have your students build and then use to collect data. If you have a picture of the device, bring it to the next workshop session to share with your colleagues.
2. Describe a situation where a mistake in your classroom lead to greater student learning.

Notes

Workshop 8
Understanding Energy

We need energy to fuel our transportation systems and light our homes, but we live in a world with a limited supply of affordable energy. This final program examines our current sources of energy and how energy is used. Conserving energy not only saves money but also has a positive environmental impact. This program will show how being smart about using energy is part of the curriculum at an urban school, where fourth-graders are getting involved in a community service project to learn about energy resources and how to conserve energy at school and at home.

This program examines the costs—economic and environmental—of using fossil fuels and points out that in the near future we will probably need to depend more and more on renewable energy sources. Viewers will see how two promising technologies—photovoltaic solar panels and fuel cells—can be combined to make solar electric power available 24 hours a day. Students taking a field trip to a solar demonstration house and using solar ovens in their classrooms experience first-hand some practical applications of renewable energy.

On-Site Activities

Getting Ready (30 minutes)

Back to Class

As a group, review and discuss the articles you read for homework.

1. Share the mistake in your class that lead to greater student learning.

2. Describe the device your students built and used to collect data. Share your pictures if you were able to bring some to the session.

Watch the Video (60 minutes)

As you watch the video, consider the following questions and answers:

1. Why is it important to understand energy resources? ***We currently face tough choices about our consumption of energy because fossil fuels that are used in every aspect of our lives are being depleted at an ever-increasing rate.***

2. Where does our energy come from and what are all the costs of using it? ***Today, most of the energy we use in our daily lives comes from fossil fuels. Using this energy has economic, environmental, and health costs.***

3. How can we reduce our consumption of energy? ***We can save energy by making responsible choices, such as investing in energy-efficient technology and modifying our behavior and habits.***

4. What alternative sources of energy can help address our energy needs? ***Renewable sources of energy such as solar energy, wind, geothermal energy, and biomass are helping now to address energy needs and will become even more important in the future.***

Going Further (30 minutes)

Reflecting on Your Understanding

1. Now that you have completed the *Energy* workshop, write on a piece of paper your new definition of energy that incorporates your new understanding.

2. Review the definition you wrote during the first workshop session. How has your definition changed?

3. Which of the workshop sessions in this series had the greatest impact on your understanding of energy?

What If You Were the Nation's Energy Czar?

If you were in charge of the nation's energy needs for the next century, what would you recommend that we do to conserve energy? What would you do to create more efficient energy use in an effort to reduce energy costs?

Appendix

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Appendix, cont'd.

Readings

Homework Assignment for Workshop 1

Hemenway, Mary Kay. "Our Star, the Sun..." *Science and Children* September 2000: 48-51.

Homework Assignment for Workshop 2

Solomon, Joan. *Getting To Know About Energy in School and Society.* London: The Falmer Press, 1989.

Homework Assignment for Workshop 7

Villano, Diane D. "Classroom Catapults." *Science Scope* February 2001: 24-28.

Galus, Pamela J. "Learning From Your Mistakes." *Science Scope* November/December 2000: 30-32.