

Annenberg/CPB
Professional Development Workshop Guide

Science in Focus

Force and Motion

An eight-part professional development workshop
for elementary and middle school science teachers

Produced by the Harvard-Smithsonian Center for Astrophysics

Science in Focus: Force and Motion

is produced by
the Harvard-Smithsonian Center for Astrophysics

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ISBN: 1-57680-446-1

Funding for
Science in Focus: Force and Motion
is provided by Annenberg/CPB.

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About the Workshop

Workshop Overview

In this workshop, teachers will explore science concepts in force and motion and come away with a deeper understanding that will help them engage students in their own explorations.

The study of force and motion really begins the first time a child picks up something or notices something move. If children are using high-quality instructional materials, they will have numerous opportunities to drop, slide, roll, float, and balance various objects and observe how the objects behave. They will also be encouraged to compare the results of these school-based investigations to their real-life experiences.

Students come to the classroom with deep-seated intuitive views about how the world works. Their K-12 science lessons should allow them to explore their own notions about common, everyday phenomena, discuss their observations with peers, and draw conclusions that can be tested. Since force and motion encompass phenomena that relate directly to the student's world, they provide a content area in which students can make predictions, practice data collection and graphing techniques, and start to make scientific sense of their observations. This also provides students with an opportunity to apply some of their growing mathematical understanding.

This content workshop consists of eight one-hour professional development programs. Each program features footage from a complete science lesson related to force and motion. These lessons, virtually unedited, take place in real classrooms across the grade levels. As children explore the relationships among motion, force, size, mass, and speed, the camera captures the students' ideas and how they change and build during the activity and subsequent discussion.

As each classroom lesson unfolds, science and education experts act as guides, highlighting and expanding on the key points that emerge. Their commentary, coupled with graphics and video demonstrations, reinforces the science concepts taught in the lessons, and supplements the lessons with background information about gravity, friction, air resistance, magnetism, and tension. As the students begin to connect science concepts to real-world phenomena, teachers will be asked to think about their own ideas on force and motion.

The lessons teachers observe in the video and the activities they do in this workshop will provide them with the opportunity to test some of their own initial ideas about force and motion. The goal is to move teachers toward a greater understanding of forces as interactions, the concept of action at a distance, the various ways to describe motion, and the effect of physical surroundings on the motion of objects.

About the Workshop, cont'd.

Workshop Goals

Concepts

You will:

- Develop an understanding of forces as interactions.
- Develop the ability to analyze the forces acting on objects.
- Develop the ability to analyze the motion of objects.
- Develop an appreciation for Newton's Laws of Motion.

Skills

You will learn to:

- Identify and represent forces, including:
 - Contact Forces:**
 - Active pushes or pulls (e.g., by the human body, rubber bands, or springs)
 - Passive pushes or pulls (e.g., by floor or rope)
 - Friction (e.g., sliding, rolling, or fluid resistance)
 - Non-Contact Forces:**
 - Gravitational, electrical, and magnetic forces
- Explain the forces acting on objects that are:
 - At rest
 - Moving with a constant speed
 - Moving with a constant acceleration
- Describe and explain (using words, pictures, data tables, and graphs) the motion of objects in one dimension, including:
 - Linear horizontal or vertical motion
 - Falling, with and without air resistance
 - Motion on an inclined plane (e.g., rolling and sliding)
- Describe the motion of objects using appropriate terms including:
 - Instant in time
 - Interval of time
 - Position
 - Instantaneous speed
 - Mass
 - Acceleration
- Develop a familiarity with terms related to force and motion including:
 - Inertia
 - Vector
 - Pressure
 - Stability
 - Net force
 - Scaling
 - Frame of reference
 - Power

About the Workshop, cont'd.

Workshop Descriptions

Workshop 1. Making an Impact

What would happen if an asteroid were to hit the surface of the Earth? How large a crater would the impact create? In this workshop, the ideas of force and motion are introduced, as seventh-grade students drop balls to simulate asteroid impacts. By varying a ball's mass, the height from which it is dropped, or the material being struck, the students explore what factors affect the size of the crater. They also learn about data collection and the proper use of measurement units.

Featured Classroom: Morse School, Cambridge, Massachusetts

Teacher Karen Spaulding's seventh-grade students model meteorite impacts by dropping balls of varying mass from different heights onto different surfaces and recording their results.

Visualizations: How Are Size, Mass, and Speed Related to Force?

Through video demonstrations and commentary, we explore the difference between mass and weight, whether objects of different masses fall at different speeds, and how quickly falling objects come to rest.

Workshop 2. Drag Races

Forces can help put objects into motion and can also bring moving objects to a stop. In this workshop, fifth-grade students explore the physics of motion using plastic cars with strings and washers attached to provide a pulling force. The students test the speed of the vehicles and explain what forces bring the vehicles to a stop, as the cars collide with and displace barriers at the end of their run. Finally, the students discuss their findings to help solidify their understanding of the effect of forces on motion.

Featured Classroom: Armstrong School, Westborough, Massachusetts

Barbara Mitchell's fifth-grade class discovers how model cars can be moved by falling weights (washers hung by a string). The students make predictions about the motion and test what forces bring their vehicles to a stop.

Visualizations: How Will a Constant Force Affect Motion?

Video and graphic demonstrations provide an introduction to the concepts of friction, vectors, and acceleration under different experimental conditions.

Workshop 3. When Rubber Meets the Road

A rubber band twisted around the axle of a plastic car provides the force that moves the car forward. In this workshop, fifth-grade students continue their exploration of force and motion by recording and comparing the distance a vehicle travels under various conditions. Students predict the distance the car will travel by counting the number of twists in the rubber band, and observe the car's speed as it rolls across the floor. When the force of the rubber band stops acting, the force of friction slows the car to a stop.

Featured Classroom: Armstrong School, Westborough, Massachusetts

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

Visualizations: How Will a Changing Force Affect Motion?

Demonstrations further illustrate vectors, frictional forces, and factors that may cause changes in acceleration or bring an object to rest.

About the Workshop, cont'd.

Workshop 4. On a Roll

The force of gravity makes a ball roll when it is placed on an incline. In this workshop, first-grade students roll balls of different sizes, masses, and materials down ramps of varying heights, comparing their speeds. The students then experiment by replacing the ramp with a cardboard tube, and try to determine how the tube must be oriented to allow the ball to roll, much as it rolled down the ramp.

Featured Classroom: Laurel Lake School, Fall River, Massachusetts

In this workshop, Joanne Aguiar's first-grade students roll balls of various sizes, masses, and materials down ramps and compare patterns of motion.

Visualizations: How Do Size and Mass Affect Motion?

Expanding on their observations, we investigate changes in motion as a result of different forces under different conditions.

Workshop 5. Keep On Rolling

Roller coasters are filled with twists and turns, as changes in height and direction supply a variety of push and pull forces. In this workshop, first-grade students build on their prior experience with rolling objects. By designing and constructing their own roller coaster made from ramps, cardboard tubes, and flexible tubes, the students experiment with ways to get a marble from the top of a table into a bucket on the floor, some distance away.

Featured Classroom: Laurel Lake School, Fall River, Massachusetts

Joanne Aguiar's first-graders continue to explore rolling motion, using ramps, tubes, and changes in height and direction to design and construct their own roller coasters.

Visualizations: How Does Changing the Angle Affect the Motion on an Inclined Plane?

Using the class activities as a springboard, we investigate the forces acting upon objects on both inclined planes and flat surfaces.

Workshop 6. Force Against Force

Magnets stick to other magnets and to metal objects made of iron or steel. How much force is required to break the attraction between two magnets? In this workshop, fourth-grade students explore ways to balance the force of magnetism against the force of gravity. A magnet placed in a cup on one side of a pan-balance is stuck to a stationary magnet beneath the cup. When enough washers are placed on the opposite side of the balance, the magnets will separate. Graphical analysis shows some unexpected results.

Featured Classroom: Harwich Elementary School, Harwich, Massachusetts

Janet Smithers' 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.

Visualizations: How Do You Measure Unseen Forces?

Expanding on the classroom work, we explore the force of attraction between magnets and how to quantify these forces.

About the Workshop, cont'd.

Workshop 7. The Lure of Magnetism

What is the difference between a permanent magnet and an electromagnet? In this workshop, fourth-grade students build an electromagnet by winding a wire around a rivet and attaching the ends to battery terminals. The students first predict how many washers they can pick up with the help of their electromagnet and then perform the experiment to test their predictions. After the number of washers is recorded and the results are discussed, the students engage in a group discussion about practical uses for electromagnets.

Featured Classroom: Harwich Elementary School, Harwich, Massachusetts

Janet Smithers' fourth-graders continue their investigation of magnetism. Working with electromagnets, they change the number of windings of the wire around the metal core, make predictions, and test their results.

Visualizations: How Do Permanent Magnets and Electromagnets Differ?

In this workshop, we learn how to control the force of electromagnets and how electromagnets differ from permanent magnets. We also explore how previous workshop ideas fit into Newton's Laws of Motion.

Workshop 8. Bend and Stretch

We all expect a spring to stretch or compress when a force is applied, but forces can even deform solid objects like the floor or the top of a table. In this workshop, students in a high school classroom explore ideas about tension and normal force. By applying a force to a spring and measuring the distance the spring is stretched, the students calculate the force constant or stretchiness of the spring. Lecture demonstrations using student volunteers help illustrate that even rigid objects bend when a force is applied.

Featured Classroom: Newton North High School, Newton, Massachusetts

Led by Paul Martenis, high school students explore how force can bend and stretch stationary objects, working with springs, rubber bands, suspended weights, and lasers on a tabletop.

Visualizations: How Can Force Deform an Object?

Science demonstrations expand on the students' work and help us visualize the deformation caused by force. We investigate the force produced by stretched and compressed objects when released.

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 that weekly programs. See Helpful Hints on the following page for information on preparing for your Site Investigations.

Getting Ready (Site Investigation)

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

Watch the Workshop Video

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

Going Further (Site Investigation)

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.

The 10-Cent Experiment

Each workshop video presents a simple hands-on activity that you can do on your own, using readily available materials, to investigate a science concept. Or, you can simply watch the demonstration and ponder the unanswered question it poses.

Workshop Journal

A critical part of taking steps toward change is representing 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 represent 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/force>

Go online for additional activities, resources, and discussion.

Channel-TalkForce

You can communicate with other workshop participants via email. To subscribe to Channel-TalkForce@learner.org (the workshop email discussion list), visit:

<http://www.learner.org/mailman/listinfo/channel-talkforce>

About the Site Investigations

Helpful Hints

Included in the materials for each workshop you will find detailed instructions for the content of your Getting Ready and Going Further activities (Site Investigations). The following hints are intended to help you and your colleagues get the most out of these pre- and post-video discussions.

Designate a Facilitator

Each week, one person should be responsible for facilitating the Site Investigations (or you might select two people—one to facilitate Getting Ready, the other to facilitate Going Further). The facilitator does not need to be the Site Leader, nor does it need to be the same person(s) each week. We recommend that participants rotate the role of facilitator on a weekly basis.

Review the Site Investigations and Bring the Necessary Materials

Be sure to read over the Getting Ready and Going Further sections of your materials before arriving at each workshop. The Site Investigations will be the most productive if you and your colleagues come to the workshops prepared for the discussions. A few of the Site Investigations require special materials. The facilitator should be responsible for bringing these when necessary. **You will need some of these materials for Workshop 1.** A complete materials list is on the following page, and materials are also listed for each workshop.

Keep an Eye on the Time

Thirty minutes go by very quickly, and it is easy to lose track of the time. You should keep an eye on the clock so that you are able to get through everything before the workshop video begins. You may want to set a small alarm clock or kitchen timer before you begin the Getting Ready Site Investigation to ensure that you won't miss the beginning of the video. (Sites that are watching the workshops on videotape will have more flexibility if their Site Investigations run longer than expected.)

Record Your Discussions

We recommend that someone take notes during each Site Discussion, or, even better, that you make an audiotape recording of the discussions each week. These notes and/or audiotape can serve as "make-up" materials in case anyone misses a workshop.

Share Your Discussions on the Internet

The Site Investigations are merely a starting point. We encourage you to continue your discussions with participants from other sites on the discussion area of the Web site and on Channel-TalkForce, the workshop email discussion list.

About the Site Investigations, cont'd.

Materials Needed

Note: You may want to do the 10-Cent Experiments at home. In that case, you would not need to bring those materials to the workshop sessions.

Workshop 1

A paper cup
A rubber band
Small objects for weighing

For the 10-Cent Experiment:

A marble
A muffin baking paper or a coffee filter

Workshop 2

For the 10-Cent Experiment:

Two raw eggs
A container of sand (depth of at least 6 inches)
A tile or other hard, flat surface

Workshop 3

Graph paper

For the 10-Cent Experiment:

A toy car
A smooth board
A stopwatch
Flat objects with different surface textures, such as:

- Sandpaper
- A dish towel

Workshop 4

Paper

For the 10-Cent Experiment:

A smooth board
Three identically sized soup cans:

- A can of thick soup, such as split pea
- A can of broth
- An empty can (with the top and bottom removed)

Workshop 5

For the 10-Cent Experiment:

A smooth board
Two wooden toy blocks, one twice as long as the other

Workshop 6

A non-carpeted floor
Two chairs, preferably with wheels
A rope or cord at least 4 to 6 meters long

For the 10-Cent Experiment:

Four small ring magnets
A pencil

Workshop 7

A 1.5-volt battery
A 2-inch or longer nail
1 yard of thin insulated wire (remove any insulation from the ends)
A box of paper clips

For the 10-Cent Experiment:

Five identical rubber bands
Two paper clips
A ruler
A set of keys (or other object that can act as a weight)

Workshop 8

Your poster from Workshop 7's homework

(Site Leaders: Please bring copies of participants' questionnaires from Workshop 1)

For the 10-Cent Experiment:

A coiled spring
A ball (of proportionate size, to rest on top of the spring)

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 currently a curriculum specialist at 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 MBA from Boston University.

Hosts

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. Dr. Baliunas has written over 200 scientific research articles, and has received the Newton-Lacy-Pierce Prize of the American Astronomical Society, the Petr Beckmann Award for Scientific Freedom, and the Bok Prize from Harvard University. In 1991, *Discover* magazine profiled her as one of America's outstanding women scientists. Dr. Baliunas is a contributing editor to *World Climate Report* and a receiving editor for *New Astronomy*, and has been science advisor for the science-fiction series, *Gene Roddenberry's Earth: Final Conflict*, which has been airing since Fall 1997. Dr. Baliunas received her Ph.D. in astrophysics from Harvard University. Her research interests include solar variability and other factors in climate change.

Katy Abel has covered education and parenting issues in broadcast television, on the Internet, and in print for the past decade. She is currently a writer for Familyeducation.com, part of Pearson's Learning Network, one of the top 50 most-visited Web sites on the Internet. For many years, Abel was a reporter, producer, and public affairs host at WHDH-TV, Boston's NBC affiliate. She also wrote a monthly column for the *Boston Parents' Paper*. Her "Family First" reports were a regular feature on the CBS Early Show with Bryant Gumbel and Jane Clayson. Abel has also produced reports for The Learning Channel's "Teacher TV" series and hosted a live, interactive program for teens, "Student Forum," beamed via satellite to high schools throughout New England via the Massachusetts Corporation for Educational Telecommunications (MCET).

Classroom Teachers

Karen Spaulding has taught sixth-, seventh-, and eighth-grade science at the Morse School, Cambridge, Massachusetts, for seven years. As a teacher leader in the Cambridge Public Schools, Spaulding supports other middle school science teachers in this diverse urban district while maintaining a full-time teaching load. Her leadership work includes curriculum development, assessment, grant writing, designing and carrying out professional development, and peer coaching. Previously, Spaulding taught eighth-grade mathematics in a school district in southern New Hampshire. She holds an M.S. degree in middle school science from Simmons College and a B.S. in

About the Contributors, cont'd.

middle school mathematics and science education from Lesley College (now Lesley University). The Commonwealth of Massachusetts named Spaulding the state's Christa McAuliffe fellow for 2001.

Barbara Mitchell is a fifth-grade science teacher and curriculum coordinator at the Armstrong School, Westborough, Massachusetts, where she has piloted and implemented standards-based, hands-on math and science curricula. Mitchell began her career designing and developing a K-6 science lab at Happy Valley School, Lafayette, California, and was program associate and project coordinator for PALMS (Partnerships Advancing the Learning of Mathematics and Science) at EcoTarium, an environmental museum in Worcester, Massachusetts. Mitchell holds an M.S. from Clark University in professional communication and a B.S. from Castleton State College in elementary education. A frequent professional development and seminar facilitator, she is active in MAST (Massachusetts Association of Science Teachers) and other professional associations.

Joanne Aguiar has taught first grade for the past 13 years at the Laurel Lake School in Fall River, Massachusetts, an urban school serving students from various ethnic and economic backgrounds. Her professional development in science, math, and technology has included long-term involvement with the University of Massachusetts Dartmouth Buzzards Bay Rim Project, which led to visits at the Woods Hole Oceanographic Institution and research trips to Nantucket and Cuttyhunk Islands. Aguiar also attended the Next Steps Institute in Seattle, Washington, and a NEW Urban workshop at NASA's Goddard Space Flight Center. Through the University of Massachusetts/Dartmouth-Fall River Peer Coaching Collaborative Project, Aguiar assists and encourages co-workers to use hands-on science kits in the classroom. She enjoys nurturing young children's curiosity for learning.

Janet Smithers is a fourth-grade teacher in Harwich, Massachusetts. Her 21 years of teaching experience include regular and special education. She enjoys teaching science to children because they easily absorb the content and process through discovery activities that are both engaging and educational. She finds that the best way for fourth-grade students to learn scientific concepts and develop strong thinking processes is through their own observations and hands-on investigations.

Paul Martenis has taught physics and physical science for eight years in the Boston area, and currently teaches at Newton North High School, Newton, Massachusetts. He also worked on the computer staff at the Harvard-Smithsonian Center for Astrophysics for seven years. Martenis holds a master's degree in education from Harvard University and a bachelor's degree in astronomy and physics from Haverford College.

Interviewers

Ingrid Allardi is an assistant principal at the Harry Lee Cole Elementary School in Boxford, Massachusetts, where she works with teachers to develop grade-appropriate science curricula. Previously, she taught first grade for six years, and helped plan and create professional development programs in math and science for the Annenberg/CPB Channel. Allardi holds an M.A. in child study from Tufts University and a B.A. in psychology from Smith College. She has a special interest in educational administration and educating children with special needs.

Joyce Gleason has been a science educator for over 30 years and is currently the director of outreach for the Annenberg/CPB Channel at the Harvard-Smithsonian Center for Astrophysics. She has been a high school teacher, K-12 coordinator, staff developer in two urban districts, educator of student teachers (undergraduate and graduate), and independent consultant. She is a past president of the Massachusetts Association of Science Teachers and currently serves as district director for the National Science Teachers Association. She was named Massachusetts Science Educator of the Year in 2000, and was program coordinator for the National Science Teachers Association national convention in 1999.

Judith Peritz has been a curriculum developer with the science education department of the Harvard-Smithsonian Center for Astrophysics for the past 10 years. She also spent 10 years in classrooms as a pre-K/elementary school teacher, and is actively involved in after-school math and science tutoring. Peritz holds an M.Ed from Boston University and a B.S. in education from Case Western Reserve University.

Instructional Materials Appearing in the Workshop

Full Option Science System (FOSS)

(Grades K-6)

“Magnetism and Electricity” Module (Grades 3-4)

FOSS K-6 is a carefully planned and coordinated elementary science curriculum comprised of 27 modules. There are five modules at the kindergarten level, six for grades 1 and 2, eight for grades 3 and 4, and eight for grades 5 and 6. The modules are organized under four strands: Life Science, Physical Science, Earth Science, and Scientific Reasoning and Technology. The modular design of the program provides versatility so that FOSS can be used in many different school settings and its advanced assessment system provides complete information about student learning.

FOSS and FOSSweb are developed at the Lawrence Hall of Science, University of California, Berkeley, copyrighted by The Regents of the University of California, and published by Delta Education, Inc. For more information on the FOSS K-6 Program or the FOSS Middle School Program contact:

FOSS, Lawrence Hall of Science, University of California, Berkeley, CA 94720

phone: 510-642-8941; Web site: www.fossweb.com or

Delta Education, Inc.

phone: 800-258-1302

Insights: An Elementary Hands-On Inquiry Science Curriculum

(Grades K-8)

“Balls and Ramps” Module (Grades K-1)

Insights is designed to meet the needs of all children in grades K-6 while specifically addressing urban students. It is a core curriculum of 17 six- to eight-week modules in life, physical, and Earth sciences. The curriculum and accompanying materials were developed by science curriculum specialists from Education Development Center, Inc. (EDC) and elementary school teachers from several urban districts. They are designed to develop children's understanding of key science concepts, improve students' abilities to think creatively and critically, encourage problem solving through experiences in the natural environment, foster positive attitudes about science, bridge science concepts to current social and environmental events, and integrate science with the rest of the curriculum, particularly with language arts and mathematics.

Module topics are based on children's experiences and interests, basic science phenomena, and concepts appropriate for each age level with potential for hands-on exploration. Modules can be taught independently to supplement existing curricula, but are conceptually linked to help lead students to a broader understanding of themselves and the world around them.

Published by Kendall/Hunt Publishing. For more information, call 800-542-6657.

Web site: www.edc.org/cse/imd/insights3.html

Instructional Materials Appearing in the Workshop, cont'd.

Science and Technology for Children™ (STC)

(Grades K-6)

“Motion and Design” Unit (Grades 3-5)

Science and Technology for Children (STC) is a hands-on science program for children in Grades 1 through 6. The program has 24 units, four for each grade level, designed to provide students with stimulating experiences in the life, Earth, and physical sciences and technology while simultaneously developing their critical-thinking and problem-solving skills.

The STC units give children the opportunity to learn age-appropriate concepts and skills and to acquire scientific attitudes and habits of mind. In the primary grades, children begin their study of science by observing, measuring, and identifying properties. Then they move through a progression of experiences that culminate in Grade 6 with the design of controlled experiments. The units’ “Focus-Explore-Reflect-Apply” learning cycle is based on research findings that knowledge is actively constructed by each learner and that children learn science best in a hands-on experimental environment where they can make their own discoveries.

The STC curriculum was developed by the National Science Resources Center (NSRC), a nonprofit organization operated jointly by the Smithsonian Institution and the National Academies. STC is published by Carolina Biological Supply Company and copyrighted by the National Academy of Sciences.

Web site: www.si.edu/nsrc/pubs/stc/stcmats.htm

Event-Based Science (EBS)

(Grades 6-9)

“Asteroid!” Module (Grades 6-9)

Event-Based Science is a new way to teach Earth, life, and physical science at the middle school level. EBS modules aim to increase science achievement by establishing relevance, a need-to-know, and a want-to-know. Videotaped television news coverage establishes the relevance; a real-world task creates the need-to-know; and engaging interviews, lively narrative, and team involvement lead to a want-to-know.

The series has 18 modules designed to last four to six weeks, each focusing on different themes and concepts across the domains of Earth, life, and physical sciences. The modules can be sequenced over all middle school grade levels and combined with other instructional materials in order to build a comprehensive middle school science program.

Event-Based Science was developed by teachers and staff from the Montgomery County (Maryland) Public Schools, and is published by Dale Seymour Publications. The EBS Project is supported by grants from the National Science Foundation and the National Aeronautics and Space Administration.

Web site: www.eventbasedscience.com

Physics: Principles With Applications

Textbook used for Workshop 8, by Douglas C. Giancoli, fifth edition, Prentice Hall, 1997.

Standards

National Science Education Standards (National Research Council)

K-4 Standards:

<http://www.nap.edu/readingroom/books/nses/html/6c.html#ps>

An object's motion can be described by tracing and measuring its position over time.

The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.

— *Content Standards: K-4: Physical Science: Position and Motion of Objects*

Magnets attract and repel each other and certain kinds of other materials.

— *Content Standards: K-4: Physical Science: Light, Heat, Electricity, and Magnetism*

5-8 Standards:

<http://www.nap.edu/readingroom/books/nses/html/6d.html#ps>

The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.

If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

— *Content Standards: 5-8: Physical Science: Motions and Forces*

9-12 Standards:

<http://www.nap.edu/readingroom/books/nses/html/6e.html#ps>

Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship $F = ma$, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.

The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them.

Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules.

— *Content Standards: 9-12: Physical Science: Motions and Forces*

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 the second grade, students should know that:

Things move in many different ways, such as straight, zigzag, round and round, back and forth, and fast and slow.

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

— *The Physical Setting: 4F Motion: K-2*

Things near the Earth fall to the ground unless something holds them up.

Magnets can be used to make some things move without being touched.

— *The Physical Setting: 4G Forces of Nature: K-2*

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

Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have.

How fast things move differs greatly. Some things are so slow that their journey takes a long time; others move too fast for people to even see them.

— *The Physical Setting: 4F Motion: 3-5*

The Earth's gravity pulls any object toward it without touching it.

Without touching them, a magnet pulls on all things made of iron and either pushes or pulls on other magnets.

Without touching them, material that has been electrically charged pulls on all other materials and may either push or pull other charged materials.

— *The Physical Setting: 4G Forces of Nature: 3-5*

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

An unbalanced force acting on an object changes its speed or direction of motion, or both. If the force acts toward a single center, the object's path may curve into an orbit around the center.

— *The Physical Setting: 4F Motion: 6-8*

Every object exerts gravitational force on every other object. The force depends on how much mass the objects have and on how far apart they are. The force is hard to detect unless at least one of the objects has a lot of mass.

— *The Physical Setting: 4G Forces of Nature: 6-8*

Standards, cont'd.

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

The change in motion of an object is proportional to the applied force and inversely proportional to the mass.

Whenever one thing exerts a force on another, an equal amount of force is exerted back on it.

— *The Physical Setting: 4F Motion: 9-12*

Gravitational force is an attraction between masses. The strength of the force is proportional to the masses and weakens rapidly with increasing distance between them.

Electromagnetic forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. At the atomic level, electric forces between oppositely charged electrons and protons hold atoms and molecules together and thus are involved in all chemical reactions. On a larger scale, these forces hold solid and liquid materials together and act between objects when they are in contact, as in sticking or sliding friction.

There are two kinds of charges, positive and negative. Like charges repel one another, opposite charges attract. In materials, there are almost exactly equal proportions of positive and negative charges, making the materials as a whole electrically neutral. Negative charges, being associated with electrons, are far more mobile in materials than positive charges are. A very small excess or deficit of negative charges in a material produces noticeable electric forces.

— *The Physical Setting: 4G Forces of Nature: 9-12*

