4H-590
1997

Science Guidelines for Nonformal Education

Developed for the National Network for Science and Technology (NNST)

Cooperative Extension Service—Children, Youth and Family Network
CSREES-USDA

Stephan Carlson
Sue Maxa

Cover photo: Richard Ponzio

Cooperative Extension System
Children, Youth and Family Network
To support collaboration among universities and community-based programs, the Cooperative State Research, Education and Extension Service (CSREES), USDA, created five National Networks to marshal faculty and program resources to directly respond to the economic, social and human stresses faced by children, youth and families.

These networks, which constitute the Cooperative Extension System Children, Youth and Family Network (CYF), are linked and accessed through CYFERNet, an Internet-based children, youth and family information system operated by CSREES.

The CSREES currently funds the five Networks for Child Care, Collaboration, Family Resiliency, Science and Technology, and Health.

Stephan Carlson, Ph.D
Sue Maxa, M.Ed
Center For 4-H Youth Development
College of Education and Human Development
University of Minnesota
340 Coffey Hall
1420 Eckles Avenue
St. Paul, MN 55108

Contents

Abstract

Science standards have historically set the course for science literacy in the United States for formal K–12 educators. However, little has been done to encourage science efforts out of school. The *Science Guidelines for Nonformal Education* are developed to help youth educators and volunteer leaders understand the importance of nurturing the skills necessary for a scientifically literate society. Participants in nonformal science education programs are able to engage in intelligent discussions about science and technology, are more employable due to their knowledge of science and their ability to use technology, and can understand science for enjoyment and personal gain.

The *Science Guidelines for Nonformal Education*, a document that is compatible with other national science standards efforts, such as *Benchmarks for Science Literacy* and the *National Science Education Standards*, includes sections on scientific inquiry, content guidelines, science and technology, and learning and teaching in nonformal settings.

The purpose of the science guidelines is to encourage understanding of science and technology, address guidelines from a nonformal perspective, and assure that nonformal guidelines are compatible with other science standards.

This document may be used by youth development professionals, curriculum developers, and volunteer leaders.

This document will be used to evaluate existing program curricula; guide the development of new science curriculum; judge a particular program's potential to fulfill the vision of a scientifically literate society; and enhance the quality of programs that were designed to improve youth's opportunity and ability to learn science.

Introduction

Scientific questions and environmental issues have been increasingly pushed to the forefront of everyday life. Issues being discussed include the use of DNA technologies, the storage of nuclear waste, the possibility of life on Mars, bioengineering and gene research, and the search for new drugs to fight diseases such as AIDS. At the same time, scientific literacy among our nation's students is at an all-time low (American Association for the Advancement of Science, 1989). This trend needs to be reversed. Combining formal school experiences, informal experiences (zoos, science and other museums, planetariums, etc.), and nonformal science experiences (4-H programs, Scouts, Boys and Girls Clubs, etc.) for youth is critical to improving their scientific literacy. Individuals from many backgrounds, such as volunteer leaders, teachers, and educators from zoos, aquariums, museums, and nature centers, play a role in improving scientific literacy. Collaboration is essential; relying solely on the K–12 formal school system is not enough.

Formal science programs encompass the K–12 science curriculum mandated by law and taught in many schools. Informal science programs include science museums, zoos, technology centers, and aquariums, where learning is less directed. Nonformal science programs include "organized, systematic teaching and learning carried on outside the formal school system with leadership from an adult or volunteer" (Walker, 1994). Most 4-H, Scouts, Boys and Girls Clubs, and other youth organizations encourage many types of nonformal science education. The richness of informal science programs has gained so much notice that the formal K–12 education system is moving toward a more interactive, self-exploratory model. Youth are encouraged to make decisions on what is to be learned, but to seek help on the how or means of the learning activity.

In contrast, formal learning includes settings where learners have no control over what or how they learn because of mandates by the state or school district. (Formal learning may or may not include the K–12 educational system, depending on teaching methods and styles.) Within an informal learning setting, such as a museum or zoo, learners control how they will learn but not what they will learn (Mocker and Spear, 1982). 4-H and other youth programs have long facilitated an experiential "learn- by-doing" model in which youth form partnerships with caring adults as volunteer leaders to present demonstrations, design project exhibits for county and state fairs, and do hands-on activities. Participants construct their own knowledge through inquiry as a way of making sense of the world. This type of learning and teaching needs to be continually encouraged because it has been shown to increase youth's retention of facts when compared to rote memory (Novak and Gowin, 1984).

The interdisciplinary nature of nonformal science education reflects the idea that science knowledge is intertwined with many different subject areas. For example, after asking questions about food poisoning and doing an investigation to find answers, a 4-H youth can display an understanding of the spread of salmonella in uncooked meat through a demonstration on proper food preparation techniques, an idea that is central to personal health, microbiology, safety, and home economics. Science is all around us and its understanding is reflected in many everyday decisions.

The purpose of *Science Guidelines for Nonformal Education* is to develop a document that encourages the understanding of science and technology; addresses science guidelines from a nonformal learning perspective; and is compatible with other national science standards efforts such as *Benchmarks for Science Literacy* and *National Science Education Standards*.

These guidelines will help professional youth educators, paraprofessionals, and volunteer leaders of 4-H and other youth organizations to stay abreast of trends in science education and to continue to provide quality science education programs. In addition, guidelines bring coordination, coherence, and consistency to the improvement of the national science education movement.

Science Guidelines for Nonformal Education draws directly from *Benchmarks for Science Literacy*, published by the American Association for the Advancement of Science (AAAS, 1993), and the *National Science Education Standards*, published in January 1996 by the National Research Council. Both resources are currently leading research efforts on scientific literacy and the development of science education guidelines. *Benchmarks for Science Literacy*, part of AAAS Project 2061, Science for All Americans, includes literacy goals for science as well as a discussion of the research used in the project. The *National Science Education Standards* offers material directly related to content standards, standards for science teaching, and program standards.

These guidelines provide criteria that 4-H youth development professionals and volunteer leaders can use to judge a particular program's potential to fulfill the vision of a scientifically literate society. The guidelines can also be used to evaluate existing 4-H program curricula and to guide the development of new science education curricula. Science guidelines are a way to enhance the quality of programs that were designed to improve youth's opportunity and ability to learn science.

The *Science Guidelines for Nonformal Education* are for all learners regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or science interest and motivation. The guidelines highlight youth in grades kindergarten through twelve. Middle school youth (grades 5–8) are the target audience for these guidelines because they comprise the majority of participants in 4-H programs and most other youth organizations. The guidelines recognize that youth with diverse backgrounds, learning styles, and interest levels acquire understanding in varying ways that are appropriate and fun for them.

Why is science education important? Scientific literacy is defined as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (National Research Council, 1996). Why is it important to encourage the scientific literacy of a population?

Members of western culture are confronted more and more with broad questions that require scientific information and scientific ways of thinking to make informed decisions. For example, many Americans have recently had to make hard decisions about the storage of nuclear waste at nuclear energy plants around the country. The storage of nuclear waste is potentially hazardous to water quality as well as to the quality of life for people living in the immediate vicinity of the storage facility. Encouraging youth to discuss science issues that affect society encourages scientific literacy.

Scientific literacy is critical to a well-prepared workforce in any technology-oriented society. The ability to understand and use science enhances the capability of all students to hold meaningful and productive jobs in the future. A sound grounding in science strengthens skills people use every day, such as creative problem-solving, critical thinking, and working cooperatively; it also helps people to use technology effectively and to value lifelong learning. The need for these skills in the business community is becoming more evident. A 1992 study by the U.S. Department of Labor (Learning a Living) showed that the number of poorly paid jobs is increasing. In 1973 the average entry-level worker with a high school diploma started at $9 per hour while in 1993 the same worker started at $6.50 per hour. In addition, science and mathematics education is central to our ability to keep pace with global competitors.

An understanding of science offers personal fulfillment, excitement, and enthusiasm for learning—benefits that can be shared by everyone. A youngster's face lights up when her straw rocket flies through the air. A boy makes a clear liquid and a white powder bubble and fizz. A pair of youth catch their first water strider in the pond.

The *Science Guidelines for Nonformal Education* have been developed for the National Network for Science and Technology (NNST), a component of the Children, Youth and Families at Risk Initiative, and a cooperative project among Land Grant Universities, 4-H, the U.S. Department of Agriculture, and the Cooperative State Research, Education, and Extension Service. The mission of NNST is to build capacity for improving literacy in science and technology through the support of creative and effective learning environments. The five primary objectives of NNST are to:

1. form a national network made up of land grant universities, cooperative extension systems, and other organizations interested in supporting and improving science literacy education, primarily through nonformal education methods and partnerships with formal education and industry.
2. identify and document the needs of communities, states, and regions for science and technology literacy education; develop programs and/or strengthen existing programs to respond to identified needs.
3. assist extension faculty and collaborators to develop and implement effective programs for children, youth, and families at risk.
4. develop, maintain, and evaluate effective partnerships at the local, state, regional, and national levels.
5. identify emerging issues related to science and technology literacy education that can and should be integrated into programming around the country to better prepare children, youth, and families for the future.

As part of a land grant institution, the University of Minnesota's Center for 4-H Youth Development has taken the leadership role in providing direction for this project. Further input has come from many other sources, including other land grant institutions, science education experts, NNST management team, Project 2061's *Benchmarks for Science Literacy*, and The *National Science Education Standards*. The Center for 4-H Youth Development is dedicated to improving the quality of 4-H and other youth development programs through research. These programs are a venue through which youth gain life skills; and youth who develop life skills become self-directed and productive citizens in the dynamic work force of today.

The following sections include guidelines for scientific inquiry, for science content, for science and technology in nonformal education, and for learning and teaching in nonformal settings. As a whole they define what a scientifically literate young person should know and describe the conditions necessary for achieving the national goal of scientific literacy for all youth.

Working your way through these guidelines

Part 1—Scientific Inquiry will:

- introduce and explain the eight scientific thinking and process skills, which are observing, communicating, comparing and measuring, ordering, categorizing, relating, inferring, and applying.
- provide a blueprint for inquiry-based science programs and learning environments.
- give an example of a technology activity that uses scientific thinking and process skills and elements of inquiry-based science.

Part 2—Content Guidelines will:

- provide a set of learner outcomes for scientific inquiry, physical science, life science, earth and space science, science and technology, science in personal and social perspectives, history of science, and unifying concepts and processes.
- give examples of hands-on science activities that draw directly from the guidelines.

Part 3—Science and Technology will:

- define "technology."
- present steps to solving technology problems.
- provide examples of technology activities that emphasize problem-solving abilities.

Part 4—Learning and Teaching in Nonformal Settings will:

- list five tenets of constructivism.
- explain the experiential learn-by-doing model.
- explain the youth-driven model.
- answer the question "Who takes charge of learning?" in nonformal settings.
- present a checklist for good learning.
- give examples of how these learning and teaching methods can be applied to science.

Appendix:

- provides hands-on science activities that directly reflect the Content Guidelines section.

Part 1

Scientific Inquiry

Children are naturally curious. They are constantly asking questions, using their taste, sight, hearing, touch, and smell to find out more. A sense of wonder is the essence of inquiry. Nurturing this natural sense of wonder in children is key to science learning.

Scientific inquiry means using knowledge, imagination, reasoning, and process skills to actively develop science understanding. Through inquiry, youth practice life skills. A skill is a learned ability to do something well. Life skills are defined as skills that help an individual to be successful in living a productive and satisfying life, such as thinking, managing, relating, caring, and giving (Hendricks, 1996). Through inquiry, youth describe an object or movement, and ask questions; they conduct experiments to answer those questions and communicate their discoveries. The scientific thinking and process skills inherent to scientific inquiry can be translated for any age group to any science activity: for example, they could be used in biological sciences, physical sciences, animal science, clothing and textiles, technology and engineering, or food and nutrition, (i.e., curricula in Form ES 237, the national reporting form for 4-H). Consider the case of a girl who comes to a 4-H meeting wondering why there are so many earthworms in the garden when she helps her grandmother with her tomato plants. The group shares her interest and decides to investigate earthworms and their role in soil as their next project. First, the group members observe worms and describe how they move, what they feel like, where they live, how they sound, and what they eat. Then they explore outdoors to see and feel the soil where earthworms live. Next, participants do an experiment to test what foods worms prefer to eat. Then they compare their results with each other and with their predictions. Finally, they talk about their experiments and use pictures or words to report on what they have learned. In this case, youth are challenged to combine critical thinking skills with their new knowledge about soil and earthworms.

The following pages explain and exhibit the scientific thinking and process skills that are essential to scientific inquiry. An inquiry-based science program uses and encourages the use of these skills in science activities. Thus, an inquiry-based science program gives youth the skills to use in investigations and maintain a sense of wonder in everyday life. A youth who wonders why the moon looks bigger on the horizon than higher in the sky may develop an experiment to find out whether the moon really is bigger on the horizon. Thus, an inquiry-based science program is a blueprint for naturally encouraging youth to work with peers, apply information, operate pieces of technology such as microscopes, computers, or scales, and use available resources like libraries, experts in the community, the World Wide Web, and/or the staff and exhibits found in museums.

Science is "the process of becoming aware of and understanding ourselves, other living things, and the environment through the senses and personal exploration" (McIntyre, 1984). It can be studied by using scientific thinking and the eight process skills that are a part of scientific inquiry: observing, communicating, comparing and measuring, ordering, categorizing information, relating knowledge, inferring to obtain explanations, and applying knowledge to solve problems and make informed decisions.

Observation through use of the senses (sight, smell, taste, touch, and hearing) is a main route to knowledge. By observing, people come to know about the characteristics of objects and the interactions between and among objects. Communication, the process by which youth can compare results and engage in discussions about their experiences, takes place between all participants, especially between peers. Comparing data allows participants to learn about the unknown by looking at similarities and differences with what is known. Compiling, ordering, and categorizing help organize data and can uncover scientific principles and laws. Relating or weaving together concrete and abstract ideas is essential to explain or test phenomena. Inferring—which helps predict simple and complex phenomena—is the process of predicting ideas that are not directly evident. The process of applying knowledge means using different kinds of knowledge to solve real-world problems, for example, inventing new technology or using mathematics to solve a problem. An inquiry-based science program combines these eight processes to encourage scientific thinking and reasoning and the construction of science knowledge. Inquiry-based science also supports the experiential, learn-by-doing model and the youth-driven model described in Part 4.

The scientific thinking process skills were adapted from the 1990 California State Science Framework and broken down into the following eight skills: observing, communicating, comparing and measuring, ordering, categorizing, relating, inferring, and applying (California Department of Education, 1990). These eight science processes match with science content and cognitive development for ages five through adulthood. Five of the processes (observing, communicating, comparing, ordering, and categorizing) have been identified as particularly relevant to learners aged five to nine (CA Dept. of Ed., 1990).

The scientific thinking process skills have been organized in a way that reflects knowledge from two research fields: developmental psychology (matching stages of development to the thinking needed to complete each activity) and cognitive science (providing particular kinds of learning experiences that relate to specific science concepts). These processes build on each other, each one inclusive of the prior one.

Scientific thinking and process skills

1 **Observing:** generating reasonable questions about the world based on observation
- seeing
- hearing
- tasting
- smelling
- feeling

2 **Communicating:** giving or sharing information and thoughts
- silent
- oral
- written
- with pictures
- questioning

3 **Comparing and measuring:** using simple measurement tools to provide consistency in an investigation
- sensory observations
- weight
- quantity
- quality
- capacity/volume

4 **Ordering:** putting objects or events in a sequence or series
- placing objects on a continuum such as large to small, smooth to rough
- placing events on a time continuum
- differentiating between linear and cyclical

5 **Categorizing:** putting objects or events in groups or classes
- putting objects or events together using a logical rationale
- sorting and grouping: putting items together on the basis of a single attribute
- classifying

6 **Relating:** developing solutions to unfamiliar problems through reasoning, observation, and experimentation
- asking questions such as how fast, how slow, at what rate
- making a logical guess about why something is happening
- understanding the relationship between evidence and explanation
- designing and conducting simple investigations
- asking inquiry-based questions
- designing and conducting a scientific investigation to identify and control the things that change (variables)
- manipulating simple machines and explaining how they work

7 **Inferring:** concluding from reasoning or evidence
- generalizing data
- looking for and predicting patterns in data
- using models to explain data or create a theory

8 **Applying:** using sources of information to help solve problems
- using knowledge to solve problems
- applying science and math learning to the resolution of current issues
- inventing new technology
- using math
- formulating additional questions

Although scientific thinking and process skills are the foundation of an inquiry-based science program, they should be viewed with flexibility. They are useful tools and distinctions, not limits on what constitutes good scientific inquiry.

Teaching of scientific inquiry is not a pursuit just for teachers and volunteer leaders. Any caring adult can encourage youth to explore. It is simply a matter of sharing with youth the joy, excitement, and mystery of the world in which we live. These feelings are the fertile soil in which the seeds of knowledge can grow. By engaging youth in interactive science experiences, helping them to build on their own knowledge, and encouraging them to apply scientific inquiry skills to everyday life, (adults) will help youth develop into scientifically literate adults.

Blueprint for inquiry-based science

Learning environments

- Allow time for youth to make mistakes, ponder, ask questions, share ideas, and make messes.
- Apply necessary safety rules.
- Select materials to give students quality products.
- Choose materials that can be reused and recycled.
- Use materials that encourage action and exhibit obvious change.
- Respect the environment in which you are studying.
- Identify and use outside resources such as scientists, universities, national labs, industry, the Web, and libraries.

Programs

- Develop long- and short-term goals for the science.
- Be flexible to encourage inquiry.
- Adapt science content to meet the interests, knowledge, and abilities of participants and leaders.
- Encourage participants to be responsible for their own learning.
- Recognize diversity among participants and encourage participation by all learners.
- Use questions to stimulate discussions.

Finding out about fibers and fabrics

An experiment using scientific thinking and process skills

Through this activity students will get an opportunity to make observations, record their data, communicate with other students, compare their results, and apply their knowledge to create a technological design.

Step 1 ▶ Divide the group into teams of 3 or 4. Materials should be centrally located. Materials include: 4 or 5 identified types of fabric remnants such as cotton, linen, wool, or nylon (preferably white); eyedroppers; plastic cups; measuring cups; pie plates; and plastic spoons. Prepare sets of 4 or 5 fabric samples. Each type of fabric should be cut into uniform 1"x 3" strips. Cut enough strips so that each team has several sets for the tests they will design.

Step 2 ▶ Announce to the group that they have been asked to design a headband for the Summer Olympic Games. But first, they must design scientific investigations to learn about the characteristics of various fabrics. Emphasize that each team's investigation must be a fair test, that is, whatever is done to one fabric sample must be done in the same way to every other sample. Give teams time to discuss how they will test the absorbency of fabrics.

Step 3 ▶ Youth should proceed to test the absorbency of the different fabrics and record their data. After the investigation, teams can share their observations. Explain that since every team did its test in a different manner, it is not valid to compare results directly but that general conclusions about the absorbency of fabrics can be drawn.

Step 4 ▶ Next, have all groups decide on one test that will be performed on all fabrics. Conduct the investigations again. Record and compare the results.

Step 5 ▶ Finally, youth will design a headband based on the results of their experiments. The headband must have superior absorption qualities and must maintain its elasticity and color in 100° F heat and 100% humidity. The headband must be easily produced, lightweight, and affordable. Draw a detailed colored sketch of the headband and label all the materials that will go into its production. Describe each material's function and the reason it was selected.

(Design Connections Through Science and Technology, National Science Foundation)

Part 2

Content Guidelines

The content guidelines provide curriculum developers with a set of learner outcomes and establish a mechanism to maintain accurate content. The content guidelines are not curriculum or science activities per se, but they describe the type of knowledge youth should develop as a result of participating in a science program. For example, someone developing an aerospace unit could look at the content guidelines on motion and force to get an idea of what youth should learn and how that knowledge contributes to scientific literacy.

The guidelines also give them a way to track the scientific consistency of their curriculum with other educators across the nation. In other words, a curriculum developer working on animal science in California and a curriculum developer working in New York on forestry are able to address and reinforce the same life science concepts and process skills. Volunteer leaders also will get an idea of the range of possibilities in science education.

The content guidelines draw directly from *Benchmarks for Science Literacy*, published by the American Association for the Advancement of Science (AAAS, 1993), and *The National Science Education Standards* published in January 1996 by the National Research Council and the National Academy of Sciences.

The guidelines are organized in an outline format, similar to the format found in *The National Science Education Standards*, which allows areas of knowledge to be divided logically and to be easily absorbed. The content guidelines were chosen based on whether they:

- represented a central event in the natural world.
- represented a central scientific idea.
- guided fruitful investigations.
- applied to situations and contexts common to everyday experiences.
- are linked to lifelong learning skills.

Eight categories of Content Guidelines

1. **Scientific inquiry:** This category includes skills such as observation, measuring, and communication that can be used in all science disciplines.
2. **Physical science:** This category describes matter, motions and forces, and energy.
3. **Life science:** This category describes living systems, populations, and behavior of organisms.
4. **Earth and space science:** This category describes the earth and its composition, as well as the region beyond the earth's atmosphere.
5. **Science and technology:** Guidelines for this category establish connections between the natural and designed worlds.
6. **Science in personal and social perspectives:** Guidelines for this category look at how science contributes to culture, recognizing that many individuals have contributed to the traditions of science and that science is practiced in many different cultures.

7 **History of science:** Guidelines for this category look at science as a human endeavor, the nature of scientific knowledge, and provides an historical perspective on scientific knowledge.

8 **Unifying concepts and processes in science:** The guidelines of this category emphasize the understanding and the abilities associated with major conceptual and procedural schemes that unify science.

These nonformal science guidelines are important because they encourage consistency in science education and share a vision of scientific literacy for all Americans. They provide criteria that 4-H youth development professionals and volunteer leaders can use to judge whether particular programs are serving the vision of a scientifically literate society. The content guidelines follow.

1 Scientific inquiry: using specific thinking and process skills to actively develop science knowledge

Youth will develop the abilities necessary to carry out scientific inquiry and understanding about scientific inquiry.

The process skills listed below can help engage all youth (grade K–12) in scientific inquiry for any science activity. Engaging youth in inquiry helps them develop an understanding of scientific concepts, an understanding of the nature of science, and the skills necessary to make independent inquires about the natural world; it also encourages the disposition to use the skills and abilities associated with science.

Skills

- observing
- communicating
- comparing and measuring
- ordering
- categorizing
- relating
- inferring
- applying

Hands-on Science

Determine the rate of germination of seeds, controlling for light, moisture, and temperature.

2 Physical Science: the study of natural laws that pertain to nonliving bodies

Youth will be able to use and understand: (by grade level)

- properties of objects and materials (K–4)
- position and motion of objects (K–4)
- light, heat, electricity, and magnetism (K–4)
- properties and changes of properties in matter (5–8)
- motions and forces (5–8)
- transfer of energy (5–8)
- structure of atoms (9–12)
- structure and properties of matter (9–12)
- chemical reactions (9–12)
- motions and forces (9–12)
- conservation of energy and increase in disorder (9–12)
- interactions of energy and matter (9–12)

Hands-on Science

Investigate how wood can sink and float in water in terms of mass, volume, and density.

Matter:

the substance of which any physical object consists

- Substances have certain properties such as density, boiling point, and ability to dissolve in water.
- Elements combine to produce compounds (a substance composed of two or more elements) which account for living and nonliving substances.
- Substances react chemically with other substances to form compounds with different properties.
- All material is made up of atoms (the smallest component of an element).
- Atoms and molecules (the smallest unit of an element consisting of one or more atoms) are continually in motion.
- Chemical elements do not break down by usual methods, such as heating, electric current, or reaction with acid.

Motions and forces

motion: *the action or process of changing position*
force: *an influence on a body that produces change in movement or shape*

- The motion of an object can be described by its position, direction of motion, and speed.
- Without friction and gravity, an object will continue in the same direction at the same speed.
- Every object places gravitational force on every other object.

Energy:

the capacity to do work

- Energy can take many forms including heat, light, chemical, nuclear, mechanical, and electrical.
- Energy can be changed from one form to another.
- Heat energy moves from warmer objects to cooler objects.
- When light and matter come together, the result is refraction (the change of direction of a ray of light, sound or heat in passing from one medium to another), absorption, or reflection.
- Electrical circuits convert electrical energy into heat, light, sound, chemical, or other forms of energy.
- The sun is the major source of energy on earth.
- Energy cannot be created or destroyed, but only changed from one form to another.

3 Life science: the study of living things

Youth will be able to use and understand: (by grade level)

- the characteristics of organisms (K–4)
- the life cycles of organisms (K–4)
- organisms and environments (K–4)
- structure and function in living systems (5–8)
- reproduction (5–8)
- regulation and behavior (5–8)
- populations and ecosystems (5–8)
- the cell (9–12)
- the molecular basis of heredity (9–12)
- the interdependence of organisms (9–12)
- matter, energy, and organization in living systems (9–12)
- the behavior of organisms (9–12)

Hands-on Science

Describe 3 objects in the room that come from plants and 3 objects in the room that come from animals. List their characteristics and life cycles.

Living systems:

a combination of things having life and forming a complex whole

- All living things have structure (composed of interrelated elements) and function (the purpose for which something is adapted).
- All organisms are made up of cells (the structural unit of plant and animal life).
- Cells work to keep an organism living.
- Specialized cells perform specialized functions.
- Two-thirds of the weight of a cell is water.
- Cells continually divide to make more cells for the growth and repair of the organism.
- Disease occurs when there is a breakdown in the structures or functions of an organism.

Reproduction:

the natural process among animals and plants by which new individuals are generated

- Reproduction is common to all living systems.
- In many animal species, females produce eggs and males produce sperm.
- Plants can reproduce sexually, the egg and the sperm are produced in the flowers of flowering plants.
- Some organisms can reproduce asexually through budding, fission, or spore formation.

regulation and behavior

regulation: *the state of being in control*
behavior: *the manner of acting*

- All living things must be able to obtain and use resources; to grow and reproduce.
- Regulation of an organism's body temperature involves sensing external changes in the environment and changing body movements to keep within the temperature range required to survive.
- Most animals must be able to keep a steady internal body temperature while living in a constantly changing external environment.
- Behavior is one way an organism may respond to an internal or external change.
- An organism's behavior changes over time to adapt to its environment.

populations and ecosystems

population: *the total number of inhabitants of a place*
ecosystem: *the interaction of a community of organisms with their environment*

- A population consists of all the individuals of a species that co-exist at a given place.
- Every organism in a population has a niche in the ecosystem (producer, decomposer, consumer).
- Sunlight is the major source of energy in ecosystems.
- The number of organisms an ecosystem can support depends on the resources available and the amount of light and water it receives, as well as its temperature range and type of soil.
- Through evolution, many different species have developed by slow processes over many generations.
- Extinction of species occurs when a species cannot keep up with the changes in its environment or is outcompeted by its neighbors.
- Organisms may interact with one another in several different ways: predator/prey, producer/consumer, parasite/host, one organism may scavenge or decompose another.
- Relationships may be competitive or mutually beneficial.

4 Earth and space science:
the study of the earth's structure and its solar system

Youth will be able to use and understand: (by grade level)

- the properties of earth materials (K-4)
- objects in the sky (K–4)
- changes in earth and sky (K–4)
- the structure of the earth system (5–8)
- earth's history (5–8)
- earth in the solar system (5–8)
- energy in the earth system (9–12)
- geochemical cycles (9–12)
- the origin and evolution of the earth system (9–12)
- origin and evolution of the universe (9–12)

Hands-on Science

Design and create instruments for measuring weather by using common objects found in your home.

the structure of the earth system:

the study of the earth, its composition, or any of its changing aspects

- The earth has three layers: a thin crust, a hot liquid mantle, and a thick metallic core.
- Continents and oceans rest on crustal plates that continually move, creating earthquakes, volcanoes, and mountains.
- Rock formation can be described as the rock cycle: old rocks break down; the pieces of rock are then buried, heated, and shaped into new rock.
- Soil consists of broken down rock, decomposed material from dead plants and animals, and bacteria.
- Water covers most of the earth's surface, it passes through the crust, oceans, and atmosphere in the water cycle.
- Water has the property of dissolving to make a solution.
- The atmosphere is a mixture of oxygen, nitrogen, and other gases that include water vapor.
- Clouds are formed when water vapor changes to a liquid state. They influence weather and climate.
- Global weather patterns influence local weather .

earth's history:

geological events that have helped to shape the face and structure of the earth

- The history of the earth is influenced by occasional catastrophes, such as the impact of an asteroid or comet (celestial body moving about the sun).
- Fossils (any remains or trace of an animal or plant of a former geological age) show how life and environmental conditions have changed over time.

earth in the solar system:
the study of the region beyond the earth's atmosphere

- The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects such as asteroids and comets.
- Most objects in the solar system rotate at a constant speed.
- Gravity is the force that keeps planets in orbit around the sun and maintains the rest of the motion in the solar system.

5 Science and technology:
science: the process of becoming aware of and understanding living things and the environment through the senses and personal exploration
technology: organized knowledge for practical purposes

Youth will be able to use and understand: (by grade level)
- abilities to distinguish between natural objects and objects made by humans (K–4)
- abilities of technological design (K–12)
- science and technology (K–12)

Hands-on Science

Propose a solution to a public transportation problem by creating a computer-controlled model.

technology design:
generating knowledge and processes to develop systems that solve problems and extend human capabilities

- Identify problems that can be helped by technology.
- Create a solution to a problem using technology.
- Test the technological solution or product.
- Rethink and make changes to your technology.
- Talk to others about your technology.
- All technologies have intended benefits and unintended consequences.

Understanding technology

- Science and technology proposes explanations to questions about the natural world and humans.
- People of many different cultures have made, and continue to make, contributions to science and technology.
- All technology has things that it cannot do.
- Rarely are technology issues simple and one-sided. Contending groups have different values and priorities. They may make very different predictions about what the future consequences of the proposed action will be.

6 Science in personal and social perspectives: the study of how science contributes to culture

Youth will be able to use and understand: (by grade level)
- personal health (K–12)
- characteristics and changes in populations (K–4)
- types of resources (K–4)
- changes in environments (K–4)
- science and technology in local challenges (K–4)
- populations, resources, and environments (5–8)
- risks and benefits of natural, chemical, biological, social, and personal hazards (5–8)
- population growth (9–12)
- natural resources (9–12)
- environmental quality (9–12)
- natural and human-induced hazards (9–12)
- science and technology in local, national, and global challenges (9–12)

Hands-on Science

List what you have done today to increase or decrease the concentration of carbon dioxide in the atmosphere.

Personal health:
one's physical and mental health

- Regular exercise is important to your health.
- The use of tobacco increases the risk of illness.
- Alcohol and other drugs are often abused substances that can cause serious health problems.
- Food provides energy and nutrients for growth and development.
- The sex drive is a natural human function that requires understanding.

Populations, resources, and environments

- An area is overpopulated when needs of the inhabitants exceed the capacity of the resources or the quantity of resources decreases.
- Internal and external processes of the earth system cause natural hazards such as earthquakes and tornadoes.
- Humans can cause natural hazards by using up natural resources, spreading out cities, and disposing of waste improperly.

Risks and benefits of natural (floods), chemical (air pollutants), biological (viruses), social (occupational safety), and personal (smoking) hazards
risk: *exposure to the chance of injury or loss*
benefit: *anything that is advantageous to a person or thing*

- Evaluating the risk of a situation means considering the type of hazard and the number of people that may be affected, as well as exploring options for reducing or eliminating risks.
- Individuals can use a system to think about risks and benefits.
- Risks and benefits relate directly to personal and social decisions.

7 History of science

Youth will be able to use and understand: (by grade level)

- science as a human endeavor (grades K–12)
- how the history of science is connected to present knowledge (grades 5–12)

Hands-on Science

Why do you think the first explorers thought the world was flat?

Science as a human endeavor

- It is normal for scientists to work with one another and yet differ with one another about some evidence or theory under consideration.
- Individuals of many cultures have contributed to science in areas such as scientific inquiry and the nature of science.

History of science

- Tracing the history of science can show how difficult it has been for scientists to put aside what they thought they knew and to look for new answers.
- In looking at the history of many peoples, one finds that scientists and engineers of high achievement are considered to be the most valued contributors to their cultures.
- Women and men from diverse cultures and races have made a variety of contributions throughout the history of science and technology.

8 Unifying concepts and processes in science: concepts that explain a range of natural and designed phenomena

Youth will be able to use and understand: (by grade level)

- order and organization (K–12)
- evidence, models, and explanation (K–12)
- constancy, change, and measurement (K–12)
- evolution and equilibrium (K–12)

These guidelines, which apply to youth aged 5-18, represent a broad view of the concepts and processes that complement the unifying ideas of science and technology.

Hands-on Science

Draw a picture of how the human body is organized. Discuss with a friend how it changes and what stays constant over time.

Order and organization

order: *a system of arrangement or classification*
organization: *a functional structure*

- Science assumes that the universe is understandable and predictable.
- To predict is to use knowledge to identify and explain observations or changes in advance.
- Statistics can be used to describe the behavior of objects, organisms, or events.

evidence, models, and explanation

evidence: *that which tends to prove or disprove something*
model: *a standard or example for imitation or comparison*
explanation: *a statement made to clarify*

- Scientific explanations are based on observations and data.
- A model is a representation of a structure.
- Scientific explanations are made up of knowledge and evidence from observations, experiments, and models.

Constancy, change, and measurement

constancy: *the quality of being unchanging*
change: *to transform or convert*
measurement: *the act of determining dimension*

- Although most things are in the process of changing, some things undergo constant change.
- Changes in systems can be measured.
- Scale is a progression of different steps or degrees.
- Rate involves comparing one measured quantity to another measured quantity.
- Symmetry, or the lack of it, may determine the properties of many objects.

evolution and equilibrium

evolution: *a step-wise change in heritable characteristics leading to diversity of organisms*
equilibrium: *a state of balance due to the equal action of two opposing forces*

- Evolution is a series of slow changes over time.
- Equilibrium is a physical state in which forces and changes occur at equal rates.

See the Appendix for more Hands-on Science activities that directly reflect the content guidelines.

Part 3

Science and Technology

Science and technology are everywhere in a child's environment. Science and technology museums, where youth experiment with soundwaves, play with pendulums, and build circuits, have become popular over the last ten years. Consumer-oriented youth visit computer and telephone stores that sell faxes, modems, and laser printers. Television programs, such as *Newton's Apple*, *Square One*, and *Spaceship Earth*, are also commonly available. Within formal education, technology is one of the least recognized disciplines. Yet, youth use technology every day: most have VCRs and most can heat up a snack in the microwave while playing a computer game. It is important that youth be encouraged to use computers, calculators, and microscopes, as well as to develop the technology skills that come with inventing simple machines and taking apart old ones to see how they work. Youth need skills to survive in an information-based, technology-driven society.

So what is technology? As with "science," there are many definitions of technology; it has meant different things over the years. At various times in the past a pencil, fountain pen, film projector, or phonograph would have come to mind as an example of technology. Broadly defined, technology is "organized knowledge for practical purposes" (Mesthene, 1979). Technology competency implies the ability to evaluate the impact of technology on an individual and societal basis (Minnesota State Council on Vocational Technical Education, 1993). Today's youth will eventually decide which technologies to develop, which technologies to use, and how to use them. Part of that responsibility is knowing how technology works, including benefits, risks, and limitations, as well as alternatives to current technologies. Youth who are prepared to ask questions about these issues will keep the long-term interests of society in perspective (AAAS, 1993).

How do science and technology fit together? Which came first, the chicken or the egg? Do we need science to develop technology or do we need technology to further advance science? The difference between the two is simple. The goal of science is to understand the natural world; the goal of technology is to make modifications in the world to meet human needs (National Research Council, 1996). Technology as design is included in the content guidelines as a parallel to science as inquiry. In other words, designing or preparing the "form as function" is inherent in technology just as inquiry is a key element of science. Both design and inquiry should be practiced by youth.

A single problem often has both scientific and technical aspects. The need to answer questions about the natural world often drives the development of technology and technological needs often drive scientific research. For example, the problem of cleaning up an oil spill requires knowledge of the chemical interaction between oil, water, and the aquatic ecosystem. It also requires the technological know-how to clean up the oil without further damaging aquatic resources. Researchers Narin and Olivastro (1992) suggest that there is a continuum within technology stretching from basic scientific research (such as the reaction between two chemicals) to applied research for a specific technological advance (such as the study of properties of a certain kind of metal to be used in the construction of lightweight spacecraft). In some fields such as communications, computing, medicine, and chemical engineering the distinction between science and technology is especially blurred due to the scientific base of the subject matter (Herschbach, 1995).

Technology is older than the discipline of science. While it is true that science may have developed at first in response to the need to build things and solve practical problems, today discoveries in science often come before practical uses (AAAS, 1993). As science has evolved, it has become increasingly linked to technology. Technology has become an essential part of scientific literacy, although it has not been given a place yet in the formal educational system. Technology is often thought of as just computers and video recording equipment. It is much more, however. It is micropipettors and electrophoresis gel boxes, tools used to analyze DNA, or y-tubing and a catheter stilette, technology tools used to transfer embryos in bioengineering. It is also thermometers, compasses, water-quality testing equipment, and telescopes, all tools that extend the senses (Patton and Kokoski, 1996).

As youth, how many of us were allowed to take things apart and put them back together to see how they work? Probably few of us. *Tinkering* is an important way to encourage wonderment and excitement about technology at a young age. Allowing children to take things apart, build things, and rearrange parts enhances the development of technology problem-solving skills and technical knowledge. Tinkering is unique to technology. Researchers make scientific discoveries and "prove" new theories using existing information and materials. When we tinker we use materials in a novel way for a new use, something that may never have been thought of before. These skills will be important for the future as resources become limited. Engineers solve problems by applying scientific principles to practical ends. Engineers must work within the limits of physics and available materials. In addition, they must account for limits on time, money, and insufficient information; they must account for moral and legal claims. By giving youth an opportunity to partake in technology activities we are developing within them technology skills, such as analyzing situations, gathering relevant information, defining a problem, generating and evaluating creative ideas, developing ideas into tangible solutions, and assessing and improving situations (AAAS, 1993).

Many of these skills are recognized as lifelong learning skills that prepare youth for the workforce and foster an appreciation for learning throughout adulthood. Design and construction problems provide a hands-on approach to learning a variety of skills and habits of mind that are essential to the professional and social well-being of all people. Information technology (computers and the electronic compilation, storage, analysis, and exchange of data) is also a crucial lifelong learning skill for youth. It is infiltrating many jobs as well as our homes and personal lives. It is a common and powerful way many of us access the world. Few jobs have not been or will not be touched by this technology. Computers help us with our financial home management, shopping, and address books. E-mail increasingly keeps us in contact with family and friends as well as business colleagues across the world. Youth use internet resources for papers and projects they do for school, as well as on-line courses and interactive, TV-taught courses. Youth need these information technology skills. This technology is the norm for youth today. They watch TV, play video and computer games, use CD ROMs and, increasingly, use the internet. Even those that don't use the technology are aware that it is out there. It is how many youth get information, practice skills, communicate, and socialize. Use of this media will enhance youth's interest in all types of nonformal learning as well as reinforce information technology skills. Sorting through these issues provides youth with engaging situations that mirror the complexity of the real world (Dugger, 1996).

Design an aerodynamic water ski

An experiment using technology problem-solving skills

It is the middle of summer and youth have water skiing on their minds. In this example youth experiment with designing an aerodynamic water ski using technology problem-solving skills.

Materials

- modeling clay
- thread
- a button
- tub filled with water
- pennies

1 First, experiment with the buoyancy of your clay. Mold different amounts of clay into aerodynamic and non-aerodynamic shapes. Drop them into the water from one foot above the surface. Do some shapes sink faster than others? Does a higher or lower dropping distance affect how quickly they sink?
Skills used: defining a problem, gathering relevant information, analyzing situations

2 Tie the button onto the end of the thread. Shape the clay around the button into your most aerodynamic shape from step 1. Using constant speed, pull the clay along the surface of the water. Does it spin or travel straight? Now try your least aerodynamic shape, using the same amount of clay, pulling it along at the same speed as before. Which shape allows you to keep the speed more constant? Which of the two sinks faster when you stop pulling?
Skills used: assessing and improving situations

3 Start thinking like a water ski designer. First, experiment with different bottom shapes—square, beveled, and concave. What happens when you change the bottom of one side of your clay "ski" but not the other? Can you create a ski that turns right while your "towrope" travels straight? a ski that dives underwater?
Skills used: generating and evaluating creative ideas, developing ideas into tangible solutions

4 Try changing the point where your thread exits the clay. Move it up and down in front, as well as back and forth in the body of the ski. What changes? Add weight with pennies at different places on the clay. Can you build a "ski" that still moves straight and stays afloat with five pennies at the tip? How does your design change when you move the pennies to the back of the ski?
Skills used: gathering relevant information, assessing and improving situations, developing ideas into tangible solutions

(Newton's Apple with NSTA)

A teaching model for technology

Stages	
Identify problem	Observe the world made by humans. Recognize a human problem. Identify possible solutions.
Create a solution	Brainstorm possible alternatives. Experiment with materials. Design a model. Construct and explain model. Employ problem-solving strategies. Discuss solutions with others. Evaluate choices. Identify risks and consequences. Analyze the data.
Test the solution	Constructively review a solution. Express multiple answers/solutions. Integrate a solution with existing knowledge and experiences.
Rethink and make changes	Make decisions. Transfer knowledge and skills. Develop products and promote ideas.

(based on Raizen et al., 1995)

Knowing and doing science and technology involve both hands-on activities and minds-on engagement by youth. Hands-on means "experiential learning that provides a degree of independence for the learners when they interact with their environment. It is direct learning that results from exploration, manipulation, or observation of the physical world." But hands-on activities without minds-on engagement are merely entertaining activities for youth. To achieve significant learning, hands-on activities must become minds-on learning. Hands-on and minds-on activities in technology elicit levels of critical and creative thinking that help youth question, rethink, and reconstruct their understandings (Raizen et al., 1995).

The thinking and doing of technology includes identifying problems, creating solutions, testing the solutions, and then rethinking and adjusting the technology. These skills are identified in the guideline on technology design, page 20, in Part 2 (National Research Council, 1996). These skills draw upon abilities in math and science and are best learned through hands-on/minds-on learning tasks.

Raizen et al. (1995) suggest things for youth to think about at each stage. Stage one is *identify problem*. Youth observe the world, recognize a human problem, and identify possible solutions. Stage two is *create a solution,* in which youth brainstorm, experiment, design, problem-solve, discuss, and evaluate. Stage three is *test the solution.* Youth construct a model, review a solution, and integrate a solution with current knowledge. In *rethink and make changes,* the final stage, youth make decisions, transfer knowledge and skills, and develop products.

So why is it important that technology be included in a nonformal science education program? It is important for two reasons. First, technology is a key vehicle for stimulating learning about science. Technology activities in a nonformal setting can create environments and present content in ways that are more engaging and that involve youth more directly than traditional learning methods. For example, manipulating and thinking about objects, actively working with data, and getting the chance to talk about their questions (or answers) all help motivate youth to learn more about science and math. Second, nonformal science programs are most often part of a youth development agency, dedicated to fostering lifelong learning skills. The skills developed through technology activities will prepare youth for the increasingly technical and information-based workforce that awaits them. Youth who have science knowledge and technological know-how will, no doubt, be valued members of the workforce. Such members are essential to the civic and economic well-being of the nation.

The egg drop

An experiment using the Teaching Model for Technology

Identify problem	Humans eat eggs. We need a way to transport eggs home from the grocery store without breaking them. Eggs inevitably get dropped and break.
Create a solution	Brainstorm things youth have seen fall gently without breaking. Talk about the size, shape, material, and construction of these items. Design and build a container that can be dropped from 6 feet without breaking an egg. Experiment with string, plastic, rolls of paper towel, egg cartons, and other materials. Discuss a possible solution with others. Draw a sketch of a suitable container. Evaluate different packing materials.
Test solution	Test with a plastic egg and a hard cooked egg. Test the model with an uncooked egg. Integrate the model with existing knowledge about eggs.
Rethink and make changes	Review the model, make changes, and retest. Make decisions about changes. Develop other products that could benefit from a drop-proof container.

(National Science Education Standards, National Research Council)

Part 4

Learning and Teaching in Nonformal Settings

Imagine a child playing on a beach. A rock is used as a shovel, a stick quickly becomes the flagpole for a sand castle, and a leaf becomes an alligator floating in the moat. Children invent alternate uses for everyday objects all the time. How does this help them learn? What can we do as parents, educators, and volunteer leaders to foster this creativity?

Much of our understanding about how children learn comes from Swiss psychologist, Jean Piaget. Piaget, who developed some of the most influential theories on intelligence development in children in the 1920s, was also one of the first psychologists to understand that a child constructs new mental processes as he or she interacts with the environment.

"What I have found in my research seems to me to speak in favor of an active methodology in teaching. Children should be able to do their own experimenting and their own research. Teachers, of course, can guide them by providing appropriate materials, but the essential thing is that in order for a child to understand something he must construct it himself, he must reinvent it. Every time we teach a child something, we keep him from inventing it himself. On the other hand, that which we allow him to discover by himself will remain with him visible for all the rest of his life" (Piaget, 1972).

Works by Piaget and others have helped in understanding how people make meaning or construct knowledge from experiences. Their theory, called *constructivism*, lays the foundation for how learning takes place.

Constructivism

Constructivism is a theory rooted in cognitive psychology. *Constructs* are bits of information in the brain that store and organize knowledge and that give meaning to what is learned (Bartlett, 1932). Constructs help the learner understand what to expect, as well as how to select and process incoming information. Youth learn best when they construct their own science understanding.

In the past, traditional science education has been based on a transmission or absorption model of teaching and learning. In this model, youth passively absorb scientific structures invented by others and recorded in texts or known by authoritative adults. Constructivism is in sharp contrast to the absorption/transmission model of teaching and learning. The application of constructivism to education is based on five basic tenets: invention, reflection, interpretation, social processing, and sense-making of knowledge (Clements and Battista, 1990).

1 **Invention:** Knowledge is actively created or *invented* by the youngster, not passively received from the environment. For example, the idea of energy cannot be directly detected by a youth's senses. It is a relation that the youth superimposes on specific experiences. This relation is constructed by the youth as he or she reflects on

his or her experiences involving energy, such as running out of energy when pedaling a bike. Although the leader may have demonstrated the concept of energy for youth, the mental entity energy can be created only by the youth's thought. Youth do not discover the way the world works in the same way that Ben Franklin stumbled upon electricity. They *invent* new ways of thinking about the world.

2 Reflection: Children create new science knowledge by *reflecting* on their physical and mental actions. Ideas are constructed, or made meaningful, when children integrate them into their existing structures of knowledge.

3 Interpretation: No one true reality exists, only individual *interpretations* of the world. Interpretations are shaped by experience and social interactions. Learning science should be thought of as a process of adapting to and organizing one's living and nonliving world, not discovering pre-existing ideas imposed by others.

4 Social Processing: Learning is a *social process* in which youth grow into the intellectual life of those around them. Scientific ideas and truths, both in use and in meaning, are cooperatively established by the members of a culture. The constructivist application to a youth organization is seen as a developing culture in which youth are involved not only in discovery and invention, but also in social discourse involving explanation, negotiation, sharing, and evaluation.

5 Sense-making: Youth's beliefs about the nature of science come from the perspective of science as *sense-making* rather than science as learning set procedures that make little sense. When a leader demands that youth use set scientific methods, the sense-making activity is seriously curtailed. Youth tend to mimic the methods by rote so that they can appear to achieve the leader's goals.

The 5 Tenets of Constructivism

1 Knowledge is actively created or **invented** by the youngster.
2 Children create new science knowledge through **reflection**.
3 Individual **interpretations** of the world are reality (seen through one's own eyes).
4 Learning is a **social process** that goes on within a culture.
5 Science is **sense-making** for the individual learner.

A constructivist perspective implies two major outcomes for nonformal science education. First, youth should develop scientific structures that are more complex, abstract, and powerful than the ones they currently possess, so that they are increasingly capable of applying science to their daily lives. Second, youth should become independent and self-motivated in their scientific activities. These individuals believe that science is a way of thinking about the world. They believe that they do not get scientific knowledge from others as much as from their own explorations, thinking, and participation in discussions. Constructivism shifts the emphasis from youth's "correct" replication of what the leader does to youth's successful organization of his or her own experiences (Driver and Leach, 1993).

Where does the hot in hot chocolate go?

An experiment using constructivism to learn about energy

Members of a science club return indoors from a long afternoon of snowshoeing. As they are drinking their hot chocolate, someone asks why hot drinks cool off. Why does the heat disappear? Someone else adds that heat does not disappear but that it changes form. A debate develops. The leader notes that a prior conception about energy—widely held—is that energy can disappear. In the case of a cup of hot chocolate in a room, some youth assert that the drink cools down and the heat energy disappears.

To encourage the construction of the notion that energy does not disappear, but that it goes somewhere, possibly "spreading out" so it is less detectable, youth conducted a series of experiments in which a hot cup of water was allowed to cool in outer containers of cold water of progressively larger volumes. The temperature of the water in the inner and outer containers was recorded and plotted at regular intervals. After inspecting the resulting graphs, the leader then asked the youth to think about what happens when the outer container is the room itself. Having done the activity and plotted the graphs, youth were able to construct in their imagination the notion of heat being spread out in the room.

Youth are influenced by the social discourse of the group because they work in small groups, share information, provide explanations, and evaluate themselves and others.

Knowledge is invented by youth	Heat spreads out so it is less detectable
Youth create knowledge through reflection	Youth ask questions about what happens when a hot cup of water is placed in an outer container of cool water
Individual interpretations of the world are reality	Youth conduct their own experiments to discover why heat seems to disappear
Learning is a social process	Youth investigate together and discuss their results
Science is sense-making	Having done the activity and plotted the graphs, youth are able to make their own sense from the activity.

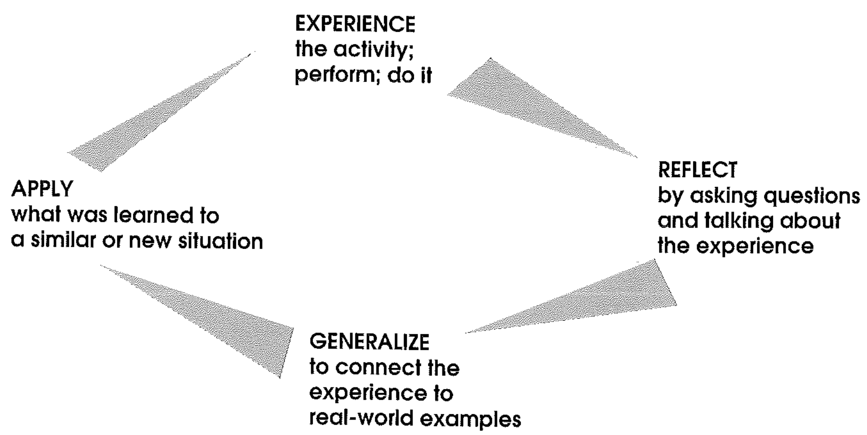
(Driver, R. and Leach, J., 1993)

Two teaching models for nonformal science education are based on the constructivist theory: the experiential learn-by-doing model (Kolb, 1984) and the youth-driven model (Pate, 1996). These two models form the basis of much of the 4-H and other youth programs' curricula. Each model addresses teaching from a slightly different perspective and emphasizes different pieces of the learning experience.

Experiential learn-by-doing model

It is no surprise that if we do or discover something on our own, for example, build a model of the Eiffel tower out of popsicle sticks, we will remember the experience much more readily than if we simply read about it in a book. The ideas of self-discovery and learning by doing are inherent in the experiential education model. Nonformal education programs such as 4-H, Scouts and Campfire promote an experiential approach to all learning, including science education.

The learn-by-doing model, developed by Kolb (1984), consists of a cycle of four processes; all must be present for optimum learning. In using this model, youth *experience*—but also *process*—the activity. The four processes are: *experience*, doing the activity; *reflect*, asking questions and talking about what the group experienced; *generalize*, relating the experience to a real world example; and *apply*, using what was learned in a similar or different situation, which may, in turn, create new experiences.



Experiential learning requires the active cooperation of the learner, coupled with guidance from the leader to awaken and maintain the learner's curiosity and intelligence. Teaching becomes a cooperative enterprise. Providing an experience alone does not create experiential learning (Dewey, 1938). Experiences lead to learning if the individual understands what happened, sees that patterns of observations emerge, generalizes from those observations and understands how to use the generalization again in a new situation.

Experiential activities require youth to interact, analyze, question, reflect, and transfer. The activity comes first; the learning comes from the thoughts and ideas that arise as a result of the learn-by-doing process.

Ice cube investigations

An experiment using the Learn-by-doing Model

Youth are given ice cubes and told to experiment with different ways of melting them. Colored paper, salt, sunlight, and liquid water are all acceptable to melt their ice cubes. After experimenting with different methods, youth share their results with the rest of the group. The leader also asks questions, such as, what method melted the ice cube the fastest? What made it melt the slowest? What effect did sunlight have on the ice? white paper? Next, the leader asks youth to discuss a few more questions in groups of two, such as, Will the ice melt faster if broken up? Will an ice cube twice as large last twice as long? Will an ice cube last longer in a glass of water at room temperature or in air? What happens to ice cubes in a glass of cold lemonade? These questions help youth look at the experience from a new perspective, and to analyze and reflect on the experiment. To apply the idea of melting ice to the real world, youth are asked to design a container that will keep an ice cube frozen for a long time. Youth work in groups to come up with drawings for the container and build a model using various types of insulation.

Component	Description	Specific content objective	Observable indicator
Experience	perform/do the activity	youth experiment with different ways of melting ice cubes	youth are actively engaged in inquiry
Reflect	communicate results, reactions, and observations; talk about the experience	youth share their results from their experiments, i.e., what made ice melt the fastest?	youth participate in discussions about the experience
Generalize	youth connect experience to real-world examples	youth connect their experience with the ice cubes to a glass of lemonade	youth can say how the experience connects to the real world
Apply	practice what was learned in a similar or different situation	youth design and make a container to insulate ice cubes	youth use their knowledge from the experience and apply it to a new situation

Youth-driven model

The youth-driven model turns the learning over to youth, allowing them to decide what they want to learn and how they want to learn it. Young people who participate in youth organizations are often self-motivated and personally committed to their own learning. Youth are more motivated to learn when they have a choice in what they learn (Carlson, 1993).

In an organization like 4-H, youth take a primary role in making decisions about what projects the group will pursue, for example, rocketry, chemistry, or animal science. The volunteer leader then becomes the facilitator for the project; leadership is shared both by youth and the volunteer leader. The volunteer leader guides the learning experience by helping youth answer questions such as, What do I want to learn? How will I learn it? How will I share it? This approach to nonformal science education leads to increased relevance and a greater connection between the daily lives of youth and science. The fact that the young person is motivated greatly influences the outcome of his or her experience and contributes to a successful interaction with science.

Youth-driven Model

Using questions to engage learners

What do I want to learn?
Identify a theme; make connections to different aspects of science; work with a diverse group of people

How do I want to learn it?
Strategies: brainstorming, storytelling, data retrieval chart, simulation, advance organizers, lecture, collaborative problem-solving

How do I want to show what I've learned?
Alternative assessments: multimedia presentations, computer-generated presentations, skits, puppet shows, murals, debates, models, speeches, magazines, journal writings, simulations

(Pate, 1996)

In the youth-driven model, youth engage in self-discovery in an atmosphere where there are no right or wrong answers. Youth thrive in an atmosphere where they can learn at their own pace and can evaluate themselves. Activities such as demonstrations, exhibit design, project work, and working with models accommodate individual learning styles and invite feedback for self-evaluation and reflection. These types of projects produce a tangible product that youth can look at, ask questions about, study, and celebrate when completed.

The youth-driven model implies that youth and adults learn together. It has proven effective only when the leader is an active listener and learner in the situation (Joplin, 1995). Youth learn by helping to choose projects, sharing in discussions, participating in activities, and being active in the group, as well as by making decisions about how they will be evaluated and by what standards.

At the same time, volunteer leaders learn from the youth with whom they work, as well as from the activities they prepare and share. Leaders develop their own self-esteem, confidence, communication skills, and leadership skills by facilitating youth through their chosen project. With this approach, adults and youth each bring something to the same environment and leave with a new experience.

Some resources for shared learning between youth and leaders include the World Wide Web, experts in the community, libraries, museums, extension services, and telephone contacts, as well as science and technology centers.

Stars and constellations

An experiment using the Youth-driven model and questions to engage learners

So how can the youth-driven model be used to study stars? Together, youth and leaders ask these questions:

What do I want to learn?	To be able to describe the makeup of a star and list 3 constellations and their locations
How do I want to learn it?	Write to communicate technical information about the makeup of a star and draw the location of 3 constellations in the sky.
How do I want to show my learning?	Youth will create a comic strip (in groups or individually) that will: ▶ describe how a star is made ▶ describe why constellations were invented ▶ tell the location of 3 constellations
Resources	World Wide Web, science museum and planetarium, books, poster file, encyclopedias

By giving youth responsibility for their own learning we foster lifelong interests that will help youth gain the skills necessary to become scientifically and technologically literate. It is up to both youth and volunteer leaders to work together in this adventure.

The role of volunteer leaders, guides, and teachers of nonformal science education programs is to help youth develop knowledge that leads to understanding science. By asking questions and by encouraging reflection in a safe environment, volunteers can help youth formulate a working knowledge of science and science topics. The nonformal approach to science education allows learners to control the objectives of their own learning, which in turn presents opportunities that may allow them to construct their own knowledge. In this case, no one teaches science, but effective leaders are those who can stimulate youth to learn science. Leaders must also be skilled in structuring the intellectual and social climate of the group so that youth discuss, reflect on, and make sense of these tasks (Clements and Battista, 1990).

Who's Responsible for the Learning

	Youth	Adult
Subject	X	
How to learn	X	
How to share	X	X
Assessment	X	
Resources		X

Below is a checklist for good learning to be used by volunteer leaders and curriculum developers as they formulate ideas about projects and curricula.

Checklist for good learning

Questions for leaders and youth

- Are youth self-motivated to learn?
- Are youth learning by doing?
- Are youth using the skills of observation, communication, application? of comparing, relating, inferring, and organizing?
- Are youth inventing their own way of thinking about the world?
- Are youth engaged in self-discovery?
- Are youth relating science to daily life?
- Does the experience allow opportunity for reflection?
- Is the learning taking place as a social process?
- Are resources outside the youth organization being used?
- Is the science content adapted to meet the interests, knowledge, and abilities of participants?
- Are youth taking responsibility for their own learning?

Questions about the learning environment

- Is there shared learning between adults and youth?
- Is the setting nonevaluative?
- Is the meeting plan flexible to allow youth time to make mistakes, ponder, ask questions, and share ideas?
- Have materials been selected that encourage action and exhibit obvious change?

"The world looks so different after learning science. For example, trees are made of air, primarily. When they are burned, they go back to air, and in the flaming heat is released the flaming heat of the sun which was bound in to convert the air into a tree. And in the ash is the small remnant of the part which did not come from the air, that came from the solid earth, instead. These are beautiful things, and the content of science is wonderfully full of them. They are very inspiring, and they can be used to inspire others."

—Richard Feynman
physicist, Nobel laureate

Conclusion

According to the Bureau of Labor Statistics and the National Science Foundation, by the year 2000 the U.S. will have a one-million-person shortage of trained scientists and technicians and more than 80 percent of all jobs will require proficiency in math and science (Bureau of Labor Statistics et al., 1992). As a result of participating in a science program based on these science education guidelines, youth will be more employable in the workforce because they will have an improved general knowledge of science and because they will be better able to manipulate technology. In addition, participants in nonformal science programs can engage in intelligent discussions about current events in science, such as B+ resistant corn, a hybrid that is resistant to corn borer damage, the possibility of life on Mars, or the potential oil crisis due to tensions in the Middle East. Finally, youth can study science for enjoyment and personal gain. Nothing compares to the magic of the sparkle in the eye of a child who discovers why a rainbow appears or how to create a musical instrument that really works. The guidelines foster lifelong learning skills that help youth to be successful in living productive and satisfying lives.

This document provides information that volunteer leaders, youth development professionals, and curriculum developers can use to evaluate existing 4-H curricula and other youth science curricula, as well as to guide the development of new science programs. The scientific thinking and process skills discussed in Part 1 set the course for an inquiry-based science program. Such a program encourages youth to use skills such as observing, communicating, inferring, and ordering in investigations and to maintain a sense of wonder in everyday life. The content guidelines in Part 2 make available learner outcomes for youth involved in nonformal science programs and provide volunteer leaders with an idea of the range of possibilities in science education. The content guidelines also give curriculum developers a way to track the consistency of their curriculum with other educators across the nation. Part 3 gives a clear definition of technology and describes why technological knowledge is important to the youth of today. The *Checklist for Good Learning* in Part 4 sums up the important points of each model and theory discussed in the chapter. It can be used as a guide to determine whether science programs are meeting the needs of learners. Implementing these science guidelines in nonformal settings will improve the quality of programs resulting in a youth's ability and opportunity to learn science.

As those involved in 4-H are preparing the ES 237 form, they will find that the *Science Guidelines for Nonformal Education* overlap with many of the curriculum categories listed in the Curriculum Classification section. For example, within the category of Environmental Education and Earth Science, Environmental Stewardship is discussed in Guideline 6 (Science in Personal and Social Perspectives), Earth, Water, and Air are covered in Guideline 4 (Earth and Space Science) and Energy is covered in Guideline 2 (Physical Science). Also included in part two are guidelines for Life Science, Guideline 3, that cover the Plants and Animals and the Biological Sciences categories in ES 237. Guidelines for Science and Technology, Guideline 5, encompasses the Technology and Engineering component of the form. See Part 2, page 13 for a more detailed outline of these guidelines.

Science Guidelines for Nonformal Education provide a vision for scientific literacy in the coming century. People literate in science are not necessarily able to do science, math, or engineering in a professional sense. However, they can use the knowledge they have acquired about math, science, and technology to make sense of the many ideas, claims, and events they encounter in everyday life. A scientifically literate person is more able to observe events perceptively, reflect on them thoughtfully, and understand explanations offered to them. Such knowledge and perception provide the person with a firmer basis for making decisions and taking action (AAAS, 1993).

These guidelines may be considered a road map for scientific literacy for use by the entire science education community, including volunteer leaders, youth, scientists, extension educators, business and industry, government agencies, museums, zoos, science centers, and others. We encourage all members of this community to be challenged by the guidelines. Youth can set personal learning goals and then volunteer leaders can use the guidelines to improve science content teaching and assessment. Curriculum developers can implement the guidelines into long-range planning. Museum, zoo, and science center staff can use the guidelines as a opportunity to collaborate in providing a rich experience for youth. Parents and community members can use these guidelines to support an increase in the quality of science education. Legislators and public officials can use the guidelines to set policy and provide funding opportunities. The responsibility for scientific literacy extends to the entire educational system, formal and nonformal alike. We encourage all members of this community to be challenged by the guidelines.

As the journey of scientific literacy continues, clearly the next step is to document how these guidelines can be implemented, including a companion piece to describe activities and lessons that adhere to the guidelines.

References

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy.* New York: Oxford University Press.

American Association for the Advancement of Science. (1989). *Science for All Americans.* Washington D.C.: American Association of Science.

Bartlett, F.C. (1932). *Remembering: A Study in Experimental and Social Psychology.* London: Cambridge University Press.

Bureau of Labor Statistics; Educational Testing Service; the EQUALS program at the Lawrence Hall of Science; National Academy of Science; the National Education Association; and the U.S. Census Bureau. (1992)

California Department of Education. (1990). *Science Framework for California Public Schools, Kindergarten through Grade Twelve.* Sacramento, CA: Bureau of Publications, California Department of Education.

Carlson, S. P. (1993). A cognitive model for learning in educationally oriented recreation facilities. Unpublished doctoral dissertation, Michigan State University, Lansing, MI.

Clements, D. and Battista, M. (1990). Constructivist learning and teaching. *Arithmetic Teacher*. September, pp. 34–37.

Dewey, J. (1938). *Experience and Education.* New York: The Macmillan Company.

Driver, R. and Leach, J. (1993). A constructivist view of learning: children's conceptions and the nature of science. *What Research Says to the Science Teacher Volume 7, The Science, Technology, Society Movement.* R.Yager, Ed. Washington, D.C.: National Science Teacher's Association.

Dugger, W.E. (1996, April). The development of standards. *Technology for All Americans.*

Hendricks, P. (1996). *Developing Youth Curriculum Using the Targeting Life Skills Model.* Ames, IA.: Iowa State Univ., University Extension, Pilot/VI-960601PH.

Herschbach, D. (1995). Technology as knowledge: implications for instruction. *Journal of Technology Education* (7) 1, pp. 31–42.

Joplin, L. (1995). Defining Experiential Education: Nine Characteristics. In Kendall, J. Hunt (eds.), *The Theory of Experiential Education*. Boulder, CO: Association for Experiential Education, pp. 15–22.

Kolb, D. (1984). *Experiential Learning: Experience as the Source of Learning and Development.* Englewood Cliffs, NJ: Prentice Hall.

McIntyre, M. (1984). *Early Childhood and Science: A Collection of Articles Reprinted from Children and Science*. Washington, D.C.: National Science Teachers Association.

Mesthene, E.G. (1979). The role of technology in society. In A.H. Teich (ed.), *Technology and the Future.* New York: St. Martin's Press, pp. 77–99.

Minnesota State Council on Vocational Technical Education. (1993). *Toward World Class Standards for Math and Science Education*. Rochester, MN: Rochester Area Math/Science Partnership.

Mocker, D. and Spear, G. (1982). *Lifelong Learning: Formal, Nonformal, Informal, and Self-Directed.* Information Series No. 241. Columbus, OH: ERIC (CE). (ERIC Document Reproduction Service Number 220723).

Narin, F. and Olivastro, D. (1992). Status Report: Linkage between technology and science. *Research Policy*, 21(3), pp. 237–249.

National 4-H Council. (1993). *4-H Youth Development Education: A National Model for Recognition in 4-H Programs.*

National Research Council. (1996). *National Science Education Standards.* Washington, D.C.: National Academy Press.

National Science Foundation. (1996). *Design Connections Through Science and Technology.* (A Publication for National Science and Technology Week 1996). Arlington, VA: National Science Foundation.

Newton's Apple with National Science Teachers Assoc. (1995). 13th season. KTCA Twin Cities Public Television, 172 East 4th Street, St. Paul, MN 55101.

Novak, J. and Gowin, B. (1984). *Learning How to Learn.* New York: Cambridge Univ. Press.

Pate, E. (1996). *Youth-Driven Model,* a paper for the Minnesota Office of Environmental Assistance and the Environmental Education Teacher Preparation Project Workshop.

Patton, M. and Kokoski, T. (1996). How good is your early childhood science, mathematics, and technology program? Strategies for extending your curriculum. *Young Children.* July p. 38–44.

Piaget, J. (1972). *Play and Development.* M. Piers (ed.). New York: W.W. Norton and Company, Inc.

Raizen, S. Sellwood, P., Todd, R., Vickers, M. (1995). *Technology Education in the Classroom: Understanding the Designed World.* San Francisco: Jossey-Bass Publishers.

Treagust, D. (1996). *Improving Teaching and Learning in Science and Mathematics.* New York: Teachers College Press.

U.S. Department of Labor. (1992). *Learning a Living.* Washington D.C.: U.S. Department of Labor.

Walker, J. (1994). *Understanding Youth Development Work.* University of Minnesota, College of Education, Center for 4-H Youth Development.

Appendix

The Hands-on Science activities may be used in the content guidelines section to bring science to our daily lives.

Scientific inquiry

Elementary age

- Investigate why the water level will drop in a glass of water that is left out overnight.
- Survey club members to determine their favorite foods by age and then create a chart to display the results.
- Design and build a model environment in which people can survive in space for an extended period of time.

Middle school age

- Determine the rate of germination of seeds, controlling for light, moisture, and temperature.
- Take apart a toy and explain how it works; include instructions and safety precautions.
- Investigate what happens when you mix cocoa with water.
- Measure the temperature of a hot liquid. Add a cool liquid (for example, cream to coffee). Measure the temperature after letting it sit for 5 minutes.

High school age

- Identify an agricultural problem and conduct an experiment to answer the question and solve the problem.
- Determine possible reasons for why a bicycle or small appliance is not working.

Physical science

Elementary age

- Describe 3 liquids, 3 solids, and 3 gases (water, milk, juice, wood, plastic, copper, air, water vapor, helium). Tell how you've used one of each today.
- Investigate what happens when you rub your hands together very fast.
- Use a magnetic compass to find direction to someplace you are familiar with.

Middle school age

- Determine whether a substance such as Silly Putty is a solid, liquid or something else.
- Measure the physical properties of common substances such as hot water, cold water, snow, and steam.
- Classify substances found in your kitchen as elements, mixtures, or compounds (*elements:* copper, aluminum, iron *mixtures:* soil, salt and pepper, *compounds:* water, salt, sugar).
- Watch a Roadrunner/Coyote cartoon and describe how a law of physics is violated.

High school age

- Describe how wood can sink and float in water in terms of mass, volume, and density.
- Analyze the properties of herbicides in terms of a risk/benefit balance.
- Describe the difference between how energy is conserved in the human body and in a power plant.
- If a spark can ignite natural gas in a stove, why is it so difficult to light charcoal briquettes?

Life science

Elementary age

- Create a visual display that illustrates the life cycle of monarch butterflies raised by youth.
- Describe and draw the functions of selected seed plant parts (carrot [root], spinach [leaf], tomato [fruit]).
- List what an earthworm needs in its habitat.
- Describe three types of ecosystems in your area (pond, wetland, forest, aquarium, river, prairie).

Middle school age

- Analyze and compare results from a field study revealing abnormalities within an animal population.
- Explain how the skeletal, muscular, and circulatory systems work together when playing basketball.
- Draw what happens to a vacant lot after a period of several years (gradual change in ecological systems).
- Describe two objects in the room that come from plants (wood, paper, cotton). Find two objects in the room that come from animals (leather, wool, oils). List their characteristics and life cycles.

High school age

- Design an experiment to analyze pond water to determine the presence of micro-organisms.
- Explain how cells grow back when you cut your finger.
- Explain why someday antibiotics may be ineffective for humans.

Earth and space science

Elementary age

- Observe and record information about the daily weather.
- Design and create instruments for measuring weather.
- Explain how we use materials taken from the earth like water, sand, oil, and glass. Cut out pictures of, or draw, products produced by these materials.
- Build a model of what happens before and after a tornado.

Middle school age

- Compare the temperatures of lakes and rivers in your area at different times of the year. Make a graph.
- Write a story about what would happen if there were no water on earth.
- Observe a constellation through binoculars.
- Take a picture of the moon when it is on the horizon and when it is high in the sky. How does the size of the moon compare in the two photos?

High school age

- Create a topographical map for a new park, including geographical features. Relate the site to the earth's equilibrium. Describe how the land features were formed and describe the atmospheric dynamics that affect the site.
- Explain why we have wind. What does it have to do with heat transfer?
- Explain to a younger child why seasons occur on earth.
- Visit a planetarium.

Science and technology

Elementary age

- Use the World Wide Web to access information on your favorite tree.
- Take a closer look at a can opener to figure out how it works.
- Describe what life would be like without cars.

Middle school age

- Use a spreadsheet to track purchases made at your club over a three-month period.
- Describe some environmental benefits and risks of electric cars.
- Design, sketch, and build a hand-launched model aircraft.
- Design a floor plan for your dream house.

High school age

- Design, draw, and build a carbon-dioxide–powered vehicle.
- Create a computer-controlled-model solution to a public transportation problem.
- Construct a solar-powered vehicle, appliance, or instrument.
- Develop a magnetic levitation transportation system that accommodates the needs of the disabled.

Science in personal and social perspectives

Elementary age
- Role play situations involving safety and first aid techniques.
- Describe which foods are best for children of your age to eat for a week.

Middle school age
- Create a nutritional plan including dietary recommendations and actual menus.
- Organize a clean-up project with a group of classmates to improve the water quality of a pond or other water source in your area.

High school age
- Design a commercial for prime-time television that promotes positive behavior in terms of accidents, substance abuse, or sexual responsibility.
- Analyze and assess injuries in simulated emergency situations and apply proper emergency care procedures.
- List what you have done today to increase the concentration of atmospheric carbon dioxide. List what you have done to decrease it.
- What do you think about the idea of "polluting rights," where certain countries have more of a right to pollute than other countries based on industry, resources, and finances?

History of science

Elementary age
- Why do you think the first explorers thought the world was flat?

Middle school age
- Name a problem or scientific discovery that some scientists see as debatable (global warming). Investigate both sides of the issue.

High school age
- Investigate the theory of gravity from a historical perspective.
- Analyze the social factors of the Renaissance which led to the discrediting of the theory of the geocentric universe.

Unifying concepts and processes in science

Elementary age
- Build a model or draw a map of your neighborhood. Predict what would be done with the land if your house or apartment wasn't there.

Middle school age
- Draw a picture of how the human body is organized. Discuss with a friend what changes and what stays constant over time.

High school age
- Explain how Darwin's Law of Natural Selection applies to you.

Contributors

The authors would like to thank the following individuals for reviewing and supporting this document.

Atkins, Beth, Auburn University, Alabama

Chapin, Julie, Michigan State University, East Lansing, Michigan

Cook, John, Auburn University, Alabama

Curry, Debbie, Iowa State University, Ames, Iowa

Dunham, Trudy, University of Minnesota, St. Paul, Minnesota

Edwards, Janet, United States Department of Agriculture, Cooperative States Research, Education and Extension Service (CSREES), Families, 4-H and Nutrition, Washington, DC

Heath, Phillip, The Ohio State University, Lima, Ohio

Hessler, Ed, Minnesota Science Teachers Association, St. Paul, Minnesota

Horton, Robert, The Ohio State University, Columbus, Ohio

Hutchinson, Suzanne, The Ohio State University, Columbus, Ohio

Johansen, LuAnn, 4-H youth field specialist, Ames, Iowa

Jones, Ron, Cornell University, Ithaca, New York

Little, Wanda, University of Connecticut, New Haven, Connecticut

Miller, Jeff, North Dakota State University, Fargo, North Dakota

Mitchell, David, University of Idaho, Moscow, Idaho

Newman, Jerry, Washington State University, Pullman, Washington

Pabst, Bill, University of Missouri, Columbia, Missouri

Pate, Elizabeth, The University of Georgia, Athens, Georgia

Ponzio, Richard, University of California, Davis, California

Seilstad, David, 4-H youth field specialist, Ames, Iowa

Tennesen, Dan, Cornell University, Ithaca, New York

Toomey, Maureen, University of Idaho, Moscow, Idaho

Wright, Sharon, United States Department of Agriculture, Cooperative States Research, Education and Extension Service (CSREES), Families, 4-H and Nutrition

To order this publication, please send check or P.O. number to:
National Network for Science and Technology
c/o Julie Chapin, 4-H Youth Programs
6H Berkey Hall
Michigan State University
E. Lansing, MI 28824-1111
FAX: (517) 355-6748
Phone: (517) 355-0180

Include complete shipping information and phone number.
Make check payable to Michigan State University.
$8.00/each
$5.00/each (10 or more)

Produced by the Educational Development System, Minnesota Extension Service, University of Minnesota.
Production Editor Phyllis W. Jenks
Graphic Design Lisa Peck

♻ Printed on recycled paper with minimum of 10% postconsumer waste, using agribased inks.