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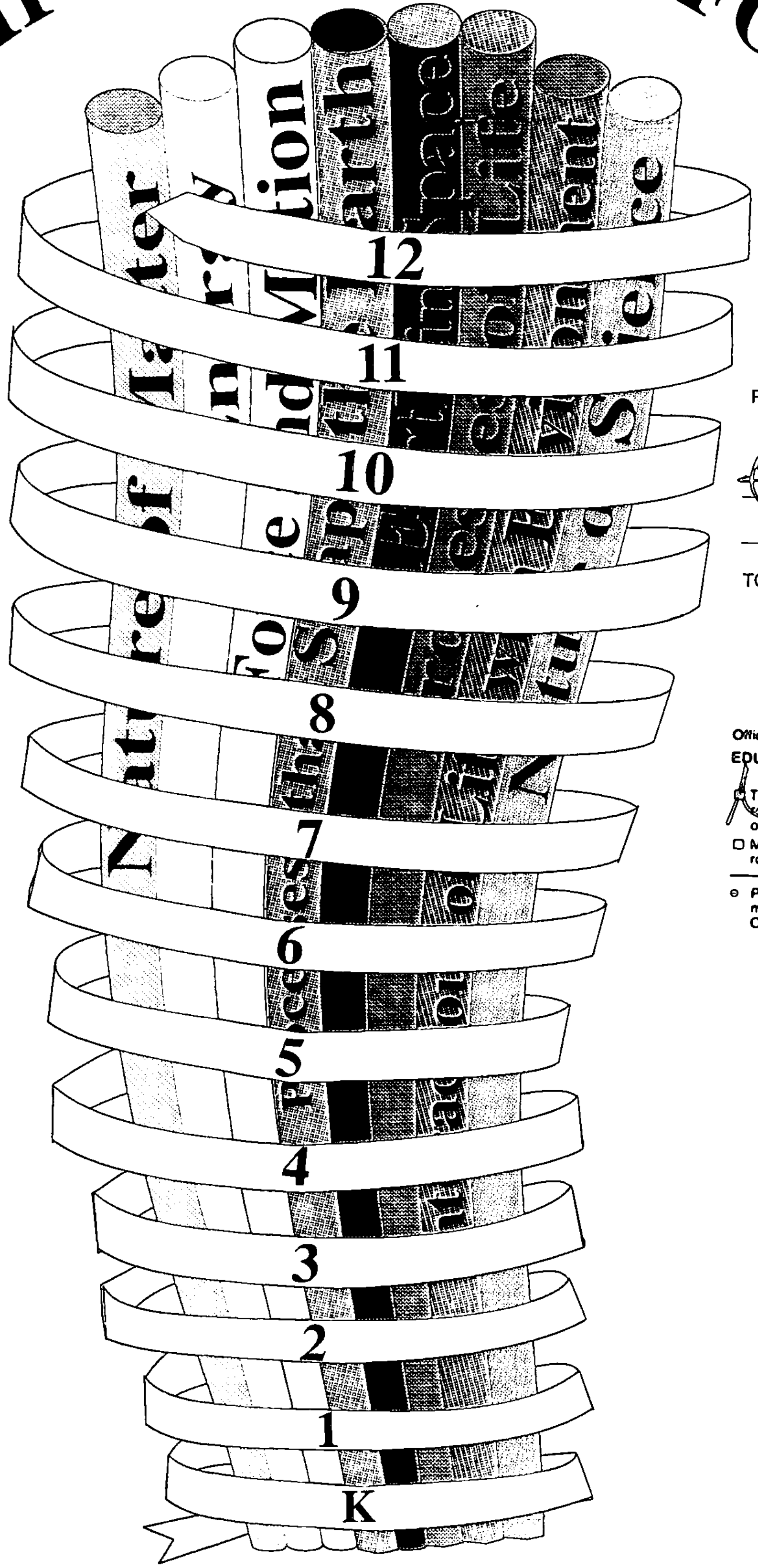
ABSTRACT

This document resulted from the efforts of the Brevard County (Florida) Science Leadership Team, a group of science teachers with a wide spectrum of experiences and philosophies. It contains a series of recommendations based on national trends for change in curriculum. Sections include Scientific Literacy for All, Stakeholders and Their Roles, Communication Among Stakeholders, Recommended Science Content Core, Spiral Progression, Concept Connections Using Themes, Home-Based Learning, Technology, Teaching Strategies, Assessment, and Program Evaluation. Contains 49 references. (JRH)

SCIENTIFIC LITERACY FOR ALL



Brevard County Public Schools

1995

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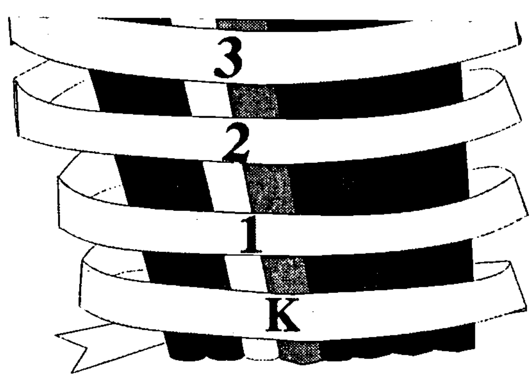

Recommendations for Science
_K-12_

Acknowledgments

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CONTENTS

CONTENTS

"... Come, my friends, 'Tis not too late to seek a newer world."

-Alfred Lord Tennyson

Introduction

Brevard County educators have a new and exciting opportunity for promoting excellence in science education for ALL students. This opportunity results from the efforts of the Brevard County Science Leadership Team, a group of science teachers with a wide spectrum of experiences and philosophies. Discussions on ideas for the future of science education were based on national trends for change in curriculum. After extensive research, the group reached consensus and established a series of recommendations to guide us in this journey.

> *"Understanding rather than vocabulary should be the main purpose of science teaching."*
>
> Science for All Americans

The resources for these recommendations were major works of research in science education. They were: *Project 2061: Science for All Americans* (sponsored by the American Association for the Advancement of Science), *Project on Scope, Sequence, and Coordination of Secondary School Science* (sponsored by the National Science Teachers Association), and *Science for All Students: the Florida PreK-12 Science Curriculum Framework* (sponsored by the Florida Department of Education). Central ideas from these documents are:

- ALL students can learn science.
- Diversity enriches science classrooms.
- There is a body of science knowledge that is important for all students to know.
- The investigation of scientific processes will develop enduring higher-order thinking and problem-solving skills.

Science education driven by these central ideas should include the following practices:

- Science teachers are asked NOT to teach more, but to teach LESS so that it can be taught BETTER. A common core of learning limits the ideas and skills to those which have the greatest scientific and educational significance. Ideas and thinking skills are promoted at the expense of specialized vocabulary and memorized procedures.
- Students are prompted to be actively engaged in the design of investigations in which they participate.
- The existing boundaries between traditional subject matters are softened, so that emphasis can be placed on the connections among the various subject matters.
- Students are given the opportunity to explore each of the sciences each year, in contrast to traditional curricula in which science is taught in discrete and separate subjects. This approach allows them to learn and retain new material better in spaced intervals. In this plan, students are guided to learn at successively higher and higher levels of abstraction.

As science teachers, we know that science is an integral part of everyone's life, and our goal has always been to share an appreciation for science with all students. Science should be a lifetime pursuit that assists individuals in responsible decision making and enriches their view of our world. *Scientific Literacy for All* leads us into the future. Our openness in accepting the ideas presented here can determine the success of that future.

Rationale and Research

Extensive research and a desire to best meet the needs of students has led this committee to recommend an integrated science approach for grades K through 11. *Science for All Students* (Florida Department of Education, 1993) recommends that students be provided with educational opportunities that enhance process, problem-solving, and critical-thinking skills. Current educational literature emphasizes this need for reform.

Science for All Americans (Rutherford and Ahlgren,1990) states that the nation can no longer ignore the science education of any student. In order to involve more students, we must change the way science courses are structured, sequenced, and taught (Pearsall, 1992).

Scope, Sequence, and Coordination of Secondary School Science: The Content Core (Pearsall, 1993) states that the typical U.S. science program discourages real learning not only in its overemphasis of facts, but in its very structure which inhibits students from making important connections between facts. In addition, traditional assessment methods have placed an emphasis on the recall of science facts. The current reform suggests a move towards a more balanced assessment which includes a mastery of concepts, skills, and processes (Pearsall, 1993). The ACT Science Reasoning Test now emphasizes scientific reasoning rather than recall of scientific content.

Current reform initiatives advocate a focus on key concepts, appropriately sequenced, manageable in their scope, and coordinated within the science disciplines. Students should encounter concepts, principles, and laws of science at successively higher levels of abstraction over several years, making it possible for them to truly learn and understand science. Earth/space science, biology, chemistry, and physics share topics and processes. Teaching strategies that coordinate these four disciplines lead students to see the interdependence of the sciences and the relevance to their lives.

The Florida Science Curriculum Framework, *Science for All Students*, provides a rationale supporting an integrated curriculum based on the following underlying principles:

- ❖ Science connects concepts and processes to everyday events.
- ❖ Schools should provide a learning environment conducive to teaching and learning science.

- Not all science learning takes place in school. Both the natural and cultural environment greatly contribute to scientific literacy.
- People learn science in different ways. Instructional programs and teaching strategies should accommodate diverse learning styles.
- Excellence in science teaching and learning grows from a commitment shared by teachers, students, parents, and administrators.
- Science learning promotes the evaluation of new ideas and alternative ways of knowing.

Collaborative efforts of educators and current research support and complement this document. The implementation of *Scientific Literacy for All* promises to create a more informed and responsible citizenry.

"We should all be concerned about the future because that is where we will spend the remainder of our lives."

-Charles Kettering

*Recommended Time Line for Implementation of The Science Content Core **

GRADE		FALL
K-5	ELEMENTARY SCIENCE K-5	1996
6-8	COMPREHENSIVE SCIENCE I-III	1995
9	INTEGRATED SCIENCE I	1996
10	INTEGRATED SCIENCE II	1997
11	INTEGRATED SCIENCE III	1998
12	INTEGRATED SCIENCE IV / SPECIALIZED SCIENCE CLASSES	1999

- Students may enroll in specialized science courses in addition to Comprehensive or Integrated Science.
- Students in the 11th grade may enroll in specialized or Advanced Placement science courses in addition to Integrated Science.
- Students in the 12th grade are encouraged to enroll in Integrated Science IV, specialized, or Advanced Placement science courses.

* Schools within a feeder system may work together on an alternate time line to best meet the needs of their students.

Stakeholders and Their Roles

Where Do You Fit?

Curriculum reform designed to promote excellence in science for all Brevard County students is guided by a vision of the lasting knowledge and skills that adults of tomorrow should possess. There are numerous stakeholders in this promising reform process, and the contributions of each are vital to the achievement of a scientifically literate population. Successful curriculum change will require collaboration and a commitment to excellence by all involved. Significant stakeholders in improved science education and their roles in the process are briefly identified below.

School Board

- Provide support and leadership for science curriculum reform.
- Commit financial support to implement reform.
- Allow sufficient time for the science reform effort to prove its effectiveness.

District Personnel

- Seek and designate funds to support science curriculum reform.
- Provide information on science curriculum reform to school personnel and the community.
- Provide training for teachers in curriculum reform.
- Invite community members to provide input concerning curriculum reform.
- Work as an advocate for science curriculum reform.

School-Based Administrators

- Maintain awareness of science curriculum reform, rationale, recommendations, and efforts.
- Encourage all science teachers to become active participants in science reform.
- Commit financial support to implement reform.
- Promote science reform efforts among parents and the community.

Teachers

- Maintain awareness of science curriculum reform rationale, recommendations, and efforts.
- Become active participants in science reform.
- Promote science reform efforts among parents and the community.

Counselors

- Maintain awareness of science curriculum reform rationale, recommendations, and efforts.
- Promote scientific literacy as essential for ALL students and design schedules accordingly.

Media Specialists

- Maintain awareness of science curriculum reform rationale, recommendations, and efforts.
- Promote scientific literacy as essential for ALL students.
- Provide resources and technological support to teachers and students.
- Become active participants in science reform.

Students

- Maintain awareness of science curriculum reform rationale, recommendations, and efforts.
- Become active participants in science reform.

Community

- Maintain awareness of science curriculum reform rationale, recommendations, and efforts.
- Contribute expertise and input to enhance science education.

Parents and Restructuring for School Improvement Program (RSIP)

- Maintain awareness of science curriculum reform rationale, recommendations, and efforts.
- Allow sufficient time for the science reform effort to prove its effectiveness.
- Contribute expertise and input to enhance science education.

Communication among Stakeholders

Curriculum change offers an opportunity to clarify goals, refresh approaches, and renew enthusiasm. Authentic change must involve *all* stakeholders. Following are suggestions for assisting teachers in establishing communication among those involved to assure the success of *Scientific Literacy For All.*

Communicating with Students

Clear, effective communication with students is essential to a positive learning environment. Students who talk with parents about positive experiences in science classes provide the best link to homes. An effective teacher needs to communicate the following to students:

- ❖ The student's role in a science class is to develop attitudes of curiosity, openness to new ideas, and skepticism.
- ❖ The teacher and other members of the class are part of a team working toward the common goal of becoming lifelong learners.
- ❖ The teacher will play many roles in the science classroom: facilitator, mentor, counselor, and advocate.

Communicating with Families

Students and their families will benefit from science reform. It is important for teachers to:

- ❖ Invite families to school to learn about the goals and expectations of the science curriculum.
- ❖ Advise families of curriculum plans for the upcoming year and discuss questions or concerns.
- ❖ Encourage families to monitor student learning in science.
- ❖ Encourage families to become involved in informal science learning opportunities.

Communicating with the Community

The community can be an important partner for science curriculum reform. An effective teacher may:

- ❖ Invite members of the community to serve as guest speakers, experts, or mentors.
- ❖ Invite members of the community to observe special presentations in the classroom.
- ❖ Articulate to members of the community a clear vision and purpose for science education.

Communication with Other Teachers

Public relations within the school will be an integral component for implementation of the *Scientific Literacy for All* curriculum. An effective science teacher encourages other teachers to:

- Visit science classrooms.
- Learn about inovative science teaching methods.
- Participate in cross-curricular activities.

Communication with Administrators

It is vital that teachers keep their administrators informed about changes and seek their input and support. An effective teacher should:

- Advise administrators of science workshops they may wish to attend.
- Report to administrators on current information and progress related to science reform.
- Invite administrators to participate in classroom projects and demonstrations.

Communicating with Feeder Schools

Communication and articulation within feeder school systems is essential to program success and continuity. The science teacher should:

- Invite teachers from other schools to observe a special classroom activity.
- Host an open-house for incoming/outgoing students, teachers, and parents to share information and answer questions about the science curriculum.
- Encourage articulation meetings involving all feeder school science teachers to plan implementation of science curriculum reform.
- Share successful strategies with feeder system science teachers.

Introduction

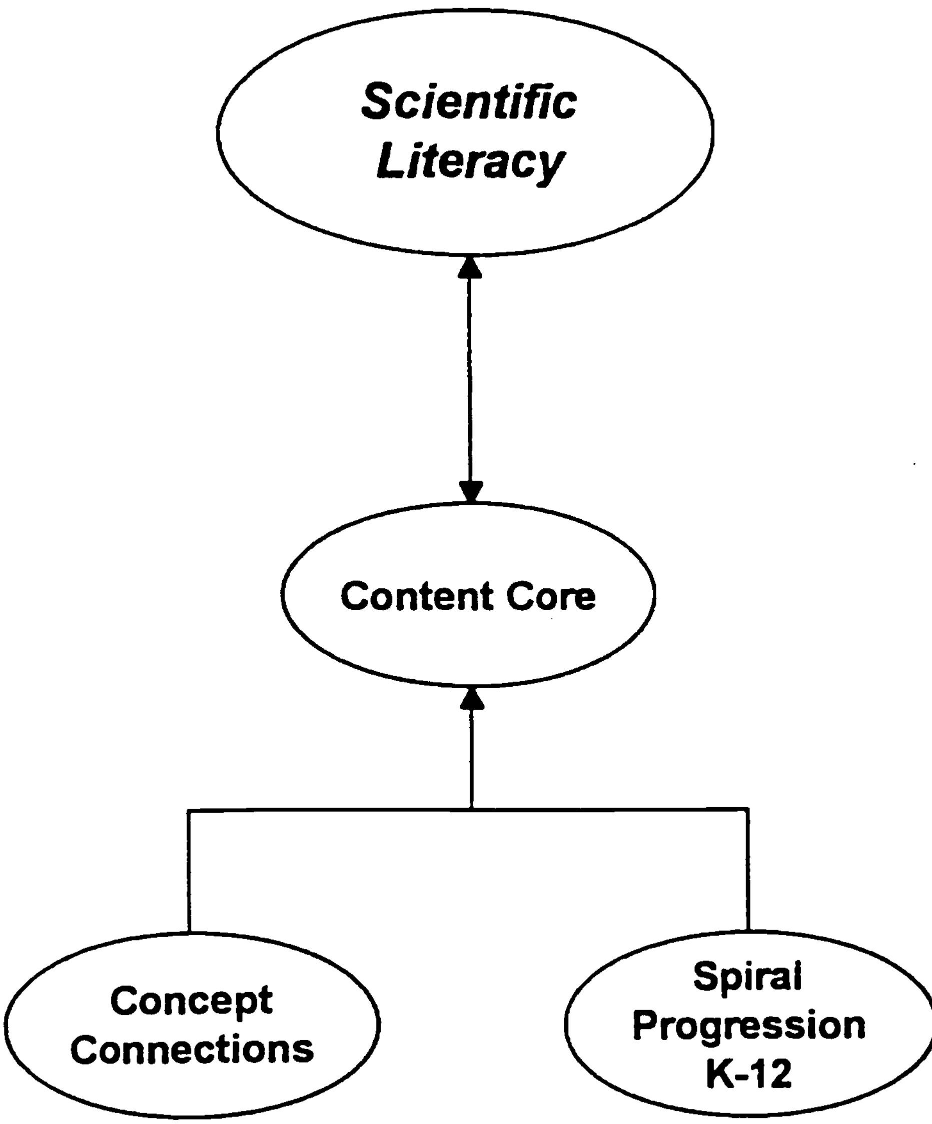
The Science Content Core reflects current research and recommendations in science. This matrix connects concepts both vertically and horizontally. The Spiral Progression builds vertically from year to year on concepts within each content strand to successively higher levels of complexity. Concepts may also be connected horizontally at each grade level using a thematic approach to instruction. The goal of the Science Content Core is to promote scientific literacy for all K-12 students through a coordinated, relevant continuum of learning experiences.

It is important that no student be limited by the Science Content Core. Some students may wish to gain a more sophisticated understanding of a topic than is suggested at their level, and some may wish to pursue topics not listed at all. These special needs can and should be served without sacrificing commitment to the Content Core.

"What you do speaks so loudly, they can't hear what you say."

-Emerson

Recommended Science Content Core



Recommended Science Content Core K-2

	Strand 1 *The Nature of Matter*	Strand 2 *Energy*	Strand 3 *Force & Motion*	Strand 4 *Processes that Shape Earth*
Kindergarten	P-Physical Properties of Solids P-Hot and Cold	P-Sun as a Source of Heat and Light	P-Motion of Objects	E-Daily and Seasonal Weather Changes
First Grade	P-Physical Properties (Sorting and Grouping) P-Physical Change (Cutting and Bending)	P-Sun Causes Changes P-Home Energy Use	P-Pushes and Pulls P-Sounds	C-Properties of Fresh and Salt Water E-Daily Weather Data
Second Grade	P,C-Different Materials Change Differently	P-Sun Warms the Land, Air, and Water P,V-Community Energy Conservation	P-Vibrations Make Sound P-Action of Forces	E-Components of Weather E-Components of Soils

Recommended Science Content Core K-2

Strand 5 ***Earth in Space***	**Strand 6** ***Processes of Life***	**Strand 7** ***How Living Things Interact w/Their Environment***	**Strand 8** ***Nature of Science***
A-Day and Night	B-Senses B-Body Parts and Their Function B-Similarities and Differences in Humans B-Healthy Bodies	V-Human Use of Land and Water B-Care of Living Things	Δ-Observe Δ-Sort Δ-Use Numbers Δ-Question Δ-Predict Δ-Communicate Δ-Follow Safety Procedures Δ-Use Science Equipment
A-Shadows	B-Human Growth and Change B-Common Characteristics of Plants B-Common Characteristics of Animals	V-Effects of Weather on Daily Life B-Products From Plants	Δ-Observe Δ-Sort Δ-Use Numbers Δ-Question Δ-Predict Δ-Communicate Δ-Follow Safety Procedures Δ-Use Science Equipment
A-Sun and Moon as Bodies	B-Basic Needs of Plants B-Basic Needs of Animals B-Similarities and Differences in Living Things B-Life Cycles/ Metamorphosis	V-Habitats V-Food Chains	Δ-Observe Δ-Classify Δ-Measure Δ-Collect/Record Data Δ-Question Δ-Predict Δ-Communicate Δ-Follow Safety Procedures Δ-Use Science Equipment

Discipline Code
- A-Astronomy
- B-Biology
- C-Chemistry
- E-Earth
- V-Environmental
- P-Physics
- Δ-Science Process

RECOMMENDED SCIENCE CONTENT CORE 3-5

	Strand 1 *The Nature of Matter*	Strand 2 *Energy*	Strand 3 *Force & Motion*	Strand 4 *Processes that Shape Earth*
Third Grade	P-Properties of Common Substances P-Solid and Liquid States	P,C-Processes that Produce Heat P-Energy Uses P-Costs of Energy	P-Characteristics of Sound P-Simple Machines P-Types of Forces	E-Evaporation and Precipitation E-Erosion, Transport, Deposition of Soils E-Properties of Rocks
Fourth Grade	P,C-Properties of Common Solids, Liquids, and Gases	P-Energy Exists in Many Forms P,C-Objects Store Energy P-Uses of Electrical Energy	P-Simple Machine Applications P-Effects of Mass on Motion	E-Features of Earth's Surface E-Water Cycle
Fifth Grade	P-Characteristics of Physical Structures P,C-Differences in Physical and Chemical Change	P-Energy Sources P-Energy Can Change Forms	P-Relationship between Force and Motion P-Effects of Friction	E-Weather Patterns E-The Atmosphere E-Causes of Changes in Earth's Surface

RECOMMENDED SCIENCE CONTENT CORE 3-5

Strand 5 *Earth in Space*	Strand 6 *Processes of Life*	Strand 7 *How Living Things Interact w/Their Environment*	Strand 8 *Nature of Science*
A-Changes of Moon Over Time A-Star Patterns	B-Food as Energy B-Human Organs and Their Roles B-Role of Plants as Food	V-Food Webs V-Natural Resources as Building Materials V-Changes in Environment V-Conservation of Water	Δ-Observe Δ-Classify Δ-Measure Δ-Collect/Record Data Δ-Question Δ-Predict Δ-Draw Conclusions Δ-Communicate Δ-Follow Safety Procedures Δ-Use Science Equipment
A-Components of Solar System A-Sun as a Star	B-Cycles of Life B-Human Body System Identification B-Living Things are Made of Cells	V-Ecosystems V,B-Interactions Among Plants and Animals	Δ-Observe Δ-Classify Δ-Measure Δ-Collect/Record Data Δ-Question Δ-Identify Variables Δ-Interpret Data Δ-Predict Δ-Draw Conclusions Δ-Communicate Δ-Follow Safety Procedures Δ-Use Science Equipment
A-Movements of the Sun, Earth, and Moon	B-Human Body System Functions B-Inherited Traits B-One-celled Living Things	V-Impact of Change on Environments V-Pollution V,C-Alternative Fuels	Δ-Observe Δ-Classify Δ-Measure Δ-Hypothesize Δ-Control Variables Δ-Collect/Record Data Δ-Analyze Data Δ-Infer Δ-Follow Safety Procedures Δ-Use Science Equipment

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RECOMMENDED SCIENCE CONTENT CORE 6-8

	Strand 1 *The Nature of Matter*	Strand 2 *Energy*	Strand 3 *Force & Motion*	Strand 4 *Processes that Shape Earth*
Sixth Grade	P,C-Structure of Matter (particles) P-Changes in State of Matter	P-Energy Applications and Implications P-Electromagnetic Spectrum P-Nature of Heat P-Properties of Waves P,C-Energy Resource Conservation	P-Machines and Work P-Gravity P-Mass and Force Related to Motion	E-Climate E,V-Impact of Humans and Natural Forces on Earth's Surface E-Geological Records
Seventh Grade	P,C-Physical and Chemical Proper-ties and Changes of Matter P-Gravitational and Magnetic Forces in Nature	P-Heat Transfer in Materials P-Nature of Light P-Nature of Sound P,C-Energy Alternatives P-Conductors and Nonconductors	P-Velocity and Acceleration P-Momentum P-Compound Machines	E-Plate tectonics E-Weather Measurements E-Weathering and Erosion E-Ocean Waves and Currents
Eighth Grade	C-Atoms, Elements and Compounds	P-Energy Transfer Systems P-Speed, Frequency and Wavelength of Waves P,C-Law of Conservation of Energy	P-Gravitational Acceleration P-Work and Efficiency of Simple Machines P-Inertia, Acceleration, Action/Reaction (Newton's Laws of Motion)	E-Landform Topography E-Weather Forecasting E-Ocean Basin Topography E-Minerals, Rocks, Soil and Fossils

RECOMMENDED SCIENCE CONTENT CORE 6-8

Strand 5 *Earth in Space*	Strand 6 *Processes of Life*	Strand 7 *How Living Things Interact w/Their Environment*	Strand 8 *Nature of Science*
A-Movement of Objects in the Solar System A-Components of the Universe	B-Plant and Animal Cells B-Human Body Systems Working Together	V,B-Technology and the Environment V,B-Adaptations	Δ-Observe (Qualitative/ Quantitative) Δ-Classify Δ-Measurement Systems Δ-Experimental Design Δ-Hypothesize Δ-Identify/Control Variables Δ-Collect/Record Data Δ-Analyze Data Δ-Dimensional Analysis Δ-Follow Safety Procedures Δ-Use Science Equipment Δ-Historical/Social Implications of Science
A-Solar System Motion and Time A-Seasons (Tilt, Rotation and Time) A-Origin of Tides and Tidal Changes	B-Cell Structure (Prokaryotic and Eukaryotic) B-Healthy Lifestyles B-Plant and Animal Reproduction B-Genetic Traits	V,B-Biotic and Abiotic Factors in Ecosystems V-Human Impact on the Natural Environment	Δ-Observe (Qualitative/ Quantitative) Δ-Classify Δ-Measurement Systems Δ-Experimental Design Δ-Hypothesize Δ-Identify/Control Variables Δ-Collect/Record Data Δ-Analyze Data Δ-Dimensional Analysis Δ-Follow Safety Procedures Δ-Use Science Equipment Δ-Historical/Social Implications of Science
A-Solar and Lunar Eclipses A-Space Exploration	B-Functions of Plant and Animal Organelles and Tissues B-Genetic Variability B-Human Body Systems and Disease	B,V-Introduction to Taxonomy/5 Kingdom System V,B-Population Interactions	Δ-Observe (Qualitative/ Quantitative) Δ-Classify Δ-Measurement Systems Δ-Experimental Design Δ-Hypothesize Δ-Identify/Control Variables Δ-Collect/Record Data Δ-Analyze Data Δ-Dimensional Analysis Δ-Follow Safety Procedures Δ-Use Science Equipment Δ-Historical/Social Implications of Science

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RECOMMENDED SCIENCE CONTENT CORE 9-11

	Strand 1 *The Nature of Matter*	Strand 2 *Energy*	Strand 3 *Force & Motion*	Strand 4 *Processes that Shape Earth*
Ninth Grade	C-Simple Stoichiometry and Equations C-Periodicity C-Atomic Structure and Chemical Bonding P,C-Electrostatics C-Acid/Base Systems	P,C-Effects of Heat & Temperature C-Endothermic/ Exothermic Reactions P,B-Energy Needs in Living Systems P-Electromagnetic Radiation P-Simple Circuits P-Wave Interactions	P-Work & Power P,B-Simple Machine Applications P-Kinematics/ Dynamics (One-dimensional) P-Newton's Law of Gravity P-Fluid Dynamics	E,V-Resource Depletion E-Geological Time E-The Rock Cycle E-Ocean/Atmosphere Interactions
Tenth Grade	C,P-Quantum Theory C-Variations in Chemical Bonding C-Transmutation C-Solution Chemistry C-Reaction Rates and Equilibrium P,C-Coulomb's Law	P,C-Electrochemical Processes P,B-Energy Transformations C,B-Catalysts P-Calorimetry C-Gas Laws & Kinetic Theory P-Energy and Matter P-Resistance and Capacitance	P-Friction, Drag, & Terminal Velocity P-Kinematics and Dynamics (Two-dimensional) P-Conservation of Linear Momentum P-Rotational Systems	E-The Climate System E-Coastal Erosion E,C-Natural Solute/ Solvent Systems E-Earth Structure (Geomorphology) E-Renewable and Nonrenewable Resources
Eleventh Grade	C-Crystallography A,C-Dark Matter P,C-Universal Forces	P-Fission/Fusion P-Energy Conversion Systems (e.g., Refrigeration) P-Duality of Light P-Magnetic Fields P-Electric Circuit Applications P-Optics and Sound Applications	P-Kinematics/ Dynamics (Applications) P-Conservation of Rotational Momentum P-Special Relativity P-Electric Motors P-Electric Power Distribution	E-Radioactive Dating E-Ice Ages (Past & Future) V-Human Interaction with Earth's Resources

RECOMMENDED SCIENCE CONTENT CORE 9-11

Strand 5 *Earth in Space*	Strand 6 *Processes of Life*	Strand 7 *How Living Things Interact w/Their Environment*	Strand 8 *Nature of Science*
A-Origin of the Solar System A-Solar System/ Minor Bodies P,A-Technology in Space Studies	B-Functions of Specific Human Cells B-Cell Reproduction B-Mendelian Genetics B-Cellular Transport B-Cellular Communication	V,B-Habitat and Niche B-Taxonomic Keys	Δ-Observe (Qualitative/ Quantitative) Δ-Classify Δ-Measurement Systems Δ-Experimental Design Δ-Hypothesize Δ-Identify/Control Variables Δ-Collect/Record Data Δ-Analyze Data Δ-Dimensional Analysis Δ-Follow Safety Procedures Δ-Use Science Equipment Δ-Historical/Social Implications of Science
A-Stellar Evolution A-Planetary Motion A-Galactic Systems E,A-Earth's Magnetism	B-Meiosis B-Chromosomes and Genes B-Human Growth and Reproduction B,C-Energy Transfers in Living Systems	V,B-Natural Selection V,B-Population Dynamics V,P-Environmental Observation Technologies	Δ-Observe (Qualitative/ Quantitative) Δ-Classify Δ-Measurement Systems Δ-Experimental Design Δ-Hypothesize Δ-Identify/Control Variables Δ-Collect/Record Data Δ-Analyze Data Δ-Dimensional Analysis Δ-Follow Safety Procedures Δ-Use Science Equipment Δ-Historical/Social Implications of Science
A-Cosmology P,A-Grand Unified Theory B,A-Theories of Life in the Universe C,A-Chemistry of the Universe	B-Transcription & Translation B,P-Biotechnology B-Human Body System Synergism	B-Epidemiology B,C-Causes of Mutations B,E-Mechanisms of Evolution B,V-Interdependence of Living Things V,B-Environmental Ethics	Δ-Observe (Qualitative/ Quantitative) Δ-Classify Δ-Measurement Systems Δ-Experimental Design Δ-Hypothesize Δ-Identify/Control Variables Δ-Collect/Record Data Δ-Analyze Data Δ-Dimensional Analysis Δ-Follow Safety Procedures Δ-Use Science Equipment Δ-Historical/Social Implications of Science

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Introduction

The Spiral Progression is a sequencing of instruction that involves students in concepts, principles and laws of science at successively higher levels of abstraction from kindergarten through eleventh grade. Repeated experiences in different contexts assist students in building concepts. Relationships between concepts will be linked with increasing complexity over time. This gradual progression of process and content helps students relate science to themselves and their lives.

Examples of the Science Content Core

The following are examples of the science content core topics as they might be taught within the spiral progression of a strand. These may be used as a guide when developing your own program.

Strand 1: Nature of Matter Examples

K	Identify several objects by size, shape, color, texture, and buoyancy.
1st Grade	Sort objects such as buttons, rocks, and shells in a variety of ways by attributes.
2nd Grade	Demonstrate/explore mixing, melting, freezing, and cutting different materials to see how they change and how they stay the same.
3rd Grade	Investigate and compare the properties of common solids (rice, beans, oatmeal) and liquids (water, oil, corn syrup).
4th Grade	Measure the time it takes for various liquids to boil as well as the additional time it takes for them to change into a gas.
5th Grade	Design and build a structure using recyclable materials. Write a description of the design and the difference between the structure and the materials from which it was constructed.
6th Grade	Describe molecular spacing in substances as they change state from solid to liquid to gas. Use a balloon to investigate the effects of heat on a gas sample.
7th Grade	Distinguish between physical and chemical changes by demonstrating repeated examples of each. Chemically combine substances to produce new substances.

8th Grade	Create a concept map showing the relationship among matter, atoms, elements, compounds, solutions, and mixtures.
9th Grade	Examine the organization of the Periodic Table of the Elements. Identify periods and groups and their relationships.
10th Grade	Use the Periodic Table of the Elements to identify patterns and make predictions in chemical bonding.
11th Grade	Predict crystal geometry through the building of crystal models. Grow and examine crystals to verify predictions.

Strand 2: Energy Examples

K	Compare sunny and shady spots in the school yard.
1st Grade	Feel different objects outdoors in sun and shade. Compare and describe the differences.
2nd Grade	Measure with a thermometer and compare the temperatures of soil, water, and air in the sun and shade.
3rd Grade	Observe processes that produce heat (friction by rubbing, burning a candle)
4th Grade	Compare the energy sources of a variety of moving toys.
5th Grade	Construct a flashlight using a bulb, wires, batteries, paper roll, tape, and a switch. Compare with a commercial flashlight.
6th Grade	Observe the difference between heat and temperature by exposing several substances (sand, soil, and water) to a heat source. Measure and evaluate the reason for differences in temperature.
7th Grade	Design and construct a device that will keep an ice cube in its solid state for at least two hours.
8th Grade	Design systems that demonstrate the effects of conduction, convection, and radiation. Analyze the components and materials of a saucepan.

9th Grade	Predict the final temperature when mixing equal amounts of ice and tap water.
10th Grade	Measure the latent heat of fusion of ice.
11th Grade	Evaluate and compare the energy efficiency of a conventional air conditioning system and a heat pump air conditioning system.

Strand 3: Force and Motion Examples

K	Observe how various items move.
1st Grade	Explore objects that can be pushed or pulled.
2nd Grade	Demonstrate how objects can be moved without being touched (magnetic forces).
3rd Grade	Observe various moving objects and identify forces acting on them.
4th Grade	Measure the distance that two objects will travel. Compare objects of similar size and different masses.
5th Grade	Roll a marble down a board that is held at different angles. Measure differences in speed. Graph the results.
6th Grade	Determine the speed of moving objects. Describe how their motion is affected by forces.
7th Grade	Identify the motion of an object that is accelerating (e.g. speeding up, slowing down, or changing direction).
8th Grade	Design a balloon rocket to demonstrate action/reaction forces and acceleration.
9th Grade	Design and build a car that is propelled by the pressure of a gas or liquid. Measure distance, speed, and acceleration.
10th Grade	Find the speed, period, frequency, acceleration, and centripetal force of an object moving in a circular path.
11th Grade	Design and build a model car that uses the energy stored in a spring or a raised mass to propel the car. Measure the distance traveled, speed, and acceleration.

Strand 4: Processes that Shape the Earth Examples

K	Choose appropriate clothing for different weather conditions from a basket of clothes.
1st Grade	Predict if tomorrow's temperature will be higher or lower than today's. Verify with thermometers.
2nd Grade	Interview parents or other adults about their experiences in unusual or severe weather, such as hurricanes, tornadoes, or snow storms.
3rd Grade	Compare evaporation of water in sunlight and shade. Make rain gauges and measure rainfall.
4th Grade	Demonstrate the water cycle by creating clouds and rain using ice and hot water.
5th Grade	Use latitude and longitude to plot the path of a hurricane.
6th Grade	Identify the factors that determine the climate of an area. Plot long-term weather data on a world map and analyze for climatic patterns.
7th Grade	Construct and use weather instruments (barometer, sling psychrometer) and measure weather conditions. Record daily.
8th Grade	Using data from local weather observations, predict local weather patterns.
9th Grade	Relate Florida's unique geographical location to its predominant weather pattern.
10th Grade	Predict how dramatic natural events, such as El Nino and volcanic eruptions, affect the Earth's climate.
11th Grade	Design a flow chart to show how one change in a climatic system will cause changes in other natural systems.

Strand 5: Earth in Space Examples

K	Create a class collage using magazine pictures that show day activities vs. night activities.
1st Grade	Measure and compare body shadows at different times of the day.
2nd Grade	Record the number of days during a month in which the moon is visible during daylight hours.
3rd Grade	Observe and draw on a calendar what the moon looks like each night over a period of one month (Home-based). Describe and analyze the observations.
4th Grade	Demonstrate the relationship between distance and apparent size/brightness using a flashlight in a large darkened room (cafeteria, media center).
5th Grade	Construct a model that shows the relationship between the Earth, Moon, and Sun.
6th Grade	Construct a model of the solar system and demonstrate each planet's rotation and revolution. Describe why it is difficult to construct an accurate scale model of the solar system.
7th Grade	Demonstrate the role of the Earth's motion and tilt in causing seasons.
8th Grade	Demonstrate the occurrence of solar and lunar eclipses in a darkened room using a light bulb and two spheres.
9th Grade	Explore, compare, and evaluate various theories of solar system formation.
10th Grade	Verify and demonstrate Kepler's 2nd Law of Planetary Motion using selected media.
11th Grade	Create a model depicting the orientation of our solar system in the galaxy. Explore theories of formation of galactic systems.

SPIRAL PROGRESSION

Strand 6: Processes of Life Examples

K	Identify body parts that are sense organs.
1st Grade	Create height, weight, and tooth loss charts. Compare throughout the year.
2nd Grade	Observe the life cycle of animals, such as frogs and butterflies. Record observations in a journal.
3rd Grade	Draw and describe human organs.
4th Grade	Construct a life size model of the human circulatory system using an outline of the body and thick red and blue yarn.
5th Grade	Construct a model of muscles and bones working together using dowels, rubber bands, and paper clips.
6th Grade	Construct a model to demonstrate the mechanics of breathing using common materials (e.g. plastic bottle-body, rubber sheeting-diaphragm, straws-trachea and bronchial tubes, balloons-lungs).
7th Grade	Create a "user's manual" for the human body that focuses on healthy lifestyles and human system maintenance.
8th Grade	Design a role playing game that depicts how a disease attacks the human body and how the body defends itself.
9th Grade	Demonstrate the interaction of human cells with their environment via the cell membrane through the use of dialysis tubing.
10th Grade	Create a brochure tracing human prenatal development which would assist an expectant parent in making healthy nutrition and lifestyle choices.
11th Grade	Examine the technology and ethics of organ transplant.

Strand 7: How Living Things Interact with Their Environment
Examples

K	Create murals depicting use of land and water.
1st Grade	Plan, plant, care for and harvest a salad garden.
2nd Grade	Draw a simple food chain within a habitat.
3rd Grade	Observe and record the environmental changes that occur throughout the year on a selected area of land.
4th Grade	Collect and observe algae. Explore the implications of excessive algal growth in a lake.
5th Grade	Examine the impact of a natural disaster on an ecosystem.
6th Grade	Identify adaptations related to an organism's niche. Design a model organism that possesses adaptations enabling it to succeed in unusual habitats and defend the benefits of each adaptation.
7th Grade	Illustrate a local ecosystem. Include the community of organisms with which humans interact and all the physical factors of the environment.
8th Grade	Show how populations in a community affect each other. Plant a mixture of seeds and observe and measure growth. Evaluate difference in terms of competition.
9th Grade	Create a three-dimensional model of a given habitat.
10th Grade	Given a list of satellites, describe which ones would best meet the requirements for measuring deforestation on Earth.
11th Grade	Conduct an environmental impact study.

Strand 8: Nature of Science Examples

K	Compare the mass of objects using balances.
1st Grade	Measure hot and cold temperatures using a thermometer.
2nd Grade	Examine soil samples using a hand lens.
3rd Grade	Measure the amount of rainfall over a specific period of time using a rain gauge.
4th Grade	Create and examine a spectrum of colors using a prism.
5th Grade	Observe pond water using a microscope and illustrate your findings.
6th Grade	Measure the mass of different substances using a triple-beam balance.
7th Grade	Create a grid to use with a microscope to accurately measure the size of microscopic organisms.
8th Grade	Determine work efficiency of simple machines by using spring scales, metric rulers and calculators.
9th Grade	Select the appropriate equipment to measure the density of an object.
10th Grade	Demonstrate the proper use of a calorimeter in determining heat loss or gain.
11th Grade	Develop an inexpensive instrument to test auto emissions.

Introduction to Themes

A theme is an idea that organizes the study of concepts. A thematic approach intertwines the various science disciplines and provides the framework necessary for students to make connections between concepts, themselves and the world. This approach can also be used to create interdisciplinary (cross-curricular) units. The time allocated for a theme varies according to the complexity of the theme.

A thematic approach helps students retain and retrieve information, emphasizes process skills and analysis of complex situations, and often enhances student motivation and participation. Themes also act as curriculum organizers so that students and teachers know what is coming next.

Teachers should consider the following questions when planning thematic units:

- Does it demonstrate real-world relevancy?
- What resources are available?
- Is it age-appropriate?
- Are the connections logical and significant?
- Is it important?
- Is the time allocated appropriate for the theme?

The following represent examples of thematic and interdisciplinary units that could provide connecting concepts for frameworks:

"You may not divide the seamless cloak of learning. There is only one subject matter for education and that is Life in all its manifestations."

-Alfred North Whitehead

Interdiscipinary Unit

The manner in which humans make use of science and technology affects the environment and changes the way we live.

Could there be a Jurassic Park?

Science
1. Describe dinosaurs and their habitats.
2. Explain DNA replication.
3. Identify predator/prey relationships.
4. Describe radioactive dating.

Reading
1. Read *Jurassic Park.*
2. Use new vocabulary words.
3. Participate in class discussion.

Writing
1. Record examples and observations.
2. Write report on new technologies and their effects on society.

Social Science
1. Research new technologies and their effects on society.
2. Examine the archeological evidence of dinosaurs.

Mathematics
1. Reduce information to digital form (binary).
2. Use probability/statistics.
3. Use scientific notation.
4. Develop a time line.

Field Experiences
1. Explore natural history museum.
2. Identify local animals most closely related to dinosaurs.

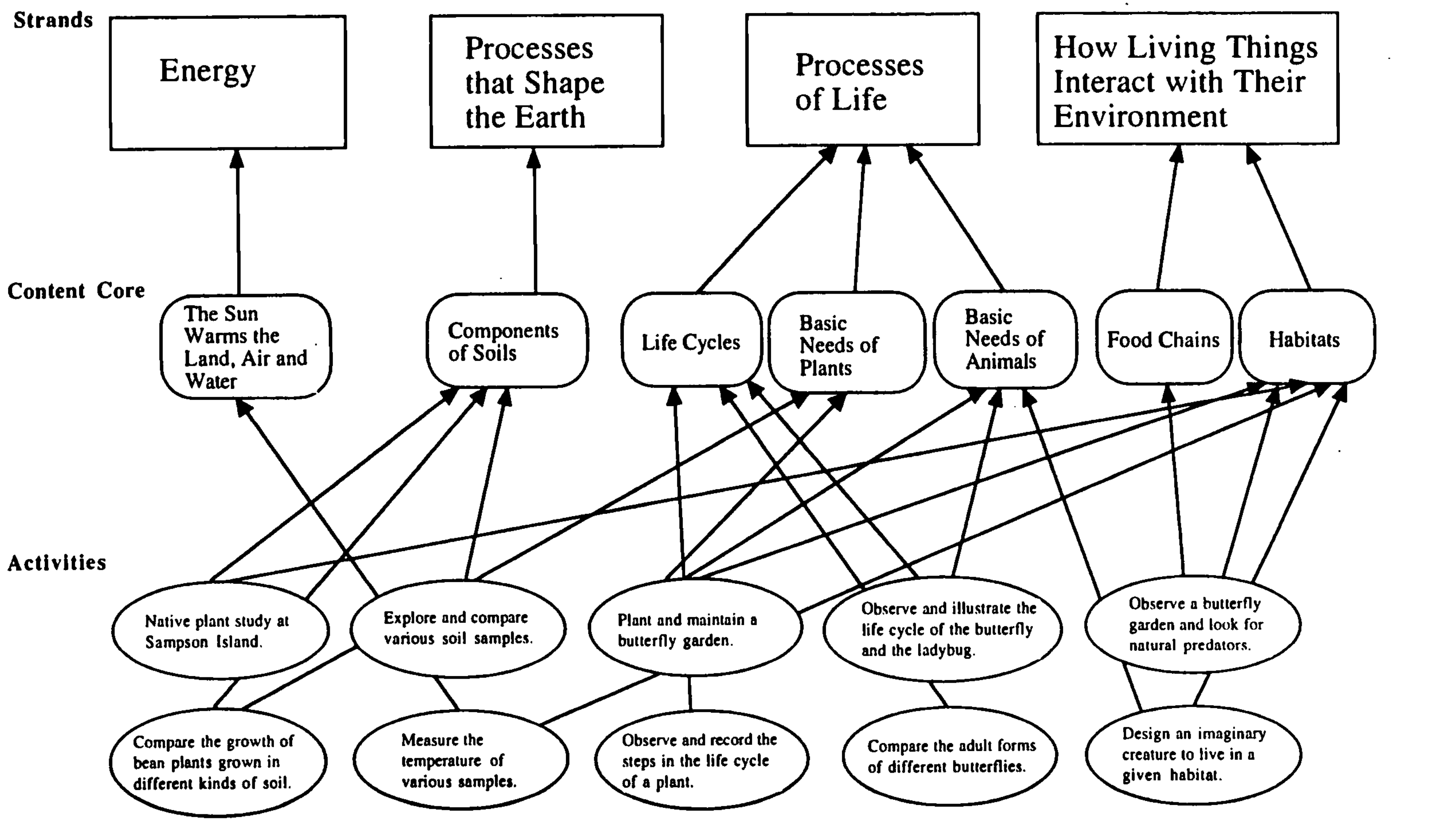
Art, Music & P.E.
1. Design and build a technological dinosaur.
2. Paint event which may have ended the dinosaur era.
3. Create music that portrays dinosaur era.

Health
1. Identify pros/cons of genetic engineering.
2. Explore extent of current genetic engineering in medicine.

Connecting Topics
Adaptations, Competition

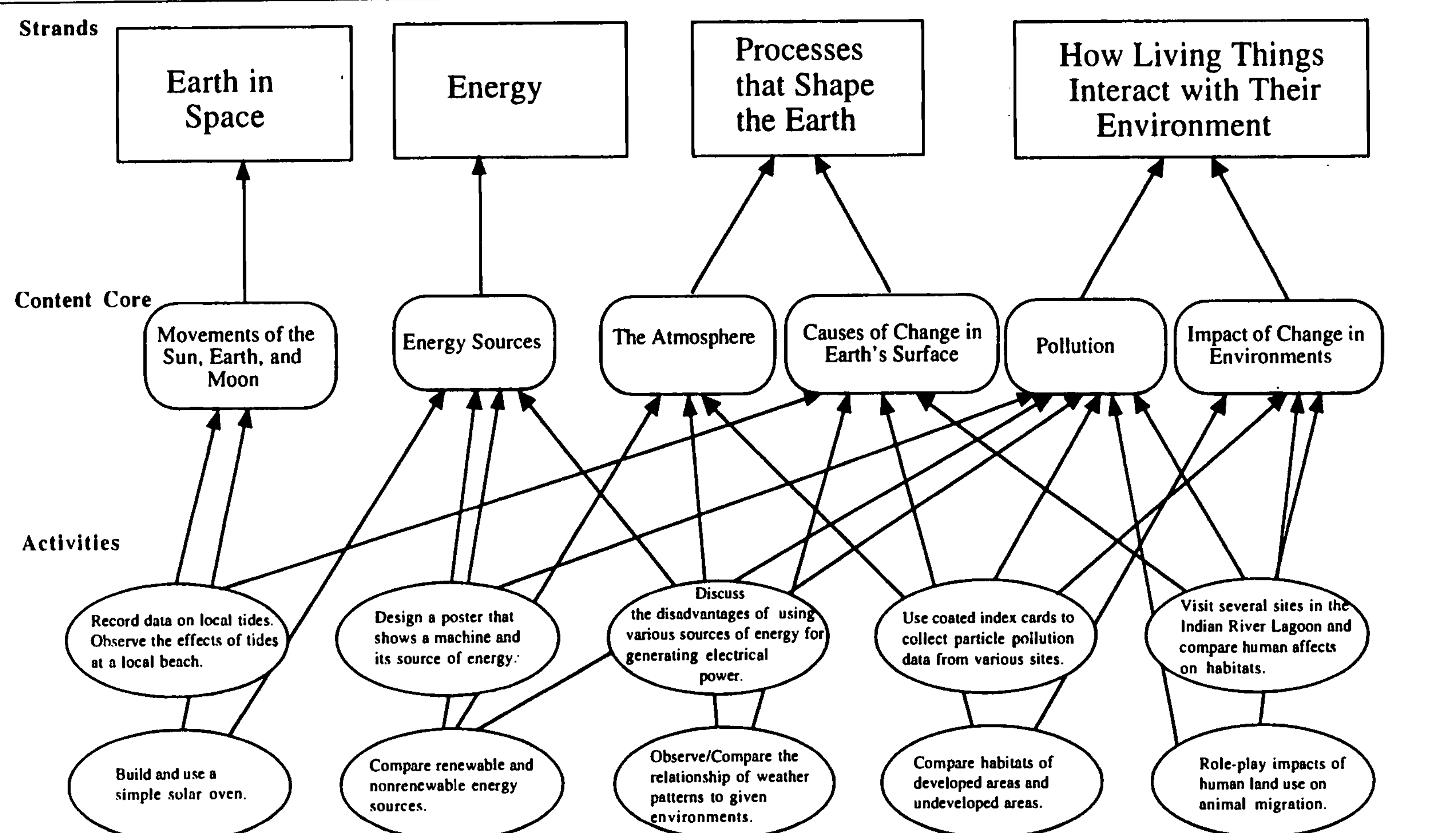
Example Science Theme
Primary: Second Grade

Exploring a Butterfly Garden



Example Science Theme
Intermediate: Fifth Grade

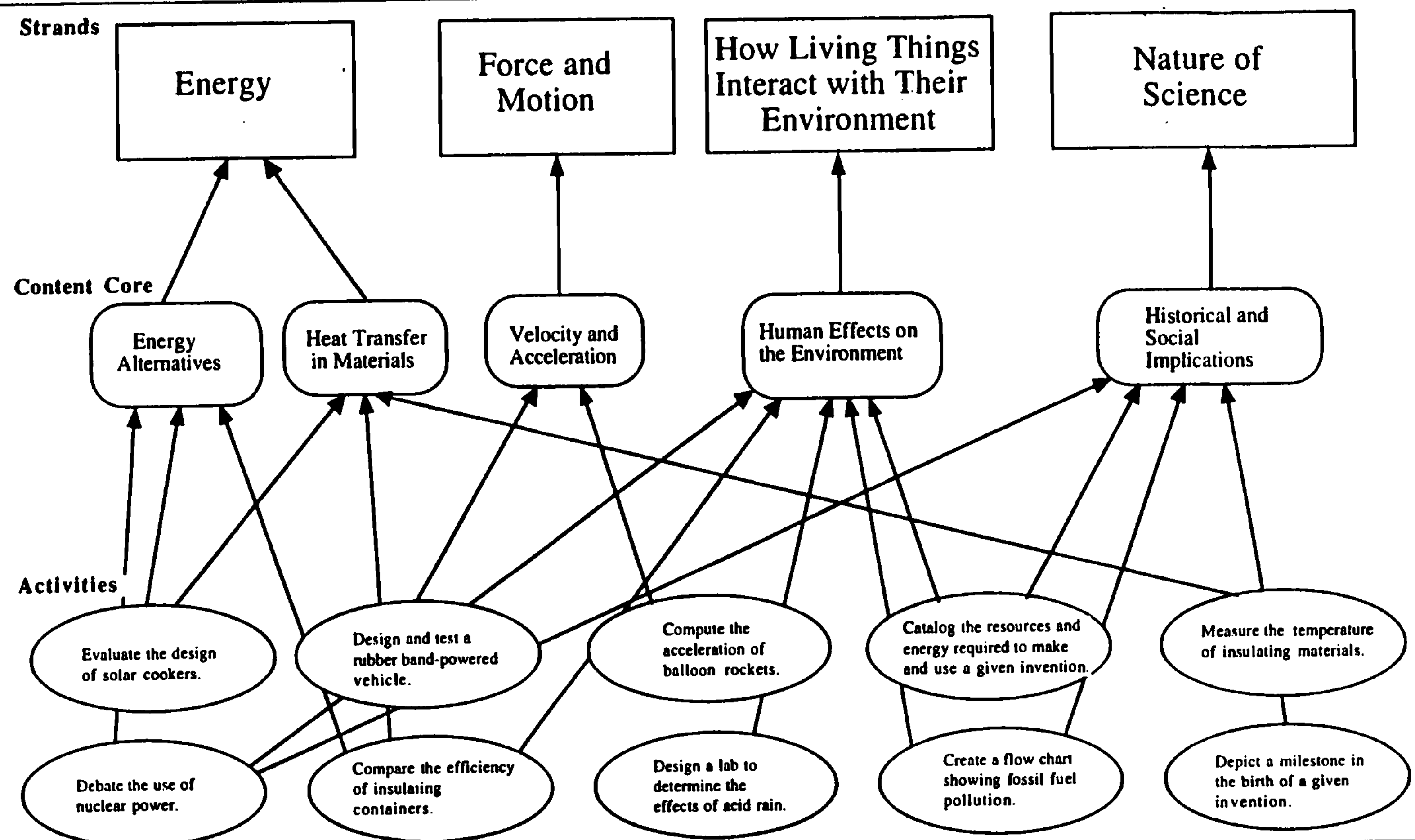
Spaceship Earth



CONCEPT CONNECTONS USING THEMES

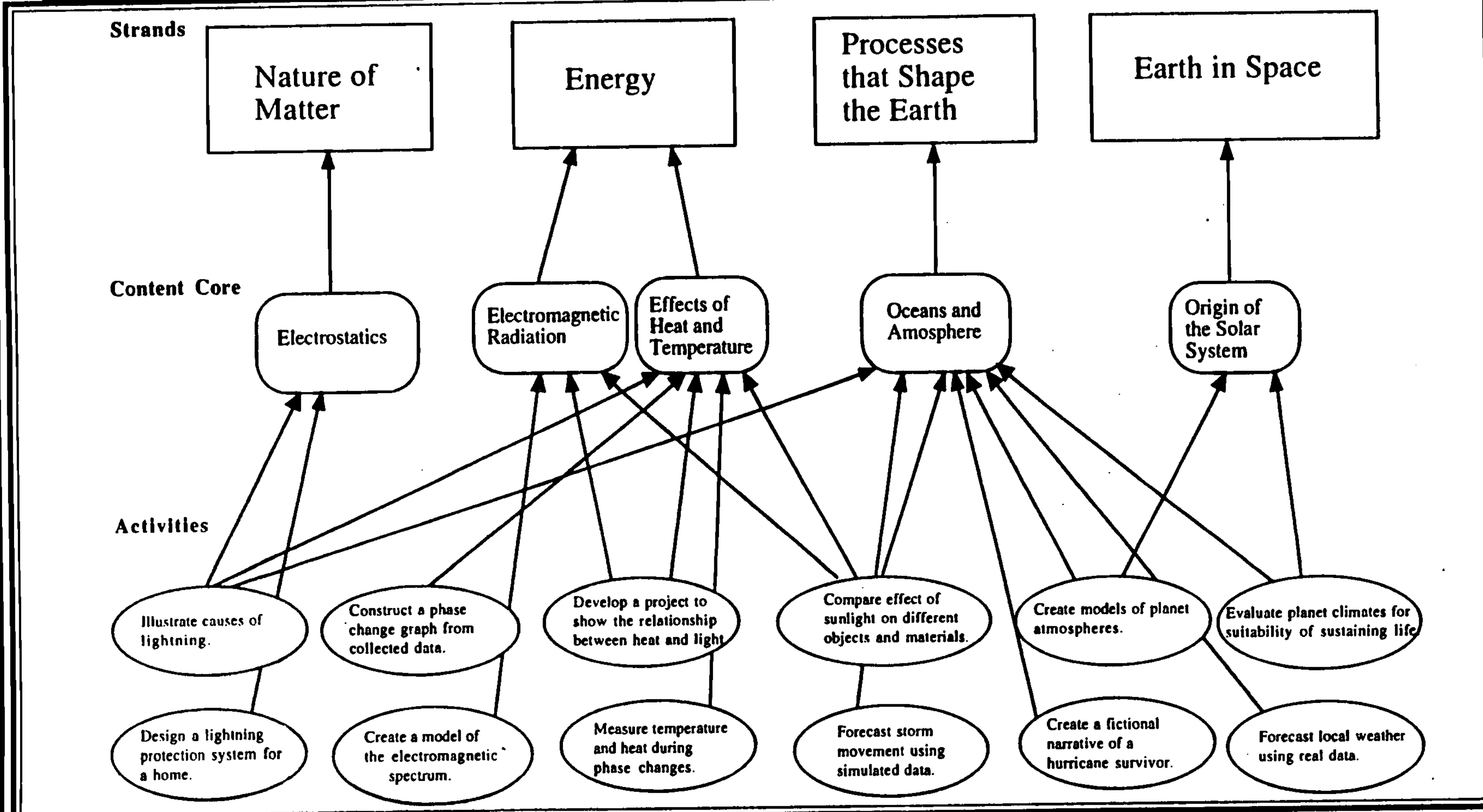
Example Science Theme
Middle/Junior High: Seventh Grade

Inventions



Example Science Theme
High School: Ninth Grade

Weather



Introduction

Not all science learning takes place in schools. Both the natural and cultural environment greatly contribute to scientific literacy. Homework and out-of-school explorations are essential extensions of the classroom, and helps maintain continuity. Home-based learning must be relevant work as opposed to busywork.

Activity Examples

1. Thought Questions.
    - Describe a journey through our atmosphere and what one might see.
    - Complete a "What if..?" statement.

2. Posters or collages.
    - Label pictures from magazines that show examples of kinetic or potential energy.
    - Create a collage of machines that do work.

3. Comic strips.
    - Create a comic strip demonstrating bean development..

4. Labeled diagrams.
    - Draw and label a diagram of a flower.
    - Draw and label an animal cell undergoing mitosis.

5. Models.
    - Make a machine composed of two or more simple machines that can perform a practical function.
    - Make a model of a plant.

6. Surveys.
    - Create and complete a survey on what people recycle.
    - Create and complete a survey about nutrition and health awareness.

7. Experiments.
    - Explore surface tension by filling a cup completely with water, add pennies until water overflows. Repeat with soap added to water.
    - Explore chromatography with pens with water soluble ink.

8. Current events.
    - Present to the class a current science issue or event.
    - Prepare a debate with a classmate representing opposing views on a current environmental issue.
9. Games.
    - Design and construct a board game about water.
    - Design and create a game similar to Bingo.
10. Energy Uses at Home.
    - Read the electric meter and graph data.
    - Compare the cost of incandescent and fluorescent.
11. Brochures.
    - Create a travel brochure for a voyage through the solar system.
    - Create a brochure for traveling through the human body.
12. Math and Science Application.
    - Count teeth on gears of a bike to determine the mechanical advantage.
    - Determine the number of petals on a variety of flowers.
13. Kitchen Labs.
    - Make fake glass from corn syrup and sugar.
14. Scavenger Hunts.
    - Find common household items from a list of scientific names.
    - Create a list of things that use energy in the home.
15. Media Research
    - Find examples of science facts and fallacies in the media.
16. Graphing
    - Produce a graph of daily precipitation for one week.
17. Concept Drawing.
    - Create a drawing which depicts the causes of wind.
18. Collections.
    - Collect and label plant parts that are used for food.

Introduction

Technology has changed the way society operates. Science educators are responding to these changes by preparing students to function in this technological world. Students should be taught how to use technology in *doing* science so that technology becomes a tool for exploring scientific principles and ideas. The following are ideas for using multimedia technology in the science classroom.

Computers in the Classroom

Computers are quickly becoming as common as the chalkboard in classrooms. Whether there is a fully networked laboratory or one computer shared among several teachers in the science department, there are ways to integrate computer technology into science lessons.

The One-Computer Classroom

The following is a brief list of suggestions for the use of a single computer:

- ❖ Use the computer to present graphics or demonstrations/simulations. The monitor can be hooked up to an overhead projection panel or to a TV monitor using an adapter and software.
- ❖ Use the single computer as a station. The computer station could present a lesson, provide the students with research information, or run a simulation program.
- ❖ Use the computer as a learning center where students may go for remediation or enrichment activities.
- ❖ Connect probeware to the computer for the students to gather data in the laboratory.
- ❖ Have classes send projects or e-mail to other schools. Telecommunication activities are often done on a single computer because there is often only one telephone line available for connection to the modem. Telecommunications can also provide students with access to the Internet and to experts in different fields of research.

Computer Labs or Networks

All of the ideas mentioned previously for the one-computer classroom can be even more effective with a dedicated computer lab or a networked group of machines. Listed below are additional ideas that are most effective when there are enough computers for small groups of students.

- Authoring software (such as *Hypercard* for Macintosh and *Authority* for DOS machines) effectively introduces students to computer use as they focus on a topic or content area. For example, teams of students can create multimedia computer lessons on a certain topic. Those lessons can be evaluated by other teams or incorporated into the lesson plans of other classes.
- CD-ROM software can be used on a network as a research and simulation tool. Simulation programs (such as a chemistry simulation of an explosive reaction) can take the place of a more expensive and less safe laboratory experiment.

Laser Videodiscs

The videodisc is an excellent way to store huge amounts of visual information and can be a great aid to the teacher's presentation. The computer and the videodisc player can combine to enhance the lesson.

- Use the images on a videodisc for visual aids during presentations or to quiz students.
- Use a videodisc as a substitute for a dangerous or logistically difficult demonstration.
- Combine a computer and videodisc as a station in a rotation. Students can use this station as a multimedia tutorial for remediation or enrichment.
- Encourage students to write videodisc lessons for other students or for project presentations.

Television/ Video Tape Player/ Camcorder

A television can enhance a teacher's lesson in many ways, especially if a video tape player and a camcorder are also available.

- Use the television as a large screen computer monitor.
- Use videotapes in short, relevant bursts to illustrate points and enhance instruction. *Scientific American Frontiers* is a great source of short video segments.
- Hook up a microscope to a video camera for class viewing of organisms or demonstrations of microscale phenomena.
- Encourage small groups of students to create their own science video program and have them present it to the class.

The Information Superhighway and Telecommunications

Education is dependent on the ability to access information, analyze it, and communicate with others. From School Net to Internet, telecommunications between computers is getting less expensive, easier to use, and faster. Most commercial online services (e.g., America Online, Compuserve and Prodigy) have special educational memberships and access areas. Consider the following opportunities:

- Compile data from an experiment in several different classes on the same campus, in the same county, in the nation, or even internationally by networking.
- Administer a survey across political, cultural, and regional boundaries and then analyze it.
- Share your students' projects by digitizing them and downloading them on a bulletin board.
- Discuss science, technology, and society issues with other students via a bulletin board.
- Research information and perhaps even *speak* with the authorities themselves through electronic mail.

Other Emerging Technologies

Many devices or systems that were out of reach of school budgets ten years ago are now quite inexpensive. Some examples of new, or less expensive, instructional technology include:

- Satellite downlink systems which can be purchased for under $4,000 and allow teachers and students to receive images directly from satellites orbiting the Earth.
- Wireless cable television which may expand the selection of educational programming available over the broadcast and cable channels at a lower cost.
- Voice recognition technologies for computers which may allow physically challenged students better access to computers.

Computers and peripherals are becoming less expensive and more powerful. The future of instructional technology is a bright one.

Introduction

Children learn about their surroundings naturally and enthusiastically, and teaching methods should encourage and build on this natural curiosity. Changes in the science curriculum must be based on how students learn science.

Recent findings in brain research indicate that the learning process is complex and unique to each individual. Students differ widely in the ways they learn. Some learn better in a group setting, while others prefer to work alone. Some need a great deal of structure and support, others are more independent and self-motivated.

These findings are driving a move toward more learner-focused methods in science education. As enhancing individual student learning becomes the focal point, old barriers are removed and creativity is encouraged. The results can be dramatic. Addressing all types of learning styles provides optimal experiences for students.

Many factors affect learning:

- student characteristics and background,
- teacher characteristics and methods, and
- the context or learning environment.

"...the logic by which we teach is not always the logic by which children learn."

Current thinking in science education reveals a change in focus in curriculum, instruction, and assessment: the needs of the learner shape curriculum planning, the learning environment, and the teacher's role.

Teaching to a Variety of Learning Styles

The Theory of Multiple Intelligence

In 1983 Howard Gardner of Harvard University proposed a theory of multiple intelligences. Gardner's research indicates that teachers can enjoy more success educating students when their lessons address these intelligences. Based on the populations studied, the following seven areas are described in Gardner's *Frames of Mind*: Linguistic Intelligence, Logical-Mathematical Intelligence, Musical Intelligence, Spatial Intelligence, Body-Kinesthetic Intelligence, Intrapersonal Intelligence, and Interpersonal Intelligence. Relative strengths in these areas is different for each person. It is important that we provide opportunities for learners to work and develop in all areas so that we do not limit human potential.

Teaching Strategies

In his book, *In Their Own Way*, Dr. Thomas Armstrong explains the different learning characteristics of each learning style. The seven basic styles and characteristics are:

Linguistic Intelligence

- Learn by listening, reading, and verbalizing
- Think in words
- Benefit from discussion
- Enjoy writing
- Like word games, books, records, and tapes
- Like tape recorders, typewriters, and word processors
- Have a good memory for verse, lyrics, or trivia
- Enjoy outings to such places as libraries, book stores, and publishing houses

Logical-Mathematical Intelligence

- Think conceptually
- Reason things out logically and clearly
- Look for abstract patterns and relationships
- Enjoy computing math problems in their heads
- Like brain teasers, logical puzzles, and strategy games
- Like to use computers
- Like to experiment and test things out
- Enjoy science kits
- Like to classify and categorize
- Enjoy outings to science museums, computer fairs, and electronic exhibitions
- Ask questions like "Where does the universe end?," "What happens when we die?," and "When did time begin?"

Musical Intelligence

- Play musical instrument
- Remember melodies of songs
- Tell when a musical note is off key
- Say they need to have music in order to study
- Collect records, tapes, and CD's
- Sing songs to themselves
- Keep time rhythmically to music
- Use rhythm or cadences to remember facts

Spatial Intelligence

- Spend free time engaged in art activities
- Report clear visual images when thinking
- Read maps, charts, and diagrams with ease
- Draw accurate representations of people or things
- Enjoy movies, slides, or photographs
- Enjoy doing jigsaw puzzles or mazes
- Daydream frequently

Body-Kinesthetic Intelligence

- Communicate through gestures
- Learn by touching, manipulating, and moving
- Like role playing and creative movement
- Demonstrate skill in crafts, such as woodworking or sewing
- Enjoy participating in sporting events

Interpersonal Intelligence

- Understand and care about people
- Have many friends
- Like to socialize
- Learn by relating and cooperating
- Enjoy group games
- Are good at teaching other children
- Enjoy clubs, committees, and volunteer organizations

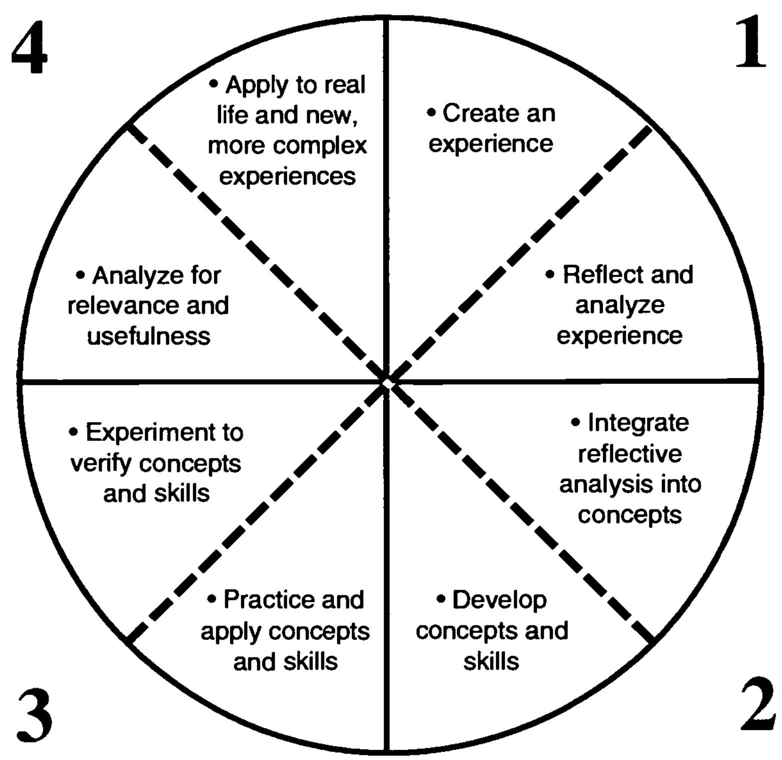
Intrapersonal Intelligence

- Display a sense of independence
- Seem to be self-motivating
- Learn more easily with independent study, self-paced instruction, and individualized projects

The 4MAT Approach

Bernice McCarthy developed an instructional system called 4MAT which is based on the research of Kolb, Lawerence, Jung, and others. In 4MAT, instruction is organized to address the different ways people learn. McCarthy identified four major, equally valuable, learning styles and recommends that the development and integration of all four styles, as well as both right and left brain processing skills, should be a major goal of education. 4MAT is also a cycle of learning and teaching that moves students through a natural learning progression designed to promote individual growth and success.

The 4MAT Learning Cycle



The following instructional strategies enhance student learning in science. They are not meant to be used in isolation or in a linear fashion. Teachers may incorporate several of them in a single lesson. Persistence is key to success. The teacher should allow time to adapt and refine strategies to fit the needs of the students.

"Success is the best kind of motivation"

Concept Mapping

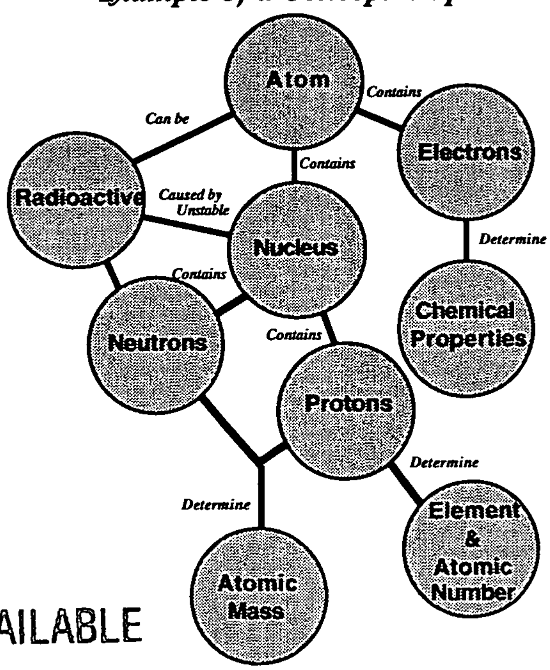
What is it?

A concept map is a diagram that shows relationships among ideas. Usually, the concepts are circled, and the relationships are shown by connecting the circles with lines. Linking verbs or short explanations are used to show the relationship between concepts. Concept mapping helps show how ideas are connected and how knowledge is organized. It improves comprehension and problem-solving skills. Concept mapping can be used by teachers to plan lessons, identify misconceptions, and assess learning.

How to do it

1) Select a main idea.
2) Write concepts associated with the main idea on slips of paper.
3) Rank concepts in related groups from the most general to the most specific.
4) Connect related concepts with lines and label the links with short verbs or phrases.
5) Revise as needed.

Example of a Concept Map



Conflicting Viewpoints

What are they?

Conflicting viewpoints are expressions of several hypotheses or points of view that are inconsistent with each other. These can be used to reinforce critical thinking skills.

How to do them

The teacher or a student selects a topic. The topic may be an ethical issue or a research-based problem.

1) Students should research topics.
2) Debate or discuss the viewpoints generated from research.
3) The teacher should summarize the viewpoints of all groups.

Example of a Conflicting Viewpoint Activity

Ms. Jones provided her class with several articles on the use of animals in research. Each student was assigned to read all the articles. The class was divided into two groups: a group in favor of using animals in research and a group against using animals in research. Students were allowed to align themselves with the group of their choice. Ms. Jones facilitated a group discussion allowing each side an opportunity to express its views. She then summarized the arguments of both sides.

"We are continually faced with great opportunities brilliantly disguised as insoluble problems."
-Lee Iacocca

Cooperative Learning

What is it?

Cooperative learning involves students working together in small groups to achieve a common goal. Often the groups are of mixed ability. Several cooperative learning models exist which are described in professional books and journals. Cooperative learning has the potential to improve achievement, attitude, and interpersonal skills by having students assume responsibility for the learning of the entire group.

How to do it

1) State the goal of the lesson.
2) Place students in groups that are culturally and intellectually mixed.
3) Facilitate the selection of individual roles within the group.
4) Monitor group progress and provide assistance as needed.
5) Evaluate the success of each group in accomplishing the task or solving the problem.

Example of Cooperative Learning

Mr. Garcia introduced a lesson on the ear and hearing. He divided his science class into groups of four to design devices to test hearing. Each individual in the group chose a role of background researcher, tester, data recorder, or communicator. The students collaborated to research, design, build, troubleshoot, and then demonstrate their devices.

Discrepant Events

What are they?

Discrepant events are phenomena that do not conform to expectations. These events can be used to gain students' attention and to interest them in finding the cause of the discrepancy.

How to do them

1) Ask students to predict what will happen when a certain procedure is performed.
2) Perform the procedure.
3) Have students observe the results and try to explain why the results did not conform to their predictions.
4) Explain the discrepant event or provide an activity that will allow students to determine why the results did not meet their expectations.

Example of a Discrepent Event

Mr. Gray showed the class two beakers, each containing 100 mL of a clear liquid. He asked the class what the volume would be if both beakers were emptied into the same container. After discussion, he poured the two liquids into a graduated cylinder and showed the class the volume. The volume was not what the class expected. He then asked the class to determine why. After an appropriate period of time, he asked the class to share their conclusions. Next, Mr. Gray told the students that the liquids were alcohol and water. He allowed time for the students to discuss possible explanations and finally guided them to the correct explanation.

Laboratory Investigation

What is it?

Laboratory investigations involve students in the process of science and help students visualize science concepts.

How to do it

1) Begin the investigation with a question.
2) Focus the investigation on a specific variable related to the question.
3) Develop a hypothesis.
4) Determine how data are going to be measured and collected and how other variables will be controlled.
5) Conduct the investigation.
6) Analyze the data using appropriate mathematical tools.
7) Draw conclusions from the results.
8) Report the results and conclusions of the investigation. Students may present their results using an oral or written presentation.

The Learning Cycle (5E's)

What is it?

The Learning Cycle is a sequence of lessons designed to engage students in exploratory investigations, construct meaning from their findings, propose tentative explanations and solutions, and relate concepts to their own lives. The Learning Cycle is an instructional model consistent with the constructivism theory. Students learn best when they are allowed to construct their own understanding of concepts over time by active engagement in the learning process.

How to do it

Stage 1: Engage the students with an event or question.

Stage 2: Explore the concept, skill, or behavior with hands-on experience related to the lesson.

Stage 3: Explain the concept, skill or behavior and define terms. Students use the terms to explain their exploration.

Stage 4: Elaborate the concept, skill or behavior by applying it to other situations. Students discuss and compare ideas with others.

Stage 5: Evaluate student understanding of the concept.

Example of the Learning Cycle

Mrs. Mundy demonstrated the formation of a cloud in a bottle. She engaged the learner with the event by asking why the cloud formed. Her students experimented to determine how changing variables, such as pressure, humidity, and temperature, affect cloud formation. Next they explained the relationships between pressure, temperature, and humidity in the formation of clouds. She guided the students in applying the concept to cloud formations on earth.

Misconceptions (Assessing and Confronting)

What are they?

Students often hold beliefs that are at odds with commonly accepted scientific thought. These misconceptions should be identified and addressed so that effective learning can take place. Determining what students think prior to instruction enables the teacher to direct meaningful instruction.

How to do it

1) Use probing questions to identify existing beliefs and misconceptions.
2) Ask students to explain their ideas of the concept.
3) Use demonstrations, activities, or computer simulations to correct misconceptions.
4) Help students to make connections with related ideas.

Example of Misconception

To explore misconceptions about volume, Mr. Polinski took two test tubes containing water. He then showed the students two cylinders with the same dimensions but different masses. (One cylinder was made of brass, and one of aluminum.) The students were asked to predict what would happen to the water level when each cylinder was placed in one of the tubes of water. The students discussed their understanding of volume. Many students had the misconception that the water level would be higher in the tube in which the brass cylinder was placed. Students then put a cylinder in each tube and observed the results. Mr. Polinski gave the students further activities to explore this concept. He made use of this foundation to show connections between volume, mass, and density.

Models

What are they?

A model is a simplified representation of a structure or concept. It may be concrete, such as a ball-and-stick model of an atom; or it may be abstract, like a model of weather systems. A model enables students to more easily understand complex ideas.

How to do it

1) The teacher or student determines the concept or structure that is to be modeled.
2) The students research the concept or structure to be modeled.
3) The students construct models.
4) The students explain how their model represents the concept or structure.

Example of a Model

Ms. Brown provided materials for students to build a model of a landfill. The landfill was built in an aquarium tank using soil, gravel, plastic bags, water, and different types of waste. Students shared their landfill models with the class.

Predict, Observe, Explain (POE)

What is it?

The Predict, Observe, Explain (POE) strategy involves showing a class a situation and asking them to predict what will happen when a change is made. POE's can be used to support correct predictions and challenge incorrect predictions. The most important aspect of POE's is identifying and discussing student's concepts.

How to do it

Demonstrate a situation and ask students to predict what will happen when specific changes are made. Students observe what actually happens and discuss differences between their predictions and observations. Students should be encouraged to support their theories with evidence or scientific principles.

Example of POE

To introduce the concept of density, Ms. White drops an apple into a tub of water, then asks the class to predict what will happen when a grape is dropped into the tub of water. Ms. White demonstrates and discussion follows. Students are then asked to predict what will happen if each fruit is cut in half and dropped into the tub of water. Students make predictions and observe the results. A class discussion and student explanations follow. Ms. White uses students' theories to lead into a discussion of density.

Problem Solving

What is it?

One of the highest forms of learning is applying knowledge to solve problems. Problem solving is a method of learning that facilitates scientific thinking. Problem solving allows students to discover relationships that may be completely new to them. Students use previously learned information, skills, and strategies to construct new ideas and concepts. Problem solving can effectively engage students in learning science.

How to do it

1) Describe a problem or have students suggest a real-world problem.
2) Guide students to define the problem by stating it in the form of a question.
3) Discuss the characteristics of the problem and set limits on possible solutions.
4) Research the solutions.
5) Choose a promising solution.
6) Test the solution.
7) Determine if the problem has been solved.

Example of Problem Solving

Ms. Otello presented the class with a packet of seeds and asked, "What kinds of things make it possible for these seeds to germinate?"

The class defined the problem by asking, "What are the conditions under which seeds germinate?" Ms. Otello asked the class to consider the physical conditions that would promote the germination of the seeds. Students gathered information and then planted sets of seeds under different light, water, and temperature conditions.

The students observed and recorded the germination and growth data for all groups of seeds. The students planted a second group of seeds under the conditions they determined were optimal. They compared the percentage and speed of germination with the previous trial. Students analyzed data to determine if the problem had been solved.

"Scientists thrive on curiosity -and so do children."

Science for All Americans

Questioning Techniques

What are they?

Good questions can expand and reinforce knowledge, provide feedback, and focus student attention. A good question is short enough for students to understand and remember, is stated clearly, and requires more than a simple yes or no answer. Questioning can be used to assess student knowledge, motivate, and reinforce. It increases student participation, improves listening skills, and promotes interaction. Questioning can also be used to raise the level of student thinking by linking recently acquired concepts with other related concepts, by applying new knowledge to a new problem, and by encouraging reflective thinking.

How to do it

1) Ask a question.
2) Allow think time. When teachers wait at least three seconds after asking a question, students tend to have longer responses, make more inferences, and compose logical arguments.
3) Select a student and listen to the response.
4) Pause before giving feedback while the teacher and students consider the answer.
5) Give feedback: reinforce, acknowledge, dignify, prompt, clarify, or refocus.

Example of a Questioning Technique

Mr. Nix's class was studying the greenhouse effect. He asked the following questions which addressed various levels of learning.

Recall: What causes the greenhouse effect?

Comprehension: Why does the greenhouse effect occur?

Creative: What if the greenhouse effect were to increase dramatically over the next twenty years?

Evaluation: How do you think the new laws concerning the use of refrigerants in air conditioners will affect the environment?

Reflective Thinking

What is it?

Reflective thinking is a valuable tool to help students assimilate what they have learned. Reflection can help connect concepts to make ideas more meaningful.

How to do it

Below are some suggestions for some reflective thinking activities.

- ❖ Have students write what they have learned in a student journal.
- ❖ Instruct students to write about the success of the lesson, questions they have, or areas they would like to explore further.
- ❖ Have students complete a questionnaire about the lesson.
- ❖ Lead a class discussion about the students' opinions of the lesson.

Example of Reflective Thinking

Ms. Chang asked the students to write down the answers to the following questions,

1) What did you do? What was the topic? Did you understand it?
2) How did you do it? What methods were used in learning? Did you like them?
3) Why did you study this? Can you relate it to your life outside of school? Did it explain something you learned earlier?

Role Playing and Simulation

What are they?

Role playing allows students to assume the identity of another person or thing and helps students understand a different perspective. Simulations involve students in representing the functioning of a system or process. Both role playing and simulations address learning styles and intelligence areas that are often overlooked. These strategies are also especially useful in integrating science, technology, and society (STS) issues into the curriculum.

How to do it

1) Choose a topic to be used in simulation. Examples are available in books, journals, and educational software. Interactive videodiscs can provide good settings and background information.

2) Have students read and gather background information.
3) Assign to each student a defined role.
4) Allow students to work in groups and to decide on their course of action.
5) Present simulations to the class.

Example of Role Playing

Mr. Jabbar was teaching about the states of matter. Students studied about the characteristics of the different states. One group in Mr. Jabbar's class used music to simulate the states of matter. First the group stood still with joined hands thus simulating solids. Next the group turned on some quiet music and began moving slowly and somewhat separated. This simulated a liquid. The group then played music with a faster tempo, started dancing, with some of the group members losing touch with the others. This simulated the movement of gas molecules.

"...this time, like all times, is a very good one, if we but know what to do with it."

~Ralph Waldo Emerson

Assessment for the 21st Century

Science, by its very nature, lends itself to a variety of assessments. Students must develop more than a factual knowledge base in order to become scientifically literate. They need to develop skills and attitudes that are appropriate for critical thinking and problem solving. Given opportunities to use resources, analyze information, and critically evaluate problems and solutions, students will be better prepared for life in the 21st century. In order to assess the students' growth in these areas, diverse assessment strategies should be used.

How and what we assess sends a clear message about what is important. Traditionally, we have almost exclusively valued students' success at retaining and reproducing assigned information within established time limits. Time has been the constant; performance has been the variable. When factual knowledge is emphasized, students may conclude that remembering facts is the goal. When opportunities for improvement are not provided, students may conclude that improvement is not valued. If higher-order thinking, problem solving, and critical thinking are valued, then classroom assessment needs to lend value to them.

Alternative assessments encourage creativity and will allow students to demonstrate knowledge in different ways. An additional advantage in using alternative assessments is that growth can be measured for each student wherever they may be on the learning continuum. Students stretch to reach new levels, competing only with themselves rather than against other students.

"In the course of their careers in the schools today, most students take hundreds, if not thousands of tests...in contrast, when one examines life outside of school, projects emerge as pervasive."

Getting Started in Alternative Assessment

In this chapter you will find brief descriptions and examples of selected alternative assessment techniques. Traditional objective tests are not included since teachers are familiar with them and abundant examples are readily available.

The process of incorporating and using a broader array of assessment methods can:

- sharpen teachers' thinking about the meaning of student success in science,
- improve the quality of instruction that teachers design for students, and
- encourage students to evaluate the quality of their own work.

Changing assessment practices is not a simple linear, lock-step process that all teachers follow in a prescribed manner. Rather, it is a process of becoming more purposeful about:

- ❖ the clarification of goals for student performance,
- ❖ the design of learning experiences in support of these goals,
- ❖ the use of assessment methods that match desired goals, and
- ❖ the use of grading systems that reflect the student's achievement of these goals.

The benefits of exploring a variety of assessment methods lie as much in the conversations they engender between and among teachers and students as they do in the information they provide on student competence. Students as well as teachers often become empowered as assessment becomes a dynamic, interactive conversation about progress using interviews, journals, projects, and portfolios. Through these assessment methods, the teacher relates to students more as a facilitator, coach, or critic rather than as an authority figure who dispenses all information and knowledge.

Hints for Getting Started in Alternative Assessment

- ❖ Share successes with other teachers.
- ❖ Analyze tests used in the past and try to incorporate new assessment strategies.
- ❖ Start a folder of assessment samples from test banks and published articles.
- ❖ Review hands-on activities and develop rubrics that could effectively assess student performance on these tasks.
- ❖ Develop a system for using a variety of assessment data in determining student grades.
- ❖ Identify colleagues who have experience in alternative assessment and use them as resources.

Continuous Quality Assessment

A new movement in student assessment, *Continuous Quality Improvement* (CQI), presents a positive outlook for education and student achievement. Traditional assessment sometimes produces a false record of student achievement. For example, if a student were to earn a series of test grades, such as 30%, 60%, 95% and 100%, the student has apparently improved in mastery of the material. Yet, the average would be 71%. This does not demonstrate that mastery was achieved and would actually be an unsatisfactory grade average.

CQI more truly reflects a student's knowledge base. Its results can be rewarding for students and teachers.

- With a specific set of criteria established prior to the assignment, the student knows what the expectations of success are. The criteria may be designed by both the teacher and student.
- If the criteria are met, the student will then earn a "Q" for Quality; if not, a "NY" for Not Yet Quality.
- The student may repeat the assignment at the instructor's discretion until "Quality" is achieved.
- The student is not penalized for not achieving quality immediately.
- All students have the opportunity to succeed.

How to transfer CQI to traditional grade sheets

A teacher can convert "Q's" and "NY's" to letter grades. The teacher counts the number of assignments and divides them into 100. For example, if a teacher made ten (10) assignments, they would be worth ten points apiece. To weight a major assignment more heavily, assessments in multiple categories may be recorded. A sample format follows:

Research Paper	1 Quality (10 points)
Presentation: Research	1 Quality (10 points)
Presentation: Visual Aid	1 Quality (10 points)
Presentation: Creativity	1 Quality (10 points)
Lab Performance 1	1 Quality (10 points)
Lab Performance 2	1 Quality (10 points)
Discussion	1 Quality (10 points)
Problem-Solving Activities	1 Quality (10 points)
Unit Quiz	1 Quality (10 points)
Journal	1 Quality (10 points)

Compute each assignment as worth 10 points. If quality is achieved, then the total of 10 would be given. If a "NY" is given and never reworked, then 5 points are earned. If the assignment is not done, then a 0 would be earned. A scale of 100 would be used to compute a percentage.

Rubrics

The term *rubric*, rather than scoring key, is used to refer to the guidelines laid out on performance-based tasks. Rubrics spell out in detailed language what learning is expected and the standard for products and performances. Rubrics are designed for reporting results, scoring, and coaching students to a higher level of performance. Furthermore, because rubrics are determined in advance, they provide clarity of focus for students and teachers. Rubrics are also helpful tools in increasing student competencies in the areas of self management, peer assistance, and self evaluation.

When students design their own rubrics, they create a sense of ownership, relevance and commitment, critical factors in creating and maintaining learner motivation.

Developing a Rubric

Building a rubric is an ongoing process. Rethinking, refining, and rewriting are a part of the process. Students, teachers, parents and others can offer valuable insight and objectivity. It is important to have a purpose for the rubric and to be certain that the rubric supports that purpose.

- ❖ Determine which concepts, skills, or performance standards you are assessing.
- ❖ List the concepts and rewrite them into statements which reflect both cognitive and performance components.
- ❖ Identify the most important concepts or skills being assessed in the task.
- ❖ Based on the purpose of your task, determine the number of points to be used for the rubric (example: 4-point scale or 6-point scale).
- ❖ Based on the purpose of your assessment, decide if you will use an analytic rubric or a holistic rubric*.
- ❖ Starting with the desired performance, determine the description for each score remembering to use the importance of each element of the task or performance to determine the score or level of the rubric.
- ❖ Compare student work to the rubric. Record the elements that caused you to assign a given rating to the work.
- ❖ Revise the rubric descriptions based on performance elements reflected by the student work that you did not capture in your draft rubric.

- ❖ Rethink your scale: Does a [ ]-point scale differentiate enough between types of student work to satisfy you?
- ❖ Adjust the scale if necessary. Reassess student work and score it against the developing rubric.

* Analytic rubric vs. Holistic rubric:

Analytic: Assigning separate scores for different traits or dimensions of a student's work. The separate scores should total your predetermined amount.

Holistic: Assigning one overall score based on the combination of performance standards being assessed.

Sample Rubrics to use for Student Products, Projects, and Problem Solving

Does the product reflect that the student made valid inferences from data sources that varied in completeness and quality?

4=The product reflects that the student made valid inferences from data sources that varied in completeness or quality.

3=The product reflects that the student made invalid inferences from data sources that varied in completeness or quality.

2=The product lacks inference from data sources that varied in completeness or quality.

1=The product lacks evidence that the student used data sources.

Does the product show evidence that the student reached valid conclusions based on data analysis and displayed the results of the analysis in appropriate formats (e.g. graphs, charts, tables, pictures and other reprentations)?

4=The product shows evidence that the student reached valid conclusions based on data analysis and displayed the results of the analysis in appropriate formats.

3=The product shows evidence that the student reached valid conclusions based on data analysis and displayed the results of the analysis in inappropriate formats.

"Multiple choice tests have their place, but so do portfolios, observations, performance tests, student interviews, and exhibitions. Once teachers are clear on what they hope to accomplish with their students, choosing appropriate assessment methods follows."

2=The product shows evidence that the student reached conclusions not based on data analysis and displayed the results of the analysis in appropriate formats. OR The product shows evidence that the student reached valid conclusions based on data analysis but lacked evidenceof the analysis.

1=The product shows no evidence of data analysis.

Portfolios

Portfolios refer to the process of assessing student progress by collecting examples of student products. Physically, it is a container of evidence of a student's achievements, competencies, or skills. It is a purposeful collection in the sense that the collection is meant to tell a story about achievement or growth in a particular area. Portfolios represent complex, qualitative, and progressive pictures of student accomplishments.

The use of portfolios, like any assessment method, starts with a consideration of purposes. A properly designed assessment portfolio can serve four important purposes. It allows:

- teachers to assess the growth of students' learning,
- students to keep a record of their achievements and progress,
- teacher and parents to communicate about student work, and/or
- teachers to collaborate with other teachers to reflect on their instructional program.

An essential step for determining what to include in a portfolio is to answer the question: *What should students know and be able to do?* This establishes criteria by which the quality of a task is judged. A portfolio may include, but is not limited to:

- a table of contents,
- a description of the concepts to be mastered,
- artifacts that demonstrate the student's mastery of concepts,
- evidence of self reflection,
- a series of work samples showing growth over time,
- examples of best work,
- assessment information and/or copies of rubrics, and
- progress notes contributed by student and teacher collaboratively.

A portfolio may be as simple as a large expandable file folder in a place that is easily accessible to students and teacher. The location invites student and teacher contributions on an ongoing basis.

It is important for students to review their portfolios to assess what they have achieved. It is in self reflection that the student realizes progress and gains ownership in learning and achievement.

Performance Assessment

Knowledge and understanding are tightly linked to the development of important process skills such as observing, measuring, graphing, writing, and analyzing. The teacher can assess such skill development by observing student performance. Many science teachers have experience with performance assessment through the use of lab practicals.

It is important to note that developing scoring guidelines for performance assessment requires careful analysis of student responses to accurately assess performance levels.

Open-Ended Questions

Open-ended questions are highly compatible with the current emphasis on teaching students to become active complex thinkers and effective communicators.

Open-ended questions can assess a variety of instructional goals, including:

- conceptual understanding,
- application of knowledge via creative writing,
- the use of science process skills, and
- divergent thinking skills.

If open-ended questions are to be included on a test that will be graded, it is important that teachers prepare students for expectations that may be new to them. Student anxiety over open-ended test questions could be reduced by sharing examples of model student responses and providing opportunities for practice.

Grading open-ended questions involves interpreting the quality of the response in terms of some criterion. Several suggestions for rating open-ended questions are offered below.

- Determine in advance the elements expected in an answer.
- Communicate the criteria that will be assessed.
- Read a sampling of answers before assigning grades to get an idea of the range of responses to each question.

Some suggestions for open-ended questions that lead to higher order thinking are listed below.

- What is the relationship between ...?
- How might this principle be applied to ...?
- What are some of the limitations of the data?
- How might this information be used in another area?

Open-Ended Labs

Open-ended labs are exploration activities in which students are responsible for all aspects of the experimental design. (Students must demonstrate sufficient knowledge of content, process and safety procedures before they are permited to proceed in order to ensure a safe and meaningful laboratory experience.) Assessing open-ended labs requires teachers to recognize that not all students will choose to explore the same aspect of a given problem. Students should be able to explain and justify each step of their procedure. Evaluation may be based on:

- reasoning skills,
- the ability to identify the question,
- the experimental design,
- documentation of data,
- drawing conclusions from data, and
- teamwork.

Self Assessment

Student self assessment questionnaires are helpful in determining how students perceive their knowledge, skills, or the quality of their work. When used appropriately, self assessments actively involve students in reflecting on their learning process and emphasize the importance of students' awareness about what they know and what they need to know.

- Teachers may find it helpful to present a science self assessment at the beginning, middle, and end of the school year to monitor student changes in attitudes towards science and their individual successes within a given class.

- Students may be requested to include self assessments as a part of project and portfolio assignments.

- ❖ Groups or teams may be required to evaluate individual and group performance related to teamwork and responsibility and to make recommendations for improving group performance on future projects.

Students can be asked to evaluate their understanding of concepts at any point in the instructional process. A teacher might announce future topics (e.g., carbohydrates, starch, glucose, digestion) and ask students to rate each concept using the following key:

1 = I have never heard of it.
2 = I have heard of it but do not understand it.
3 = I think I understand it partially.
4 = I know and understand it.
5 = I can explain it to a friend.

Such an approach to assessing students' understanding is less threatening than a pre-test and can give students a sense of the different levels of knowledge, particularly if used frequently in a class situation. Results of student ratings of each concept could be tabulated as a class activity, which may promote positive peer interactions and expand learning opportunities.

Peer Assessment

Peer assessment occurs every time students collaborate on assignments, explain their understanding of a topic to another, or ask their neighbor in class how to proceed with a lab experiment. Many times the most valued opinions and assessments are those which students determine with one another.

Peer assessment requires students to put aside any biases toward each other and truly reflect on accomplishments. Procedures and criteria for peer assessment should be developed with the class. By assessing others' work, students often see alternative reasoning patterns and develop an appreciation for the diverse ways of approaching problems. Some advantages of peer assessment are:

- ❖ increased quality of performance,
- ❖ improved cooperative attitudes, and
- ❖ enhanced leadership skills.

Teacher Observation

Some goals and objectives can only be assessed by observation. For example, it is difficult to imagine how a teacher would assess students' team problem-solving skills or success at independent lab work without observing them. The three types of teacher observation are informal, structured and narrative.

Informal Observations

Teachers constantly observe students and make assessments about their performance that influence future instruction. With informal observations, teachers observe with no predetermined focus. The information gathered may be used for parent or student conferences. Informal observations occur daily, and occasionally teachers may want to record information from their observations.

Structured Observations

The components of structured observations include a specified focus and a sample behavior to be observed systematically. The information may be used to show which students need improvement or to give students feedback about how they are improving.

Narratives

Progress on some objectives can be tracked best through narrative records of observed behavior. A narrative is a written record. Such narratives are particularly appropriate for complex behaviors, such as group interactions, which cannot be described effectively with a checklist. For example, a teacher might observe and describe a cooperative team learning activity. Over time, a series of these narratives might demonstrate how students improved in working as a team.

Interviews

In an interview, the teacher questions students individually about learning. A series of probing questions can be developed that are useful in deciding how to help students improve their performance. Many benefits can result from interviews:

- Rapport is encouraged and student motivation may be increased.
- Students who are intimidated by written tests may express what they understand in a less threatening context.
- Interviews provide teachers the opportunity to probe and ask follow-up questions in ways that challenge students to think beyond their current level of understanding and to organize their knowledge in more systematic ways.

Some suggestions for effective interviewing follow:

- Keep the tone of the interview positive and constructive. Remember to avoid giving verbal cues or exhibiting facial expressions that can be interpreted as meaning that an answer is incorrect.
- Let students respond without interruptions and give them time to think before they respond.
- Try to keep interviews short, and focus on relevant questions.

Journals

A journal is a student's record of activities and reflections. Journals are dynamic assessment tools that promote communication between the teacher and student, reflection on what students are learning, and active involvement in classroom activities.

Journals can also be used to assess attitudes toward science. To realize the full potential of the journal, the teacher should probe, challenge, or ask for elaborations about the entries submitted.

Assessment of journals depends on the purpose of the journal and the age of the student. The act of keeping a journal can be considered a goal in itself if a teacher wants the students to structure or feel ownership of their own learning, and the criterion for success of this objective might simply be the completion of the assigned journal entries.

Products and Projects

Products can include models, drawings, stories, videotapes, and any other objects by which students demonstrate what they know. Models and drawings allow students to use tactile skills to represent ideas, feelings, structures, or concepts. Oral and dramatic presentations help students with public speaking skills and reinforce their own knowledge and that of the audience. Whenever possible, other classes, the community, and families could be invited to participate in the presentation.

Projects are assignments that require students to perform more than one type of activity or task. Projects usually result in one or more products, and may include a research paper. Sharing the project with the class or another audience should be encouraged.

The variety of products and projects that students may produce is immense. The following are examples of products and projects.

- Build a model cell.
- Build a model human.
- Establish a classroom zoo.
- Present a favorite scientist in costume.

- Create an interdisciplinary Medieval Fair.
- Gather items for a semester long scavenger hunt (dicot seed, bone from an endotherm, a third class lever, a substance made of only one element, a force-measuring device, a marine arthropod).

Criteria for evaluating products and projects should be established and understood before work begins.

Graphic Organizers

Graphic organizers allow students to organize large amounts of information in a limited space, usually one page. Student-developed graphic organizers can be displayed to show how other students have connected ideas.

Examples of graphic organizers include concept maps, diagrams, word webs, idea balloons, and Vee diagrams.

See page 47 for an example of a concept map.

"A wise question is half of knowledge."

-Lord Bacon

Program Evaluation

Improving science programs is a continuous process that requires regular evaluation of purposes, context, resources, methods, and program goals.

It is important that the success of district science programs be evaluated on a regular, on-going basis. Information should be collected and reviewed within the context of current research and reform criteria. Informal evaluation will take place as part of the day-to-day activity of teaching and learning. Formal program evaluations may include information gathered from the following sources:

- questionnaires,
- interviews,
- school statistics (enrollment in subjects, electives),
- evidence of student performance,
- reports from external evaluators such as the Southern Association of Colleges and Schools.

Systemic change takes time and succeeds only in an environment that permits people to do things differently. Effective school and district science improvement must provide time for implementation, practice, reflection, revision, and renewal.

"To grow is to change, and to become perfect is to have changed many times."

-Newman

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"What we call the beginning
is often the end
And to make an end is to
make a beginning
The end is where we start from."

-T.S. Eliot

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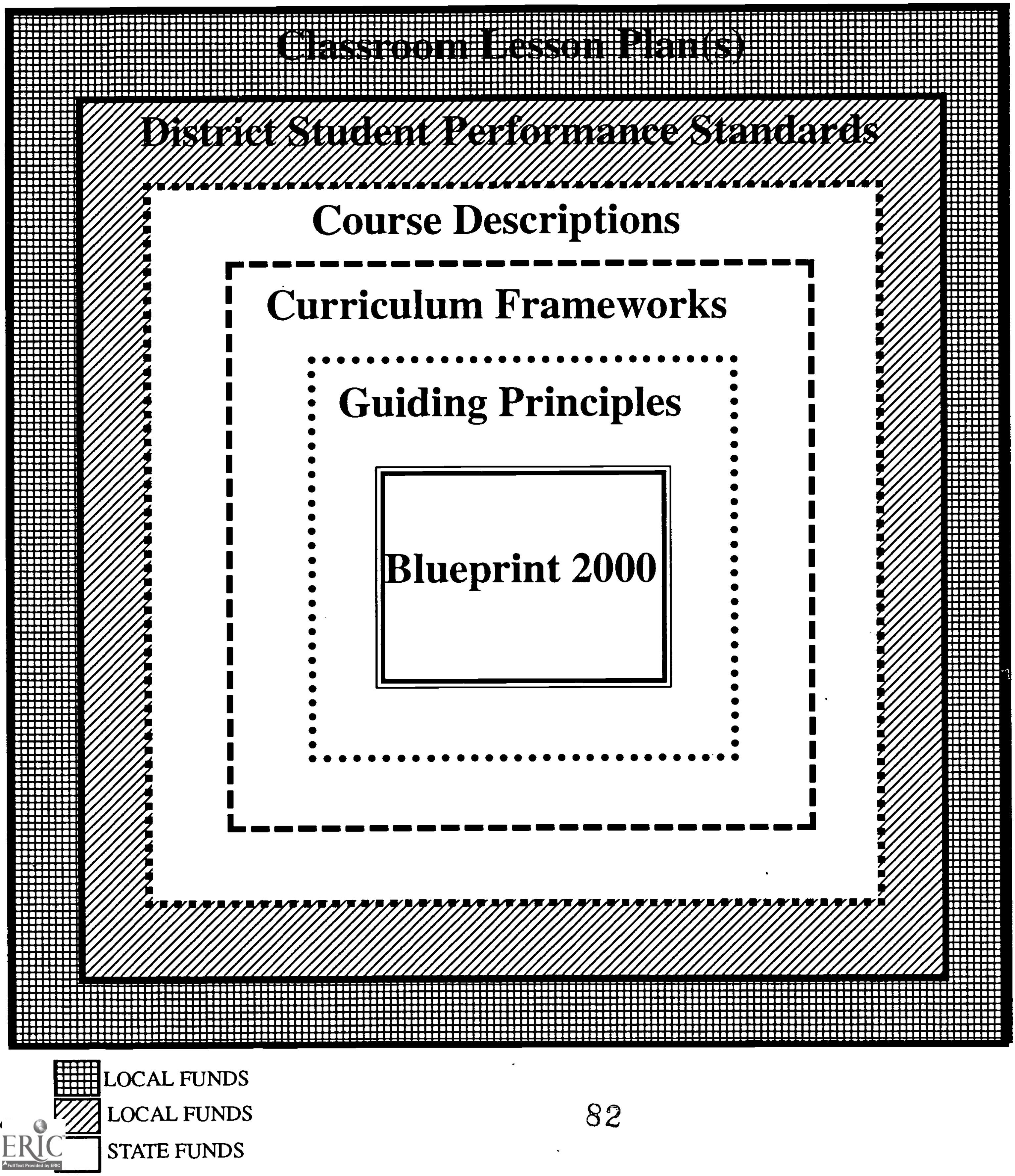

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