Standards-Based Curriculum

Traditionally, the term *curriculum* has been associated exclusively with course content. Recently, however, it has been expanded to encompass not only content but also instructional methods and assessment strategies. The *Louisiana Science Framework* serves as a guide for curriculum and instruction and as a general reference to the basic principles of science assessment.

Content

The *Framework* defines five content strands with benchmarks for each content strand at three levels of education: K-4, 5-8, and 9-12. The standards and benchmarks define what Louisiana graduates should know and be able to do in science. (See Appendix A for a brief description of the Science Content Strands.)

The five content strands are as follows:

- Science as Inquiry
- Physical Science
- Life Science
- Earth and Space Science
- Science and the Environment

The content, or what is learned in each course, should reflect all five strands of the *Framework*.

Instruction

Although a more delineated course content is an important step toward improving school science, improved instruction, or how teachers teach, also plays an important role. Teachers should incorporate a variety of instructional techniques in their classrooms. Instructional strategies must complement content in classroom environments in which

- science tasks engage students' interests and intellect;
- classroom discourse promotes the investigation and growth of scientific ideas;
- technology and other tools and materials are used to pursue scientific investigations; and
- students work individually, in small groups, and as a whole class.

Assessment

Assessment, or how teachers assess student learning in science, is a process through which evidence is gathered about a student's understanding and ability to apply that understanding. If real change in the science curriculum is to take place, the manner in which assessment is conducted will also have to change. Changes in science content and in the way science is taught must be reflected through accompanying changes in assessment. Assessment is an ongoing, dynamic process both diagnostic and prescriptive in nature.

Assessment and instruction must be intertwined so that each supports the other in promoting the development of scientific literacy for all students. Various assessment techniques should be used to evaluate student progress and to assist in making decisions regarding individual student performance. Some of the assessment techniques and activities that can be used include the following:

- Teacher observation
- Oral questioning
- Written tests requiring constructed responses
- Open-ended questions
- Class presentations
- Projects completed individually and collectively
- Journals
- Performance tasks
- Portfolios
- State assessments
- Standardized tests
- Student designed investigations

Introduction: Agriscience II

Agriscience II builds and expands on the knowledge gained in Agriscience II. Laboratory units include animal science, soil science, entomology, plant science, agricultural mechanics, supervised agricultural experiences and agricultural leadership. The course emphasizes reasoning, problem solving, communication, and connections to everyday life.

It is important that teaching strategies meet the needs of students enrolled in this course. Many students will need individual attention and considerable reinforcement. Although basic skills and processes will need to be reviewed, this information should be transmitted through the instruction of new skills and processes. When possible, teachers should use appropriate technology to help students learn, use, and understand science.

One of the goals of this course is to build students' self esteem and confidence in their ability to understand key and pervasive concepts in science. This goal can be met through meaningful real-life applications of the science the students are learning. Teachers should encourage students to use both oral and written communication through such activities as projects, research papers, journals, portfolios, etc.

Students enrolled in Agriscience II may vary significantly in science aptitude and learning styles. It is important for educators to address these difference through a variety of teaching strategies, materials, and activities. Many students will be at the concrete level, requiring use of appropriate hands-on activities.

Correlation of Framework Benchmarks

The authors of this model curriculum guide have correlated curricular planning guides with the Louisiana Science Frameworks. To assist teachers in planning, the authors have correlated the content outline and course outlines that follow to the *Framework*. Parenthetical notation follows each section of the guidelines indicating the correlating benchmarks. See Appendix A for Benchmarks for Grades 9 - 12.

Scientific Literacy for All

Resources for these recommended guidelines were two major works of research in science education, *Project 2061: Science for All Americans, Benchmarks for Science Literacy* (sponsored by the American Association for the Advancement of Science), and *National Science Education Standards* (sponsored by the National Research Council and the National Science Teachers Association).

Central ideas from these documents include the following:

- 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 investigations of science 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 that have the greatest scientific and educational significance. Ideas and thinking skills are promoted rather than specialized vocabulary and memorized procedures.
- Students are prompted to be engaged actively in the design of investigations in which they participate.
- The existing boundaries between traditional disciplines soften, so that emphasis can be placed on the connections among the various disciplines.

The current movement to reform science education differs from the one in the late 1950's and 1960's that followed the launch of Sputnik. This time the focus is on *science for all* rather than science for the education of future scientists. More specifically, discussions associated with science education reform emphasize general scientific literacy with particular attention to those groups, such as ethnic and language minorities and women, previously bypassed by such efforts. Although it is still important to prepare future scientists, there is also a need for the general population to be able to make informed decisions about their personal health, the environment, and other related issues. In order to participate fully in our society, all citizens need to achieve a high level of scientific literacy.

The American Association for the Advancement of Science (AAAS, 1990,1993) defines *scientific literacy* as "being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend on one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes."

Moreover, AAAS advocates the need for schools to focus on quality instruction aimed at the concepts and skills that are essential to science literacy rather than teaching an ever increasing body of science content.

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 all individuals in responsible decision making and enriches their view of the world. *Scientific literacy for all* leads us into the future.

Inquiry-Based Science

Inquiry into authentic questions generated from student experiences is the central strategy for teaching science.

National Science Education Standards, Teaching Strand B, p. 32.

Inquiry-based science teaching derives its meaning not only from a historical perspective but also from newly accepted approaches to science teaching and learning. Historically, inquiry meant many things such as the Socratic Method or Discovery Learning. The problem with the Socratic approach is that Socratic style questions originate from the teacher and are used to guide a student down a path that the teacher has already mapped out, eventually ending in the conclusions the teacher wanted. Discovery learning manifests itself as free-form exploration with little guidance, and students derive the meaning of concepts through exploration and manipulation of materials. While these approaches were certainly worth exploring, they did not promote any improvement on student achievement as judged by standardized test scores. These and other approaches, such as process-oriented curricula, did provide a foundation for a new synthesis of inquiry-based science. Among the many factors that added to and helped create the current view of inquiry were

- the understanding and teaching of the nature of science,
- meaningful learning theory, and
- constructivism.

The National Research Council defines *inquiry* as:

> a set of processes where teachers and students pose questions about the natural world and investigate phenomena; in doing so students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories. Inquiry is a critical component of a science program at all grade levels and in every domain of science, and for designers of curricula and programs. Students will learn science in a way that reflects how science actually works (214).

Further, inquiry-based instruction involves teachers using student-centered approaches that engage their students in pursuing the answers to important questions. Students describe objects and events, ask questions, construct explanations, and test their explanations against each other and current scientific knowledge. Below are characteristics that help define and shape inquiry-based science:

- Students think scientifically.
- Students are engaged in hands-on, minds-on, real-world science.
- Instruction is grounded in authentic problems.
- Collaborations are fostered between students and teachers.
- Connections with society are encouraged.
- The student gains a sense of ownership.

Technology

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 as 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 leaning 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 Roger Wagner's *Hyperstudio*, *Power Point*, *and 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, which is an excellent tool to store huge amounts of visual information, 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 to supplement 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 a 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 programs and have them present them 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 parish, in the nation, or even internationally by networking.
- Administer a survey across political, cultural, and regional boundaries and then analyze the collected data.
- 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 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 the following:

- Digital cameras.
- Satellite downlink systems, which can be purchased for under $4,000 and which allow teachers and students to receive images **directly** from satellites orbiting 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 that may allow physically challenged students better access to computers.
- LCD projectors to be used to project images from the computer screen.
- Smart Boards, which display interactive computer screens.

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

Teaching Strategies

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 most effectively 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. Many factors affect learning, such as student characteristics, teacher characteristics and methods, and the context or learning environment. 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.

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 Intelligences

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. Gardner added Naturalist Intelligence. Relative strengths in these are 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.

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 the following:

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
- Keep time rhythmically to music
- Use rhythm or cadences to remember facts

Spatial Intelligence

- Spend free time engaged in art activities
- Read maps, charts, and diagrams with ease
- Draw accurate representations of people or things
- 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
- 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

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

Naturalistic Intelligence

- Discriminate among living things
- Are sensitive to features of the natural world
- Display strong pattern recognition

STRATEGIES

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 a key to success. The teacher should allow time to adapt and refine strategies to fit the needs of the students.

Concept Mapping

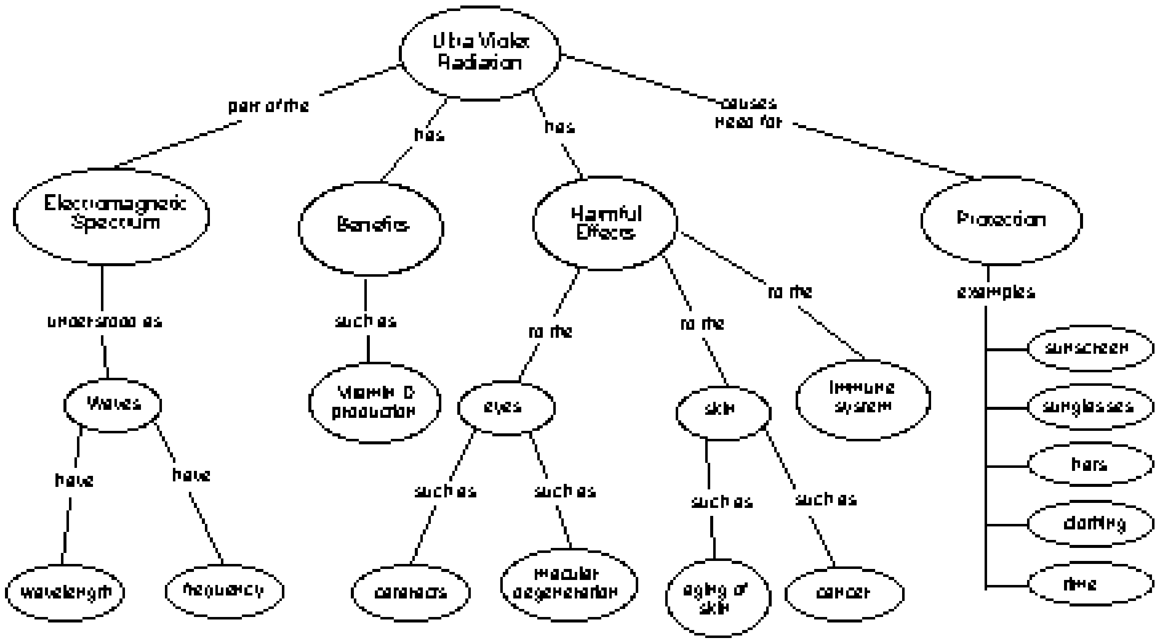
What is it?

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 or 3x5 cards.
3) Rank concepts in related groups from the most general to the most specific.
4) Arrange concepts so that related terms are close to each other.
5) Stick paper clips or cards on a large sheet of paper as soon as you are satisfied with your arrangement.
6) Connect related concepts with lines and add short connecting verbs or phrases.
7) 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) Students debate or discuss the viewpoints generated from research.
3) The teacher should summarize the viewpoints of all groups.

Sample conflicting view point 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 summed the arguments of both sides.

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 that 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.

Sample cooperative learning activity

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 expectation.

Sample discrepant event activity

Mr. Gray showed the class two beakers, each containing 100 mL of 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 work with science concepts.

How to do it
1) Begin the investigation with a question or problem.
2) Focus the investigation on a specific variable related to the question.
3) Develop and write correctly an 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 write or interpret 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 that states that 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 experiences related to the lesson.
Stage 3: Explain the concept, skill or behavior and define the 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.

Sample Learning Cycle activity
Mrs. Mundy demonstrated the formation of a cloud in a bottle. She engaged the learners 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 among 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 a misconception

To explore misconceptions about volume, Mr. Smith 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 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. Smith 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 understand complex ideas more easily.

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 aspects of POE's are identifying and discussing students' misconceptions.

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 activity

To introduce the concept of density, Ms. White drops an apple into a tub of water; then she 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 were cut in half and dropped into the tub of water. Students make predictions and observe the results. A class discussion of student explanations followed. Ms. White uses students' theories to lead into a discussion of density.

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 thinking 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 to allow students time to consider the answer.
5) Ask another student to confirm or add to the answer.
6) 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 to assess 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 limitations on burning coal will affect the environment?

Problem Solving

What is it?
One of the highest forms of learning is applying knowledge to 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 whether the problem has been solved.

Sample of problem–solving activity
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 whether the problem had been solved.

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 in a journal what they have learned.
- 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.

Examples 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 intelligences that are often overlooked. These strategies are also especially useful in integrating science, technology, and society (STS) into the curriculum.

How to do it

1) Choose a topic to be used in a 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 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 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 apart. This activity 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 activity simulated the movement of gas molecules.

Assessment

NSES ASSESSMENT STANDARDS

The National Science Education Assessment Standards provide criteria to judge progress toward the science education vision of literacy for all. The Assessment Standards identify essential characteristics of effective assessment policies, practices, and tasks at all levels. They can be used in preparing evaluations of students, teachers, programs, and policies.

Guiding Principles for Assessment

Assessments should

- be deliberately designed for the decisions they are intended to inform,
- measure both achievement and opportunity to learn,
- clearly relate decisions to data,
- demonstrate fairness in design and use, and
- support their inferences with data

Large-Scale Assessments

The Assessment Standards address the need for systems to reconsider the purpose, data analysis, and sample size in all large-scale assessments. Changes in these items on common standardized tests are already being implemented; and there are indications of changes in the designs used by states, districts, and others who conduct large-scale science assessment.

Classroom Assessments

Teaching and testing, which are integral components of instruction, cannot be separated. As content and teaching strategies become aligned with the Assessment Standards, so must classroom assessments. Teachers who use the Assessment Standards will learn to think differently about what to assess, when to do so, and how best to determine what students are learning. They will consider carefully the students' level of understanding and a variety of alternatives to help their students demonstrate what they know.

LOUISIANA STATE SCIENCE ASSESSMENTS

Standards-Based Assessment Development Plan

Background

State-level assessment should be closely aligned with what is taught in Louisiana classrooms in order to determine what students know. During the past several years, Louisiana teachers have developed content standards in mathematics, science, social studies, English/language arts, the arts, and foreign languages. Over 2,000 Louisiana teachers have been directly involved with this project. Benchmarks, or reference points for judging quality, have been recommended for grade 4, grade 8, and the secondary level. Committees of educators targeted these particular grades in order to align Louisiana's standards with recently developed national standards.

Benchmarks at these levels meet *Improving America's Schools Act* (IASA) requirements and follow the recommendations of the National Association for the Education of Young Children (NAEYC) to eliminate or minimize standardized testing below the third grade. Through the Louisiana Systemic Initiatives Program (LaSIP), the Louisiana Science Framework (with benchmarks at grades 4, 8, and the secondary level) has influenced the preparation of teachers in university preservice programs and summer institutes. In addition, the new content standards and benchmarks are aligned with the grades tested in the National Assessment of Educational Progress (NAEP).

In order to measure students' progress and to complement the content standards, assessment frameworks are now being developed for grades 4, 8, and the secondary level. These assessment frameworks are designed to lead to criterion-referenced tests (CRTs) at complementary grade levels. Throughout the development process, the Department of Education has served as facilitator for the content standards groups. Acting in an advisory Capacity, the Louisiana Educational Assessment Program (LEAP) Testing Commission has been apprised of all developments. *A Teachers' Guide to Statewide Assessment in Science* for grades 4, 8, and 11 is now available.

Recent Legislation

Act 40 of the 1996 First Extraordinary Session reenacted R.S. 17:24.4 and enacted R.S. 17:100.7. Current legislation, R.S. 17:24(F)(2) specifies norm-referenced testing (NRT) at grades 3, 5, 6, and at the secondary level in grade 9. Current legislation, R.S. 17:24:4(F)(1)(C) and (D), specifies that criterion-referenced tests (CRTs) be administered at grades 4 and 8, and the secondary level in grades 10 and 11.

Policy Implications

Benchmarks for achievement of content standards have been established at grades 4 and 8, and at the secondary level. For criterion–referenced tests (CRTs) to align with the newly developed content standards, assessment instruments should correspond with these grade levels.

Currently, criterion-referenced testing takes place at grades 4 and 8 and at the secondary level at grades 10 and 11. In order to align assessment with content standards, the State Board of Elementary and Secondary Education (SBESE) has approved the following assessment plan and schedule.

Standards-Based Assessment Grade Configuration

Under the SBESE-approved assessment plan, CRTs have moved to grades 4, 8, and the secondary level; NRTs have moved to grades 3, 5, 6, 7, and 9 as shown.

Assessment	**Grade Levels**						
CRT		4				8	Graduation Exit Exam (10, 11)
NRT	3		5	6	7		Secondary Level (9)

CLASSROOM ASSESSMENT AND EVALUATION

(Excerpted from American Association of Physics Teachers'
Powell Ideas in Physical Science, 1996)

What is the difference between assessment and evaluation?

Assessment is gathering information about students' knowledge, skills, abilities, and attitudes. Assessment may take many forms, such as tests, problem sets, essays, term papers, journals, laboratory exercises, demonstrations, projects, presentations, extended investigations, interviews, concept maps, and portfolios. Use of computers and other technological tools may be an integral part of producing and recording the results of assessment activities. Evaluation is making judgments based on the information gathered. Assessment and evaluation are pivotal elements of teaching.

When should assessment and evaluation take place?

If teaching is viewed as synonymous with lecturing, then assessment and evaluation are seen as intrusive, taking away time from teaching. However, when teaching involves facilitating learner-centered activities, then teaching, assessment, and evaluation all blend together and enhance each other. All three are part of interesting and challenging activities related to important themes in the curriculum. Assessment and evaluation should be conducted before, during, and after each instructional unit.

What do assessment and evaluation involve?

Not only teachers, but also students should engage in assessment and evaluation because acquiring the requisite abilities and habits are a critical part of becoming a life-long learner.

By having students participate in assessment and evaluation, a teacher can focus on the more substantive aspects of these tasks rather than be overly concerned with record keeping and simplistic inferences. Students can help construct tests for the class, can provide feedback to peers, and can respond on self-assessment sheets.

For evaluations to be more than opinions, they must be grounded in valid and reliable assessment tools. Performance assessment measures (which elicit from students the behaviors targeted in curriculum goals) should be used more than objective tests (which elicit from students the behavior of choosing the correct response to multiple choice, true/false, and matching questions).

To reduce rewards for memorization and routine skills and to increase rewards for critical thinking and complex problem solving, the schools should see that students have access to books, calculators, and other sources of information during test taking and other assessment activities.

Assessment should be as **authentic** as possible (given in complex and realistic rather than fragmented and contrived contexts). Authenticity needs to be considered for many facets of assessment including **task difficulty, stimuli, spontaneity**, and **consequences**. In authentic assessment, some locus of control rests with the student being assessed. Scoring criteria should be related to behaviors essential to success, not to behaviors easily counted or observed. Some assessment measures that allow for multiple correct responses or products should be used so students do not acquire the misconception that science questions, debates, and controversies always have one right answer. Not all assessment should be done on an individual basis; instead, some assessment should be done for cooperative learning groups of students.

Behaviors assessed should be a representative sample of all the goal behaviors. Any ability consistently slighted during assessment may come to be regarded by students as unimportant. Assessment should draw on the strengths of a range of learning styles. Evaluation should be fair to all groups of students, with no biases due to characteristics like gender or race.

How are assessment and evaluation reported?

A teacher's assessment and evaluation should be reported to his/her students in a clear and meaningful way. Criterion-referenced assessment instruments are often better than norm-referenced ones for providing feedback. Labeling students with letter grades is not sufficient. Students should acquire a detailed picture of what they do know, rather than being overwhelmed by a summary of what they do not know. Through activities designed for assessment and through judgment of their results, a teacher should help students direct their energies productively. The result of good assessment and evaluation should be an increase in students' motivation to learn.

TYPES OF ASSESSMENT

Journals

A journal is a collection of student writings bound together to record the student's ideas over a period of time. The selections need not be long. Even one-half page is sufficient. However, writings should be produced on a regular schedule, whether during every class period or once a week. Each passage should be dated.

Length, content requirements, and any other criteria should be made explicit to students. It is inadvisable to use a complex scoring rubric for journals because that would focus students' attention on pleasing the instructor rather than on recording their own thoughts. The same amount of credit may be given for each acceptable passage, without further delineation of merit. Rewarding effort and commitment is more important in journa1 writing than rewarding recall of facts.

Ideally, the instructor will respond to each student's comments each time a passage is written. This response might simply be a few words of praise or caution next to the relevant section in a student's journal. It might be a note requesting the student to see the instructor for extra help. It might be a paragraph explaining a concept discussed in class. If short of time, the instructor could read a random sample of journals each day, making sure all students' journals are read at reasonable intervals.

As an alternative approach, journal entries may be private with certain passages chosen for sharing with the instructor. For this approach, students may write in class or at home. Whatever approach is used, procedures need to be clear to all students in advance.

The instructor must keep confidential whatever students share in their journals. Instructor's comments should be specific and honest. In addition, the instructor, recognizing students' sensitivities, should not make hurtful remarks. Anxious students should be given reassurance and encouragement as part of the instructor's comments to them. Students for whom English is a second language should not be berated for writing less fluently than others. Sexist and racist remarks are to be avoided conscientiously. Students need both positive and negative comments, but the balance should favor the positive ones. This approach will increase students' motivation to participate and to learn.

Instructors need to build students' trust. No one should be penalized through grading or humiliated for expressing ideas in the initial stages of learning about a topic. Students should not get upset with themselves for writing down thoughts they later want to change. Learning must be viewed developmentally, not seen as a task completed.

In their journals, relating present knowledge to prior understanding is to be encouraged as evidence of growth. Also, students may record successes in learning, ask questions about material not mastered, request an appointment to get help outside of class, give preferences for topics, comment on classroom interactions, and evaluate classroom activities. Students should periodically make affective responses, such as expressing their frustrations and satisfactions with studying science.

Requiring students to put their thoughts in writing makes apparent any gaps in their thinking. By reading students' journals, the instructor can detect misconceptions and naive ideas that are held by the students. (Without this kind of feedback, it is difficult for the instructor to imagine what is in the minds of students.) Based on their expressed beliefs and understandings, class activities may be structured to help students move toward more scientifically acceptable ideas. Journals used in this manner are excellent formative evaluation tools to improve courses.

Besides being valuable for assessment, journal writing is a powerful catalyst for thinking. Journal writing can give students practice with both inductive and deductive thinking. Writing helps clarify and organize one's thinking. Writing can even create ideas that did not exist before the writing began. Also, journals give students opportunities to apply concepts to practical, everyday situations. Journal writing improves the ability to use scientific words appropriately, focuses attention on the most important concepts, and improves recall of generalizations. Journal entries are tangible records of once amorphous concepts. In this way, journals aid understanding, preserve insight, and bring order to confusion. Students are empowered when they perceive how much they know and what they need to learn.

Sample Journal Prompts

- Summarize what you learned today.
- The large (completely filled) helium balloon that you saw in class today floated in air. Why doesn't the small (partially filled) helium balloon that you saw in class today also float in air? What happens when water boils?
- How well prepared did you feel for today's lesson?

Concept Maps

One of the goals of assessment is to gain insight into students' understanding of conceptual linkages. Concept maps, as first developed by D. Bob Gowin and Joseph D. Novak, are diagrams indicating perceived hierarchical relationships among concepts in an activity, an investigation, or a unit.

Each student should draw his/her own concept maps, rather than being provided with maps prepared by the instructor. An exception to this rule may be made when an instructor shows an example of how a concept map is constructed before suggesting or requiring that students construct maps on other topics. The instructor may give one word or several related words to start students on an assigned concept map. Minimum competency is shown by using all the words supplied by the instructor with all the obvious connections written by the student. More understanding is shown by a student who adds appropriate words and forms creative connections in his/her concept map.

There is no one right way to draw a concept map for a particular topic. Concepts maps reveal the propositions (two or more words used to represent concepts along with words connecting these concepts) held by students. Concept maps allow teachers and learners to recognize that some linkages may be inappropriate or missing, a situation that suggests the need for more learning. Creating one's own schema through concept maps facilitates conceptual change.

Interviews

An interview is a structured conversation between the teacher and one or more students for the purpose of establishing what students think. A record of an interview is made with written notes, audio tape, or videotape.

A planned sequence of questions should be used with impromptu follow-up questions inserted as the situation warrants because of inconsistencies or obscure points in the students' thinking. A variety of questions–such as those that ask for predictions, descriptions, or explanations–should be used. A balance of closed and open questions most quickly puts students at ease. Simple and difficult should be alternated to keep students talking. Questions should not allow students simply to agree with the interviewer, but should elicit richer answers.

During an interview, students may be asked to draw pictures, diagrams, graphs, or concept maps. They may also be asked to classify pictures. Three-dimensional models or other hands-on materials may be provided for students' use. No matter what the task, students should explain their reasoning orally. Drawing, pointing, and manipulating objects all supplement and complement (but do not replace) oral responses.

The interviewer needs to develop and maintain the students' confidence by being friendly and relaxed. Students should be told that their perspective is important to the interviewer. Waiting time must be generous enough (20 to 30 seconds long) to encourage thoughtful responses. However, embarrassing silences should be avoided. The interviewer should rephrase a question when a student is hesitant to answer. Yet even the most skillful interviewing cannot make an articulate student out of a taciturn one. A student's right to refuse to answer must be respected with patience, empathy, and kindness.

Understanding is needed, also, when students express doubt about their own statements. Students should be given ample opportunities to justify, explain, and elaborate upon their previous answers. Interrupting a student is never appropriate. Mastery of a generalization may be checked by asking the students to apply it to common situations. The interviewer must listen carefully, pondering the students' responses and formulating follow-up questions to clarify points not made clear initially by the students. Students' terminology, rather than formal scientific terminology, should be used in follow-up questions. A student response may be repeated exactly by the interviewer, if necessary, to confirm what was said; but a response should not be interpreted and rephrased. The interviewer should explore with sensitivity any unanticipated response and any possible misinterpretations of questions asked. If the interviewer doubts the stability or authenticity of an answer, the question that elicited that answer should be asked again later in the interview with some minor changes. As the interview progresses, the interviewer needs to remember all responses made in order to spot contradictions. Questions should be asked to lead students toward an awareness of their own inconsistencies and to give them a chance to sort out what they really believe about natural phenomena.

The interviewer should refrain from teaching during the interview. Any instructional interventions needed should occur in a different setting on a later day. During an interview, feedback to the students should be kept to a minimum so as not to cue responses to acceptable scientific thinking. The interviewer should monitor carefully body language, facial expressions, tone of voice, and oral statements that might indicate student answers are correct or incorrect. The strength of interviews is that they can provide a detailed assessment of a student's thinking and also can measure a student's confidence in his or her own ideas. Interviewers can distinguish between parroting of information and responding with deep meaning. Interviewers can determine whether a student lacks understanding of a concept or whether a student understands the concept but has labeled it with nonstandard terminology. Interviewers can ascertain whether a student holds isolated ideas or whether a student has made complex connections between ideas.

Interviews are very useful in evaluating instructional activities. Interviews may also be used to diagnose a particular student's difficulties learning physical science. Although interviews are time consuming for the interviewer, the amount of information gathered justifies their use.

Sample Interview Questions

- Look at these pictures of birds. Why do they have such different shaped beaks?
- In what ways could you classify these household chemicals?
- Why can you see an image of yourself in a mirror?

Questions

Assessment, whether in conventional or alternative forms, should give evidence of students' notions about phenomena studied and should provide insight into students' logic for analyzing the world around them. Distracters for multiple-choice questions should offer choices that fit frameworks often used by naive students. The answer that is counted as correct should make sense only in the context of scientifically acceptable frameworks. Likewise, free response and other types of questions should detect whether students are holding on to old ideas or moving toward the powerful ideas presented in the units studied. Questions constructed in this manner may be used for diagnostic purposes as well as for formative and summative evaluation.

Questions should ask about concepts discussed or skills developed in the units studied. Higher-order thinking should be required rather than memorization. Opened book and/or opened notes during testing are one method to eliminate the need for memorization. The best questions not only elicit correct answers, but also elicit reasoning for students to arrive at their own answers.

Open-ended questions have several avenues of access and more than one correct answer. They are excellent for generating higher-level thinking. Simply allowing students to supply answers, rather than identify answers, does not make questions open ended. If nearly identical answers are the only ones counted correct, then the question is free response (also called open response), but not open ended.

Questions may take many forms, each with its own set of advantages and disadvantages. Over reliance on one type of question should be avoided. Judicious use of several types of questions can give more information about the knowledge and reasoning of various types of learners.

Practical laboratory questions ask students to perform for assessment purposes the manipulation of physical objects (the same as or similar to those already used during class sessions). In addition, the instructor may expect students to apply processes and concepts to new situations. In that case, the instructor may want to provide more apparatuses than are necessary to answer the question.

That method tests whether students can choose an appropriate apparatus. Allowing students to request additional supplies and apparatuses increases their creativity. Making diagrams and drawings should be encouraged. The instructor may want students to work together or alone for this hands-on work. Sometimes, these exercises are called performance assessment. Scoring can give points for the extent of science knowledge, sophistication of laboratory procedure, and ratio of systematic to random problem-solving approaches.

Demonstration questions are another effective way to learn whether students can apply concepts Demonstrations used during tests should be based on the same concepts that students developed during class work. An instructor should seldom speak during a demonstration performed as part of a test. Upon a student's request, the demonstration should be repeated to ensure that everyone has an adequate chance to see the phenomena. Students should be instructed to write down both observations and inferences. As with practical questions, making diagrams and drawings should be encouraged. Detailed observations with few inferences should correspond to a passing grade. Students should earn higher grades for more numerous and complex inferences. Demonstration questions are valuable for testing ability to communicate concepts and their interconnections.

Completion questions should be written so that only one important word or phrase completes the sentence given. Deletions should be limited to the central thought of the sentence and should be placed near the end of the sentence. Lower-level thinking is all that is required to answer most completion questions.

A **multiple-choice question** consists of a stem in the form of a question or an incomplete sentence followed by several choices, one of which is correct. The other choices are called distracters, or foils, or decoys. All the choices should be grammatically correct and logically consistent when combined with the stem. All questions should be similar in length, parallel in construction, and equally precise in expression. Keyed responses (the correct choices) should be equally frequent at all response positions. If possible, a logical sequence should be followed in placement of the choices for a particular stem. One example of this sequencing is placing numerical choices in ascending order. For any multiple-choice question, the choices must be mutually exclusive and unambiguous. Avoid using "more than one of the above," "all of the above," and "none of the above" as choices for answers.

Distracters should contain commonly believed misinformation or widely-used erroneous conclusions. Although the distracters must appear plausible to a student with a vague or incomplete understanding of the topic studied, those same distracters must appear obviously wrong to a student with an adequate comprehension of that topic. After a question has been used in a course, the instructor can tally the number of students choosing each option. Distracters chosen by few or no students should be subsequently replaced. The difficulty of a question can be increased by making the choices more numerically or semantically similar. Multiple-choice questions can be improved by requesting that students give the reasons for their choices. The knowledge of a fact, application of a principle, solution to a problem, and interpretation of a situation can all be tested with multiple-choice questions.

Because *true-false* items must be judged unequivocally, they tend to test trivia. Sometimes students are required to correct any statement he/she marks false. This method does not increase the amount of knowledge tested because students may simply insert the word "not" into each false statement. Another limitation for true-false items is that guessing can result in a high proportion of correct answers. Scores may be calculated as the number of correct responses minus the number of incorrect responses, but this formula does not totally eliminate the effects of guessing. If true-false questions are used, a disproportionate number of either true or false statements should be avoided. Quantitative expressions should be used instead of qualitative expressions like "few," "large," and "cold." Do not use double negatives. Compound sentences that are partly true and partly false are not appropriate true-false items. For complex sentences, the main clause should be true so that the subordinate clause determines the truth or falsity of the entire sentence.

Portfolios

A *portfolio* is a collection of student work that records the student's efforts, progress, plans, insight, and achievement. A student should participate in the selection and organization of documents for the portfolio, following guidelines stated by the instructor (for example, particular categories of evidence required). Portfolios are rich in detail about a student's learning. What is seen as important learning is more encompassing in portfolios than in narrow forms of assessment such as objective tests. Therefore, assessment with portfolios is appropriate for all types of learners.

Instructors find portfolios useful in evaluating the course they teach and in helping both instructors and students identify and meet instructional goals. Before they begin to assemble their portfolios, students should know the criteria that will be used to judge the merit of their efforts. Criteria may address the following aspects of portfolios:

- amount of evidence included
- level of organization used
- quality of the pieces selected
- variety in the learning substantiated
- amount of growth in knowledge documented
- connections between topics made

- increase in skills established
- changes in attitudes displayed
- creativity shown in compiling
- depth of the reflection statements written.

Portfolios may begin with a goal statement written by the instructor, whole class, or individual students. Each document put into a portfolio should be labeled with the date it was produced. For group work, all members of the group should be listed on the document. If it is not obvious what the document is, a caption should be provided.

Essential elements of portfolios are the reflections written by students. Each document in the portfolio should be accompanied by a statement as to why the document was chosen for inclusion. Students should reflect upon how they produced a document and what knowledge and skills they developed while producing it.

They should comment on salient characteristics of the document, aspects that changed as they produced the document, and things they would still like to modify in the document. Students may suggest logical extensions of the work they did to produce the document, possibly with a timeline for accomplishing that supplemental work.

Selecting documents and writing reflection statements are valuable instruction activities besides being assessment activities. Students practice higher-order thinking like analysis, synthesis, and evaluation. Self-assessment is a valuable skill throughout one's lifetime. A prime advantage of portfolios is that they give the students responsibility for their own learning. Portfolios motivate and empower students by making them aware of how much they have accomplished. Portfolios assist students in identifying for themselves which practices improve performance.

Evidence in portfolios may be classified into four categories. *Artifacts* are samples of usual work such as laboratory reports. *Reproductions*, like a list of books read, capture situations that are not permanent. *Attestations* are commendations by someone other than the student compiling the portfolio and include letters of gratitude, prizes, and acknowledgments of individual efforts in group activities. *Productions*, including the reflection statements, are prepared especially for the portfolio.

Inserting between five and seven documents into a portfolio usually provides enough evidence for the instructor to feel confident in making a judgment about how well a student has met the goals of the course. A student who chooses too many documents for inclusion into a portfolio does not show ability to discriminate. Students should ask themselves, "What additional knowledge, skill, or attitude will I have evidence of by including this piece in my portfolio?" If they cannot supply a concrete answer to this question, then they should omit the document.

Portfolios may be organized in a number of ways. Documents may be put in chronological order, grouped by content themes, or organized by learning schemes. Another option is to order documents from strongest evidence of learning to weakest evidence or vice versa.

Portfolios may vary in their focus also. Some are a record of best work, some are a record of a project from beginning to end, some are a record of work in progress, and some are a record of personal favorites. Whatever its focus, a portfolio should portray the student's learning as an adventure that highlights the student's successes along the way and helps the student prioritize his or her efforts on the path ahead.

Group Assessment and Evaluation

Group assessment involves a teacher's determining the performance level of a small group of two to six students completing a short assignment, an extended project, or a test. Groups consisting of three to four individuals seem to work best. Usually the same number of points, the same grade, or the same descriptor is earned by each member of a group.

Group assessment cannot happen when students are working individually and/or competing with one another. Interaction and communication are restricted when any student views work with others as a waste of time or believes the group effort will lower his/her own norm-referenced grade by raising others' grades.

In cooperative situations, students perceive that they can reach their learning goals if, and only if, the other students in their group succeed also.

Cooperative learning involves more than students sitting at a table together and/or sharing laboratory equipment. David W. Johnson and Roger T. Johnson have determined that the following five elements are essential for a cooperative group lesson: positive interdependence, face-to-face interaction, individual accountability, small group and interpersonal skills, and evaluating group effectiveness. Robert E. Slovene has formulated cooperative methods around team rewards, individual accountability, and equal opportunities for success.

Several assessment methods work well with cooperative groups. Observations of students interacting as they work through activities can give much information about their reasoning skills, problem-solving abilities, and metacognitive strategies. Group processes may also be observed: for example, speaking unambiguously, asking appropriate questions, listening carefully, synthesizing information, identifying points of disagreement and facilitating their resolution. **Checklists** and **rating scales** may be used to systematize observations. Grading one activity or laboratory report per group is another useful assessment method. Each student may be required to produce his/her own report before working on the group report. An instructor may grade group reports more thoroughly and/or in less time than individual reports.

A third method is **oral tests**. After the entire group has prepared, the instructor may choose a student at random to answer a question about the topic being studied. Other students in that group may be chosen for other questions. All members of the group either pass or don't pass the oral test together.

Closed book and written tests are a fourth method of group assessment. They may be given individually with students keeping one copy of their answers and turning the other copy in to the instructor. Then a small group of students will go over their answers together and agree on one revised set of answers that is turned in for additional credit. The reverse procedure is fine also, with the group test given first and the individual test following. In either order, the individual test may be closed book and the group test may be opened book if that combination fits the instructor's objectives for students' learning.

A potential problem with group assessment is that an ambitious or talented student may take on a very large portion of the group's task and then resent other group members who made lesser contributions but received the same amount of credit. The students who neglected their responsibilities may develop cynicism toward a system that rewards them in spite of lack of effort. Another problematic situation occurs when a student with strong leadership skills overwhelms the rest of the group with his/her ideas, even though other members of the group have more extensive science backgrounds or more developed intellectual capacities. The instructor should monitor all groups and intervene if these situations start to develop. Each student may be required to sign a statement that he/she individually accomplished the learning outcomes for a group task. Each may also have to attest to his/her belief that all other members of the group have successfully completed the assignment. These statements should be supplied by the instructor. Varying them periodically helps keep students from signing the statements automatically.

Students may be allowed to turn in a minority report if they cannot reach consensus within their group. When this situation occurs the instructor should help the group change its style of working together to avoid frequent minority reports.

Group assessment has many positive features. The intellectual discussion and disagreement that occur during group assessment stimulate meaningful learning, cognitive reasoning, divergent thinking, creativity, and long-term retention. Students have chances to get immediate feedback on their ideas; social skills are practiced and improved during group assessments. Because working cooperatively with classmates is very satisfying to most students, the ratio of intrinsic rewards to extrinsic rewards is higher for group assessment tasks than for individual assessment tasks.

BOOKS ON ASSESSMENT

Raizen, Senta A., Joan B. Baron, Audry B. Champagne, et al. *Assessment in Elementary School Science Education*. National Center for Improving Science Education. Colorado Springs: NETWORK, Inc. 1989. 149 pp.

Price: $18. 00 Available from NCISE.

This report is one of three that served as the basis for a national program of science education for American elementary school children; it discusses the assessment component of the plan in depth. Chapters discuss issues in assessment such as how to test what matters, what and how to assess, how to assess program features, and how to improve assessments.

Elizabeth Meng and Rodney Doran. *Improving Instruction and Learning through Evaluation: Elementary School Science*. Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education, 1993. 182 pp.

Price: $16.75 Available through ERIC

Designed to help teachers and supervisors expand and improve their assessment efforts, the book addresses different reasons for assessing science learning and discusses the kinds of information that can be gathered. Advantages and disadvantages of different methods—written tests, practical tests, observations, interviews–are presented. The book also gives tips on how to develop assessment instruments.

George Hein, Ed. *The Assessment of Hands-On Elementary Science Programs*. North Dakota Study Group on Evaluation, 1990. 300 pp.

Price: $17.00 Available from the National Science Teachers Association,
1 (800) 722-NSTA

This book explains how to assess the results, values, and success of science activities. Chapters address assessment theory, large-scale assessments, assessment in science education research and development, and new assessment approaches.

National Science Teachers Association *Guidelines for Self-Assessment*, Revised ed. NSTA: 1989.

Available from NSTA	*Call 1(800) 722-NSTA*
Elementary Programs (#PBOOSX 1)	$16.50/pkg
Middle/Junior High Programs (#PBOOSX2)	$16.50/pkg
High School Programs (#PBOOSX4)	$16.50/pkg

Designed to meet the needs of schools and school districts that desire to evaluate their science programs periodically, this book includes matrices are included for hand tallying and scoring and 30 computer-scannable for assessments that involve large numbers of participants. Use the guidelines to analyze program strengths and weaknesses and to lay the foundation for the best possible science education design for a school or community. Electric Scoring Service is available.

Edward D. Brikon and Senta A. Raizen, Eds. *Examining the Examinations*. The National Center for Improving Science Education, Washington, DC. 1996. 320 pp.

Price: $79.95 (lSBN-0-7923-9692-8)

A study of the required advanced science and mathematics examinations taken by university-bound students in seven countries, this research examines the topics covered, the types of questions used, and the performances expected from students. The international comparisons offer a window on science education and its assessment in seven countries.

Robert J. Marzano, Debra Pickering, and Jay McTighe. *Assessing Student Outcomes: Performance Assessment Using the Dimensions of Learning Model*. Association for Supervision and Curriculum Development (ASCD). Boulder, CO: McREL Institute, 1993. 137pp.

Price:$13.95 (ISBN0-87120-225-5) Order from ASCD, Stock # 611-93179, Telephone (703) 549-9110

The Dimensions of Learning Model is based on the premise that five types of thinking are essential to the learning process. The authors have used this instructional model to develop a practical approach to student assessment that answers many of the recent demands for reform in this area. The book provides valuable guidelines for constructing performance tasks and developing rubrics for assessing performance. Numerous rubrics that can be adapted for classroom use are included.

George E. Hein and Sabra Price. *Active Assessment for Active Science: A Guide for Elementary School Teachers*. Portsmouth, NH: Heinemann, 1994. 155 pp.

Price: $18.00 (ISBN0435-08361-9)

This guide is designed for teachers who develop their own assessments for hands-on science. It includes chapters on different forms of assessment, on managing assessment in the classroom, on scoring, on ways that national curriculum developers grapple with and formulate assessments, and on the relationship between assessments and educational values. Numerous classroom examples of assessments and student work are given.

Diane Hart. *Authentic Assessment*. Menlo Park, CA: Addison Wesley, Inc. 1994. 120 pp.

Available from NSTA
Price: $16.20

Call 1 (8001 722-NSTA
Publication # OP282X

This book provides a clear overview of assessment for grades 3-12, including making time for assessment; tailoring assessments to desired outcomes; scoring and evaluating student performance; and other topics such as scoring rubrics, mastery, portfolios, etc. Examples are included from many subjects and grade levels.

Assessing Science Laboratory Process Skills at the Elementary and Middle/Junior High Levels. New York, NY: Teachers College, Columbia University, 1990. 204 pp.

Available from NSTA
Price: $13.00

Call I (800) 722-NSTA
Publication # MS046X5

This volume includes the instrument used in the Second EA Science Study and the results of the testing.

National Center for Improving Science Education. *Assessment in Science Education: The Middle Years*. Colorado Springs, CO: NETWORK, Inc. 1990

Price and ordering information available from NCI SE.

This book focuses on strategies for assessing the science understandings and skills of students in the middle grades.

Gerald Kulm and Shirley Malcolm, Eds. *Science Assessment in the Service of Reform*. Washington, DC: American Association for the Advancement of Science (AAAS), 1991. 400 pp.

Available from AAAS, 1333 H St., Washington, DC, 20005
AAAS publication # 91-335 (ISBN-87168~26-5)

This compendium of 30 papers, written by experts in the fields of science assessment and curriculum, covers all aspects of science assessment. Broad topics include policy issues, science assessment, science assessment and curricular reform, science assessment in service of instruction, and examples from the field. It is an invaluable resource and reference.

Safety

The wide ranges of experiences that students will encounter when engaging in science lessons may put them at risk. Beyond following guidelines and position statements by professional organizations teachers need to assess the risk associated with any activity. There are several good books and journal articles about laboratory safety. However, a great deal of science teaching occurs in other locations such as the outdoors, including a class garden, greenhouse, nature trail, or field trip. For these examples, the teacher should assess risk by considering poisonous plants, stinging insects, and the use of chemicals such as fertilizer, herbicides, and pesticides. Prudent teachers will also incorporate safety considerations into their written lesson plans. In today's litigious society, safety monitoring and safety plans should be as much a part of science teaching as performance objectives and assessment.

Laboratory Safety

The National Council of State Science Supervisors has established a written position on laboratory safety. The Council supports the premise that science should be taught in a space specifically dedicated to science classes with provisions for laboratory activities.
A safe and well–equipped preparation and work space for students and teacher must be provided. Adequate storage space for equipment and supplies, including a separate storage area for potentially dangerous materials, must be provided. Adequate budget for the facilities, equipment, supplies, and proper waste management must be provided to support the laboratory experiences. They must be maintained and updated on a regular basis. Unique science supplies must be provided in sufficient quantity that students have a direct, hands-on experience.

The number of students assigned to each laboratory class should not exceed 24. Students must have immediate access to the teacher in order to provide a safe, effective learning environment.

Training in laboratory safety must be provided to the teacher. Necessary safety equipment, such as safety goggles, fire extinguishers, fire blankets, fume hoods, and eye washes must be provided and maintained.

Eye Protective Devices

LOUISIANA LAW

17:2114: Furnishing protective glasses or goggles

Any student using in the course of his studies any device dangerous or hazardous to the eyes– such as welding equipment, acid or abrasives, or any other dangerous devices–shall be furnished with and shall wear safety or protective glasses or goggles made of a material suitable to protect eyes from such hazards.

Eye protection devices must to be worn in courses including, but not limited to, vocational or industrial arts shops or laboratories, and chemistry, physics, or combined chemistry-physics laboratories at any time when the individual is engaged in or observing an activity or is engaged in the use of hazardous substances likely to cause injury to the eyes.

Hazardous substances likely to cause physical injury to the eyes include materials that are flammable, toxic, corrosive to living tissues, irritating, strongly sensitizing, radioactive, or that generate pressure through heat, decomposition, or other means. Activity or the use of hazardous substances likely to cause injury to the eyes includes, but is not necessarily limited to, working with hot liquids or solids or chemicals that are flammable, toxic, corrosive to living tissues, irritating, strongly sensitizing, radioactive, or that generate pressure through heat, decomposition, or other means.

Eye protective devices should be industrial quality eye protective devices that meet the standards of the American National Standards Institute for "practice for Occupational and Educational Eye and Face Protection" (1968), and subsequent standards that are adopted by the American National Standards Institute for "practice for Occupational and Educational Eye and Face Protection."

(Adapted from the *Science Framework for California Public Schools*, *1990*. The above recommendations are consistent with Louisiana law regarding the use of protective eyewear.)

CHECKLIST FOR SAFETY IN THE SCIENCE CLASSROOM

Grades 9 - 12

_____ Document safety procedures in lesson plans (for your own safety)
- for liability reasons
- for emergency response procedures

_____ Safety contracts are on file for each student.

- Check the teacher's edition of textbook or other resource materials for an example.
- See the attached example.
- All laboratory activities will be conducted with teacher supervision.

I. CLASSROOM ACTIVITIES

Classroom Materials

- The following materials must be NON-TOXIC:

_____ Glue

_____ Play-dough

_____ Crayons/marking pens

- Equipment used must not have sharp edges.

_____ Rulers (They should have rounded corners.)

_____ Scissors (Use safety scissors.)

_____ Other materials

- Equipment must NOT be made of glass: use plastic or non-glass materials.

_____ Hand Lenses

_____ Containers

_____ Microscope Slides

Scientific Equipment in the Classroom

_____ Microscopes (Do not use sunlight as a light source.)

_____ Telescopes (Do not look at the sun.)

_____ Computers, Television, VCR (They should be properly housed and positioned AND never moved by students.)

_____ Hot Plates (Use only under the teacher's supervision.)

_____ Alcohol Burners

- Use ethanol as the fuel.
- Use in a well-ventilated room.
- Use only under the teacher's supervision.
- Fire extinguishers MUST be available; KNOW where they are located.

Safety Equipment

_____ Fire Extinguishers

_____ First Aid Kits **(BE AWARE OF YOUR SCHOOL'S POLICY ON FIRST AID.)**

_____ Use appropriate eye protection when applicable.

Use of Animals in the Classroom

_____ Teach students about the organism being used.

_____ Supervise student use of animals, organisms, aquariums, etc.

_____ Train students in the proper care of the organism.

_____ Have proper literature and information about handling and the care of organisms.

CAUTION: BECAUSE OF LIABILITY AND HEALTH CONCERNS, DO NOT ALLOW STUDENTS TO TAKE LIVING ORGANISMS INTO THE CLASSROOM.

II. FIELD TRIP SAFETY

_____ Investigate site for safety concerns (telephone call, visit, literature).

- Document any safety concerns and the procedures by which they will be addressed.

_____ Discuss field trip safety procedures with the students prior to the trip.

_____ Prepare and send permission slips home for parent/guardian signature.
- Specify the date, time of departure, time of return, emergency information.
- Use the parish/school field trip form, if available.

_____ Secure sufficient adult supervision (1 adult to 5 students).

_____ Use the buddy system. (Pair the students.)

_____ Have an emergency contingency plan.
- Take a cell phone or two way communication device.
- Take a list of telephone numbers of the school, 911, etc.
- Take a first aid kit.
- Be aware of special needs of students (physical, medical, etc.).
- Establish a chain of command in the event the teacher becomes unavailable.

III. GENERIC SAFETY PLAN

_____ Keep the safety plan well displayed:
- telephone numbers
- emergency evacuation routes
- emergency procedures
- location of safety equipment.