Inquiry Labs:
What Science Lab Activities Should Look Like

An Adaptation of the Illinois Learning Standard's Applications of Learning
By Carl J. Wenning (9/22/03)

INQUIRY LABS
Through the inquiry form of laboratory activities students will deepen their understanding of basic content knowledge, intellectual skills, and processes of experimental science. Lab activities should provide avenues for inspiration and discovery, and not merely reinforce the learning of the classroom. There are several fundamental skills that any physics laboratory should be expected to develop and enhance:

- Recognizing and investigating problems; formulating and proposing solutions supported by reason and evidence.

- Developing a scientific methodology to solve an identified scientific problem; conducting the experiment using standard scientific practices.

- Expressing and interpreting information and ideas in concise language and using statistics as appropriate.

- Using appropriate instruments, electronic equipment, computers and networks to access information, process ideas and communicate results.

- Learning and contributing productively as individuals and as members of groups.

- Recognizing and applying connections of important information and ideas within and among learning areas.

IDENTIFYING PROBLEMS
Asking appropriate questions and seeking reasonable answers are at the heart of all scientific inquiry. Following the initial steps of inquiry (inductive reasoning), students will learn how to develop hypotheses. In the process, they learn and apply scientific principles. They also learn to be objective in deciding whether their solutions meet specifications and perform as desired.

DEVISING AND CONDUCTING EXPERIMENTS
Identified problems must be solved by appropriate scientific means – identification and management of pertinent variables with a logical analysis of the outcomes. This includes identification of dependent, independent, and extraneous variables; variable control; data collection and analysis, including statistics; review and understand their findings, and compare their solutions with those of others.

COMMUNICATING
Scientists must carefully describe their methods and results to a variety of audiences,

including other scientists. This requires precise and complete descriptions and the presentation of conclusions supported by evidence. Young science students develop the powers of observation and description. Older students gain the ability to organize and study data, to determine its meaning, to translate their findings into clear understandable language and to compare their results with those of other investigators.

USING TECHNOLOGY
Technology is invented and improved by the use of scientific principles. In turn, scientists depend on technology in performing experiments, analyzing data and communicating the results. Science students learn to use a range of technologies: instruments, computer hardware and software, on-line services and equipment, primary source data and images, and communication networks. They learn how technology, in turn, is the result of a scientific design process that includes continual refinements and improvements.

WORKING ON TEAMS
The practical application of science requires both individual and group efforts. Individuals bring unique insight and focus to the work of inquiry and problem solving. Working in groups, scientists pose questions, share hypotheses, divide their experimental efforts, and share data and results. Science students have the opportunity to work both ways—as individuals and as members of teams organized to conduct complex investigations and solve problems.

MAKING CONNECTIONS
Science has many disciplines, all interrelated. Understanding the functioning of living things depends on knowing chemistry; understanding chemistry depends on knowing physics. In the same way, science itself is highly dependent on mathematics—and it also relates strongly to medicine, geography, physical development and health, social trends and issues, and many other topics. Science, at its best, provides knowledge and skills that improve the understanding of virtually all subjects.

Enhanced Science Process Skills

An additional reflection by Carl J Wenning
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Science educators generally have identified two variously named categories of scientific intellectual process skills to be developed though appropriate educational practices. While variously named, I'll use rudimentary skills and integrated skills to define this distinction. Rudimentary skills are typically those to be developed by younger children in, say, elementary and middle school. Integrated skills are typically those to be fostered in middle school and high school. Regardless of these definitions and distinctions, all of these scientific intellectual process skills are probably developed at even the high school level, and people continue to develop them throughout thief life times. Here is how some have chosen to list these science process skills (see for example *Science Process Skills:*

Assessing Hands-On Student Performance, written by Karen L. Ostlund, Addison-Wesley Publishing Company, Inc. 1992; and *Learning and Assessing Science Process Skills,* Rezba, R J., Sprague, C. & Fiel, R. Debuque, IA: Kendall'Hunt Publishing Co. 4th edition, 2003; see Anton E. Lawson's characterization in *Science Teaching and the Development of Thinking,* Belmont, CA: Wadsworth Publishing Co., 1995).

Rudimentary Science Process Skills	**Integrated Science Process Skills**
• *Observing* • *Communicating* • *Classifying* • *Measuring Metrically* • *Inferring* • *Predicting* • *Decision Making 1* and according to some: • *Estimating* • *Collecting Data*	• *Identifying Variables* • *Constructing a Table of Data* • *Constructing a Graph* • *Describing Relationships Between Variables* • *Acquiring and Processing Data* • *Analyzing Investigations* • *Constructing Hypotheses* • *Defining Variables Operationally* • *Designing Investigations* • *Experimenting* • *Decision Making 2* and according to some: • *Developing Models* • *Controlling Variables*

Enhanced Science Process Skills

While most of the science reform movement literature has focused on these skills, it seems that more advanced scientific thinking skills are being overlooked. Clearly, if students are to be more critical thinkers, they probably should possess what I propose calling the skills of inquiry Enhanced Science Process Skills. Enhanced process skills are those skills that represent the end-goal of an inquiry-oriented education. They include:

- *Solving complex, real-world problems:* Helping students to solve complex problems must be the fundamental reason of why we educate out students in the sciences and other disciplines.

- *Establishing empirical laws:* Student can, by collecting and graphically depicting and interpreting data, establish basic empirical laws.

- *Synthesizing theoretical explanations:* While not essentially different from hypothesizing, providing theoretical explanations is done at a substantially more advanced level. It is fundamentally a synthesis of scientific knowledge, intellectual processes, and mathematics to answer questions that might not be so readily determined via experimentation. For instance, it is hard to evaluate the basis of buoyancy. While students can readily determine the empirical relationship for buoyancy, $B = \rho Vg$, they reason that the buoyant force exists is not readily determined. Theoretical consideration of the possibility of differences between downward pressure at the top of a submersed object and the upward pressure at the bottom of a submersed object, if examined mathematically, can be shown to be the most likely cause of buoyancy. Why the weight of a teacup increases when a tea bag is held suspended in the water, is also an example of providing theoretical explanations.

- *Analyzing and evaluating scientific arguments:* Includes breaking down arguments into their constituent parts, determining the accuracy of scientific statements, evaluating data and conclusions drawn from that data, etc.

- *Constructing logical proofs:* Closely related to analysis and evaluation of scientific arguments, this process flows in the reverse: developing complex arguments from their simpler parts, making scientifically accurate statements, interpreting and drawing conclusions from data, etc.

- *Generating principles through the process of induction:* Inductive processes are generally conceived of as moving from specific observations to their generalization in the statement of principles. Most closely associated with induction is the generation of general principles derived from observations of specific cases.

- *Generating predictions through the process of deduction:* Deductive processes are generally conceived of as moving from general statements of principle to predictions of the specific.

Science teachers employing inquiry practices will want to do more than focus entirely upon the students' ability to derive principles and laws. Science is much more than this, and a variety of activities should be included in the school curriculum to help students develop these enhanced inquiry skills.

In the end—what labs should not be like…