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ABSTRACT

Whether for use in a special methods course in teaching chemistry or a general methods course in teaching science, this guidebook is designed to assist the methods instructor in the task of fitting the ChemSource materials into the established patterns of the course. Each of three sections contains a number of units that accommodate the patterns of most methods courses. Each unit contains an introduction to the topic; some organization and implementation strategies; the identification of specific module/episode locations from the ChemSource materials; and useful resources. Unit topics include: (1) philosophy of instruction; (2) instructional objectives; (3) daily lesson planning; (4) longterm planning; (5) management, motivation, and self esteem; (6) beginning the activity, lesson, or unit; (7) ending the activity, lesson, or unit; (8) models and analogies; (9) demonstrations; (10) questioning; (11) pacing instruction; (12) peer learning; (13) laboratory learning; (14) safety; (15) problem solving; (16) educational technology; (17) contemporary issues and decision making; (18) assessment; and (19) professional development. Appendices include an example of a course syllabus for a science methods course, and sample student assignments. (LZ)

# GuideBook to Pre-Service Use of ChemSource

**Version 1.0 1994**



ChemSource

*Instructional Resources for Preservice and Inservice Chemistry Teachers*

GUIDE BOOK



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# GuideBook to Pre-Service Use of ChemSource

## Version 1.0 1994

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# GuideBook

## *Table of Contents*

# Preface

Over the past several years, two sets of ChemSource materials, SourceBook modules and SourceView videotapes, have been developed, reviewed, tested, and shaped for final distribution. The ChemSource materials represent an array of linked products designed to provide chemistry teachers with quality support to enhance their effectiveness in the classroom.

SourceBook is a resource containing the collected wisdom of experienced chemistry teachers from around the country. SourceView consists of over five hours of videotapes of exemplary and simulated poor chemistry instruction at the high school level. Both sets of materials promote excellence in chemistry teaching and learning at various levels of instruction. ChemSource materials were especially designed for high school chemistry teachers in their first three years of teaching or science teachers from other disciplines who are teaching chemistry for the first time. These materials are also an excellent resource for the prospective chemistry teacher.

However, the skills for effective teaching of science are not unique to any discipline. The context of ChemSource is chemistry, but the SourceBook modules and SourceView videotape episodes offer to the science methods instructor a set of materials that can be utilized to develop effective teaching skills for all preservice teachers of science. In particular, the SourceView videotapes and accompanying written materials provide a series of information rich "cases" for prospective teachers to analyze from multiple perspectives. Through the use of these materials, novice teachers can be taught to pick-up clues and signals given off by experienced teachers to further their own development.

Whether for use in a special methods course in teaching chemistry or a general methods course in teaching science, this GuideBook to Preservice Use of ChemSource is designed to assist you, the methods instructor, in the task of fitting these materials into the established patterns of your course. The GuideBook is a resource for the methods teacher in conjunction with the use of the ChemSource materials.

The main body of the GuideBook is divided into three sections; Where are we going?, How do we get there?, and How do we know we have arrived? Each section contains a number of units that "fit-into" the patterns of most methods courses. Each unit contains:

A. an introduction to the topic,

B. some organization and implementation strategies,

C. the identification of specific module/episode locations from the SourceView and SourceBook materials,

D. useful references.

For each unit, videotaped episodes from the SourceView materials have been identified that would contribute most to your students' development. Other activities have been chosen from among the four SourceBook modules recommended for use with preservice teachers. While each section contains more activities than those that might be used in a methods course, a minimal set of activities is suggested by those contain a * by the activity.

In the Appendices of the GuideBook you will find the Teacher Resources section, which includes the introduction to each unit reprinted for use as a student handout, an example of a course syllabus for a science methods course, and sample student assignments.

What is important to remember that the GuideBook units are suggestions for you to consider as you see fit. These units were written by experienced chemistry teachers and methods instructors as stimulus materials for use in your course.

Generally the GuideBook will refer only to four SourceBook modules. They are (ACID) for Acids and Bases; (ROCK) for The Chemistry of Rocks, Minerals, and Gems; (ENZY) for Enzymes: Biochemical Catalysts; and (MOLE) for The Mole. There are many additional content modules in the SourceBook with valuable information. The (ACID) module was chosen because all the videotaped episodes deal with this module. The (MOLE) module was chosen for its illustration of problem solving techniques. The other modules were selected to appeal to non-chemistry majors taking your course.

The four modules cannot be obtained separately, but permission can be obtained for photo duplication of these modules in classroom quantities.

A number of other SourceBook modules are referred to for your use. These consist of four categories: Basic Modules in which chemical principles involved are developed and organized; Descriptive Modules in which the properties and behavior of elements and compounds are described and related to the fundamental chemical principles; Enrichment/Applied Modules where chemistry as a human activity is examined; and Teacher Resources. For a complete listing of the modules, refer to pages 4 and 5 of the SourceBook User's Guide (USER).

An important resource is the SourceView User's Guide containing episode outlines, questions and answers relating to each episode, teaching skill overviews and inventories, and time codes of teaching skill video segments. All the videotaped episodes contain a time code that is referred to in the GuideBook and SourceView User's Guide for easy reference.

Some other important conventions are used in the GuideBook. A methods teacher is identified by the term instructor, whereas a classroom teacher is referred to as teacher. Methods students are identified as either students, or preservice teachers. Precollege students are referred to as either students, or high school students.

This GuideBook is not meant to be an all inclusive methods textbook, but an additional resource of content material, model teacher behavior, and specific activities for preservice teachers. Some topics of a general nature are covered in several units. For example, constructivist approaches are covered in Units 6 (Beginning the Activity, Lesson ,or Unit), 10 (Questioning), and 11 (Pacing Instruction). Important considerations not addressed directly in the GuideBook are awareness of gender equity, teaching disabled students, and preservice student teaching.

# Finding Your Way Around SourceBook

Since SourceBook is a comprehensive collection of a very large amount of information, it is a good idea to become familiar with the User's Guide (USER) and Chemical Pedagogy (PEDA) modules in Volume 1. The User's Guide module will help you make good use of SourceBook. The Chemical Pedagogy module provides an overview of teaching and learning of high school chemistry and a survey of the research on teaching chemistry. Volume 4 also has an exhaustive set of indices and cross-references:

Cross-Referencing of Modules (CROS)
Index of Chemicals (INDC)
Index of Demonstrations (INDD)
Index of Experiments (INDE)
Media Index (INDM)
Index of Names (INDN)
Subject Index (INDS)

## Module Format

SourceBook Modules have tables of contents. Each module is organized according to the same format, as described in detail in the SourceBook User's Guide module (USER) in Volume 1 and summarized below.

### Topic Overview

Content in a Nutshell (introduction)
Place in the Curriculum
Central Concepts
Related Concepts
Related Skills
Performance Skills

### Concept/Skill Development

Laboratory Activities (includes student and teacher versions)
Demonstrations (purpose, materials, safety notes, procedures)
Group and Discussion Activities (questions, examples, analogies, metaphors)
Tips for the Teacher (language and misconceptions)
History
Humor
Media (films, videos, and software)

### Links and Connections

Within Chemistry
Between Chemistry and Other Disciplines
To the Contemporary World

### References

### Appendix (transparency masters and ancillary materials)

### Extensions and Projects (included at the end of some modules)

# Acknowledgments


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# Where Are We Going

## Unit 1: Philosophy of Instruction

### Introduction

*"What am I going to teach?"* and *"How am I going to do it?"* are two questions foremost in teachers' minds. The decisions teachers make with regard to these two questions are influenced by the philosophy of instruction they possess at that moment. All teachers have a viewpoint about the nature of science, the nature of teaching and learning, the nature of students, the goals and directions of science education, and what is a good teaching style. Points of view about these and other issues go into making up a teacher's individual philosophy of instruction. A teacher's philosophy may or may not change with experience and exposure to other forms of learning.

Beginning or preservice teachers bring a philosophy of instruction to the methods course. This philosophy has been built as a result of all their previous experiences in science courses throughout their academic careers. They have viewed models of teaching and learning, experienced science as a learner, have formulated views about what they believe is important to accomplish, identified teaching styles they think are effective, and pinpointed what they wish to avoid in teaching. Most often, this initial philosophy of preservice teachers is amorphous or ill defined because they have never been put into positions where they were forced to "think-it-through".

In general, preservice teachers have experienced science taught in a lecture/recitation format in which learning knowledge for the next level was important. Laboratory experiences were of a verification variety. Learning consisted of rote memorization. The nature of science that was experienced presented an image of science as a collection of facts, principles, laws and algorithms to be applied. The view of science as a process of inquiring into the world was not experienced. Learning how science can meet personal, societal, and career needs was lacking. These and a variety of other concerns go into making up a view about a modern philosophy of instruction of science teaching.

The concern of science educators is to invite preservice teachers to construct or reconstruct a philosophy of instruction that incorporates a modern view about what is the nature of science, the goals and directions of science education, the nature of teaching and learning, and the nature of students. The initial construction of this philosophy must occur early in the methods course and will continue throughout the balance of the methods course. These *GuideBook* materials are designed to assist with the development of a philosophy of instruction among preservice teachers.

### Organization/Implementation Strategies

Because preservice teachers enter your course with an initial philosophy, you might begin the reconstruction process as part of your beginning course activities. Your students can be challenged to view teaching episodes from a number of perspectives. Several activities suggested below will provide opportunities for developing new perspectives that can be further refined over the balance of the course of instruction.

The strategy suggested below is to contrast two videotaped episodes of teachers introducing the topic of acids and bases. One episode is a simulated poor lesson. The other episode is a high quality lesson that begins with an activity. By contrasting these two episodes with questions suggested below, each episode can be viewed from a certain perspective. Learning how to view a teaching episode from multiple perspectives will invite re-examination of one's own viewpoints about what is important in science teaching.

**Teaching suggestions:**

*1. Show Episodes 1 and 2 from *SourceView*. 'th whole class discussion or small group activity, consider the following questions:

   a. Which lesson was most effective and why?

   b. What was the nature of science being portrayed by each episode?

   c. What was the view of how science should be taught and learned in each episode?

   d. What was the role of the students in each episode?

   e. Which episode fostered the development of positive attitudes about science?

   f. How would you characterize how boys and girls responded in each episode?

   g. Consider other questions from *SourceView* Episode Questions for Episodes 1 and 2.

*2. Show *SourceView*. Episode 21. With whole class discussion or small group activity, consider the follow questions:

   a. What view about the nature of science is being presented in this episode?

   b. How would you compare this teacher's style with others you have seen?

   c. Consider other questions from *SourceView* Episode Questions for Episode 21

3. Ask the students to project themselves into the teacher's role in the episodes they have observed. In which of the episodes would they feel more comfortable? Why? This discussion might conclude with a written assignment in which the students do a self-assessment of their strengths, weaknesses, things that they feel comfortable doing and things that they do not enjoy.

4. At the beginning of the course, have students create their own philosophy of instruction including their beliefs about the goals and directions of science education, the nature of science teaching and learning, and how students will benefit from their teaching. At the end of the course, have students submit a revision of their philosophies and compare both versions.

5. Have students write an autobiography of their experiences as a student in science courses, citing the best and worst of what they have experienced.

## Identification of Specific Module/Episode Locations

SV(Episode 1) 00:00:00-00:19:30. Simulated Poor Lesson: Beginning, conducting, ending.

SV(Episode Questions), pp. 27-28, for Episode 1.

SV(Episode 2) 00:20:00-00:30:40. Expert Lesson: Beginning the Unit: Using an activity.

SV(Episode Questions), pp. 28-29, for Episode 2.

SV(Episode 21) 04:38:10-04:54:30. Post-Lab: Titration with unexpected results (looking for the nature of science is portrayed by this teacher).

SV(Episode Questions), pp. 47-48, for Episode 21.

SV(Overview), p. 116, Awareness of Rote vs. Real Learning.

SV (Overview), p. 128, Nature of Science.

## References

Collette, A.T., & Chiappetta, E.L. (1994). Directions and goals of science teaching. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 3-27). Columbus, OH: Merrill.

Collette, A.T., & Chiappetta, E.L. (1994). The nature of science and science teaching. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 29-43). Columbus, OH: Merrill.

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Trowbridge, L.T., & Bybee, R.W. (1990). Beginning your instructional theory. *Becoming a secondary school science teacher* (5th ed.). (pp. 23-42). Columbus, OH: Merrill.

# Unit 2: Instructional Objectives

## Introduction

"If you're not sure where you're going, you're liable to end up someplace else–and not even know it"! (Mager, 1962) The science teacher must have a clear understanding of the objectives of the science classes being taught. Students must also know what is expected of them, and have some knowledge of how to achieve the objectives.

It is customary to group instructional objectives in three categories–cognitive, psychomotor, and affective. Cognitive objectives refer to knowledge, information and understandings. These objectives have received primary attention in traditional science teaching. Psychomotor objectives are those that emphasize skills of movement, muscular coordination, hand and eye coordination, balance, and the tactile senses. Affective objectives pertain to attitudes, feelings, interests, appreciations, and values.

Effective science teaching should give attention to all of the above objectives. Students bring to their classes their whole being, encompassing all aspects of learning. The teacher must consider all aspects of their education as well.

When considering objectives for science teaching, several criteria can be used for their selection:

a. They should be understandable for all parties concerned–students, teachers, administrators and parents.

b. They should be relatively few in number, but comprehensive for any lesson, unit, or program.

c. They should be challenging but attainable by teachers and students.

d. They should be relevant and appropriate for the subject being taught.

## Organization/Implementation Strategies

*1. Have each student select one *SourceBook* module of interest to him/her and scrutinize the objectives given at the beginning of the module. Which are teacher objectives? Which are student objectives? Which objectives, if achieved, may result in changed behavior in the affective domain?

2. Assign your preservice teachers an exercise in which they rate a list of objectives as excellent, good, fair, and poor according to their own criteria and then discuss why they rated the objectives as they did. You can also ask students to evaluate objectives as found in science programs or textbooks, and answer a series of questions relating to them. [See Trowbridge and Bybee (1990), pp. 156-57 for a related series of questions.]

*3. Have students examine *SourceView* Episode 1 and Episode 16, which are examples of poor and good teaching, respectively with the assigned task of identifying the teaching objectives, at both student and teacher levels. Which objectives are cognitive? Which objectives are psychomotor? Which deal with the affective domain? What is the teacher's purpose in emphasizing each of the objectives identified?

4. Understanding of the importance of clear objectives can be advanced by having students prepare a lesson, identify one or two objectives followed by a teaching presentation in which a direct effort toward achieving the objectives is carried out. You may wish to require selection of psychomotor or affective objectives rather than cognitive types to emphasize the need to focus directly on their achievement rather than leaving their accomplishment to chance.

5. Make available to your preservice teachers the lists of general and specific science teaching skills found in the *SourceView* User's Guide, pp. 84-141. Have them scrutinize these skills and prepare cognitive, psychomotor and affective objectives which represent the outcomes expected for students in their classes. This assignment could be followed by viewing selected videotapes to assess whether the objectives were successfully addressed and achieved in the classes viewed. Discussion of the difficulties of translating objectives into achieved results would be a useful culminating activity.

6. Your role in educating preservice teachers to the need and value of clearly

expressed objectives is to model the formulation of objectives of the methods class you are teaching. Discussion and explication of *your* objectives for the course might be followed by discussion of the specific objectives you hold for the students in your class. The importance of having clear and varied objectives might be emphasized by viewing several *SourceView* episodes in which clear objectives may be lacking, *e.g.*, Episode 15.

## Identification of Specific Module/Episode Locations

All *SourceBook* content modules have excellent lists of performance objectives for students in science classes e.g., SB(ROCK), p.5.

SV(USER), pp. 84-141. This lists science teaching skills in two categories, general and specific. Each of these gives helpful information for teachers identifying content, psychomotor, and affective objectives suitable for science classes.

SB(USER), pp. 10-12. This is an outline of subject matter and strategies for reaching today's objectives in the *SourceBook* module, "Acids and Bases," when the module is used as a primary resource. Ten strategies are listed with suggestions for use.

SB(USER), pp. 12-14. This is an outline of subject matter and strategies for reaching today's objectives for teachers and students in the *SourceBook* module, "Acids and Bases," when the module is used as a secondary resource. Ten strategies are explicated with suggestions for teacher usage in the classroom.

## References

Collette, A.T. & Chiappetta, E.L. (1994). Constructing instructional objectives. *Science instruction in the middle and secondary schools.* (3rd ed.). (pp. 371-374). Columbus, OH: Merrill.

Hassard, J. (1992). Categorize outcomes: cognitions, affects, and skills. *Minds on science: middle and secondary school methods.* (pp. 306-11). New York, NY: HarperCollins.

Mager, R.F. (1962). *Preparing instructional objectives.* Palo Alto, CA: Fearon.

Trowbridge, L.W. & Bybee, R.W. (1990). The goals of science teaching, ( pp. 133-39), and The objectives of science teaching, (pp. 145-55). *Becoming a secondary school science teacher* (5th ed.). Columbus, OH: Merrill.

# How Do We Get There

## UNIT 3: DAILY LESSON PLANNING

### Introduction

Instruction in lesson planning in a methods class in science is important for many reasons. One practical reason is that many school districts require it. They must be prepared to give direction to a substitute teacher if the need arises. They wish to insure that the curriculum objectives are being met when the regular teacher is not there.

Beginning science teachers find daily lesson planning to be an essential component of good instruction. It assists in classroom management and organization. Teachers must think through the kinds of potential problems that might arise and prepare some preventive strategies. Good plans will provide a measure of confidence for the beginning teacher. Two elements of teaching are of primary concern for new teachers. One is having enough plans and materials to insure a full class period and another is managing the class so as to minimize discipline problems. Thoughtfully prepared daily lesson plans can help to alleviate the new teacher's concerns on both of these elements.

Well prepared lesson plans can help meet instructional goals and objectives, both for the teacher and the students. They provide organization and focus for the class period. They provide a solid basis for evaluation and assessment of content, process, and attitude objectives.

A lesson plan should provide for two or three varied activities within the class period to maintain high motivation and interest. An effective lesson plan will clarify what the objectives are for each activity and insure that all needed materials are available. In addition the lesson plan provides a record of what transpires in the class and gives a basis for necessary modifications for future classes.

The *SourceBook* and *SourceView* materials provide several examples of daily lesson plans for specific topics. [See *SourceBook* module (USER), pp 10-12] These examples can be useful in developing lesson plans. It is important to recognize that lesson planning is broader than just preparing a written plan. Much preliminary thought is needed to identify objectives, organize the plan, determine how you will know if the objectives were met, and gather necessary materials.

### Organization/Implementation Strategies

It is important to model lesson planning and teaching that exemplify desirable practice in science classes for the future teachers in the class. The maxim that "teachers teach as they were taught" is a valid one. Prospective teachers should witness a variety of teaching methods that highlight student activity and participation, rather than merely passively listening to large-group instruction.

Because of the importance of daily lesson planning, it is critical that students in the science methods course have a vested interest in the development of good plans and become proficient in preparing them. To do this, it is suggested that they see examples of effective and ineffective lesson plans and the resulting classroom atmosphere of each. Several *SourceView* episodes provide examples of classroom situations resulting from good and poor lesson planning. The *SourceBook* module entitled (USER), pp. 9-15, shows examples of daily lesson plans that make use of *SourceBook* materials.

*1. Students should develop their own daily lesson plan and microteach, or teach a portion of a lesson using it. As a basis for these activities, they might be instructed to develop a plan using a *SourceBook* module e.g., (ROCK). This module could be used to develop a lesson on crystallization, followed by a class presentation in which all or part of the lesson planning was exemplified and critiqued. The follow-up could be a small group activity with evaluation of the planning and teaching being the main focus. Overall effectiveness as a teaching tool should be the primary consideration for a good lesson plan.

*2. As a culminating activity, students might view *SourceView* episodes to compare and contrast results of effective and ineffective lesson planning. Suggested episodes are Episode 2 (shows effective planning), and Episode 15 (shows a lack of adequate laboratory planning). This could be followed by discussion of the good and poor features of each situation.

3. After perusing several ineffective and effective lesson plans, students, in small groups, might try to answer the questions, "How would the classroom atmosphere differ under each plan?", "What would be the differences in strategies used in fulfilling each plan?", and "If you were a substitute teacher with a choice between two plans, what reasons would you give for your preference?"

4. Provide frequent opportunities for students to practice the requisite skills for lesson planning and teaching. Classroom organization and management, pacing of instruction, questioning, acquisition and usage of teaching materials, and enhancing student self esteem are but a few of those needed for effective teaching. Additional science teaching skills can be found in the *SourceView* User's Guide.

## Identification of Specific Module/Episode Locations

SB(USER), p. 5, helps teachers select appropriate laboratory activities for a particular grade level.

SB(USER), pp. 10-12, gives a sample lesson plan on conceptual definitions of acids, bases, and acid strength.

SB(USER), pp. 12-14, gives a sample lesson plan on pH and indicators, using activities and applications from several SB modules.

SB(Topic Overview) for each module helps the teacher define the scope of the lesson plan. Concepts, related skills, performance objectives, and place in the curriculum are presented in these sections.

All SV episodes are based on teacher-created lesson plans and can be used to illustrate the principles of lesson planning.

SV(Episode 1), a simulated poor lesson and SV(Episode 2), a model lesson on the same topic, can be used to compare and contrast effective *vs.* ineffective lesson planning.

SV(Episode 15), a simulated poor lesson, shows the result of a lack of planning.

## References

Collette, A.T. & Chiappetta, E.L.(1994). Planning and teaching science lessons. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 363-85). Columbus, OH: Merrill.

Hassard, J. (1992). Designing and assessing units and courses of study. *Minds on science: middle and secondary school methods.* (pp. 310-24). New York, NY: HarperCollins.

Trowbridge, L.W. & Bybee, R.W. (1990). Planning for effective science teaching. *Becoming a secondary school science teacher*, (5th ed.). (pp. 325-45). Columbus, OH: Merrill.

# UNIT 4: LONGTERM PLANNING

## Introduction

Long term lesson plans consist of at least two forms - yearly plans and unit plans. Each requires consideration of goals and objectives for the teacher and the students. The yearly and unit objectives may differ in scope and degree of specificity, with unit objectives being subsumed under yearly plans.

Teacher objectives take the form of overall expectations for the year. Student objectives are usually more specific and should generally be formulated in performance terms to permit teachers to observe and evaluate academic progress and changes in the behavior of their students.

Long term plans must include a time framework, content and process skills to be covered, materials required and methods of evaluation. They are used to set the direction, pace, and expectations of the class.

1. Yearly Plans

   a. Content

      Topics to be covered during the year are frequently determined by a school curriculum guide or the textbook. It is important to recognize that the textbook in itself is not the curriculum but only a part of it. The *SourceBook* and *SourceView* materials as well as current newspaper and popular journal articles can be useful ancillary resources. Teachers usually have considerable freedom to decide on the order of topics and may wish to take into consideration student interests and preferences. Current teaching in science is tending to de-emphasize coverage of many topics and is concentrating on fewer topics at greater depth. This permits more attention to the development of inquiry skills and understanding of the nature of science.

   b. Materials and Facilities

      Planning for a year's work requires attention to procurement of materials when needed and availability of equipment and facilities for maximum teaching effectiveness. This usually entails ordering supplies and working within certain budgetary constraints.

2. Unit Plans

   Unit plans fall into two categories - teaching units and resource units. The first of these is a planned sequence of teaching for a period of several weeks

(See *SourceView* User's Guide, p.10). The second is an organized file of materials on a specific topic that can be drawn upon as the need arises. Good examples are found in the *SourceBook* modules.

a. Content

A unit usually refers to a content topic such as "Weather," "Global Warming" or "Acids and Bases." If matched to a textbook or curriculum unit, general objectives will have been suggested by the author of the unit. Specific student objectives may also be suggested, but the classroom teacher may wish to refine these objectives to apply to the particular students in his or her class.

b. Materials and Facilities

Teachers making unit plans are concerned with making materials and resources available to their students to carry out the study of the unit. These may include resource books, textbooks other than the primary one chosen for the class, films, film strips, computer programs, video tapes, video discs, newspaper articles, popular journal articles, speakers from local businesses and industries, and many other resources. The success in effective teaching of a topical unit depends on the availability of a variety of resource materials.

c. Time Framework

The resource unit is relatively free of time constraints, other than making sure the collected materials are fairly current and relevant. In the teaching unit, time becomes a highly relevant factor. The number of required class periods for completion of the unit must be estimated. This must include introduction, body of the unit, and time for evaluation. Also note that class interruptions may occur that will interfere with completion of the planned schedule.

d. Evaluation

The teaching unit should contain diagnostic, formative, and summative evaluation plans.

## Organization/Implementation Strategies

1. Ask your preservice students to examine several *SourceBook* modules to see how unit objectives are formulated and stated. Some examples are *SourceBook* (ACID), p. 6 and *SourceBook* (MOLE), p. 3.

*2. Have your preservice teachers compile a teaching unit on a topic of their choice or a resource file for a particular unit, or small group of units.

3. To give experience in performing these types of evaluation, assign students the preparation of these three types of tests for a chosen unit. These tests could then be critiqued and discussed by classmates. Because tests have a large influence on what and how high school students study, criteria for evaluation of the prepared tests by your students should include attention to inquiry skills, psychomotor skills, and decision making skills as well as traditional cognitive questions.

## Identification of Specific Module/Episode Locations

SB(USER), pp. 10-11. This resource gives a sample unit lesson plan on "Acids and Bases." Information is given on the suggested placement of the unit in the year's work and suggestions for appropriate extensions of the coverage of the unit's content.

## References


Collette, A.T. & Chiappetta, E.L. (1994). Planning science units. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 387-409). Columbus, OH: Merrill.

Hassard, J. (1992). Designing and assessing science units and courses of study. *Minds on science: middle and secondary school methods*. (pp. 298-311). New York, NY: HarperCollins.

Trowbridge, L.W. & Bybee, R.W. (1990). Planning for effective science teaching. *Becoming a secondary school science teacher* (5th ed.). (pp. 325-31). Columbus, OH: Merrill.


# UNIT 5: MAMAGEMENT, MOTIVATION, AND SELF ESTEEM

## Introduction

### Managemen+

It is the teacher's job to provide an environment in which all students have the opportunity to succeed. Maslow's hierarchy of needs (Ornstein & Hunkins, 1988) tells us that 1) physical and 2) safety needs must be met before one can attend to 3) belonging, 4) self esteem, and 5) self-actualization needs. Since self-actualization is what we wish our students to achieve, we must help them meet their other needs through appropriate classroom management and by building a climate for success.

Good science classroom management does not differ substantially from good generic classroom management, but the inclusion of laboratories and demonstrations adds another dimension to management problems. Laboratories require that teachers plan for rapid and safe dissemination of equipment and supplies, the inevitable problems of breakage and solution shortages, and the rapid restocking, replacing, and possible rethinking between class periods.

Pre-service teachers should think through a laboratory activity as if they were a student performing each step, writing down all the supplies, consumables, and ancillary items they will need. Often minor but significant items are left out of teacher's guides (*e.g.*, test tube brushes, waste disposal containers). Having everything available allows high school students to concentrate on learning and prevents wasted time.

Teachers should also visualize how materials will be disseminated. Will materials be on laboratory desks, requiring teachers to restock between classes? Will a student from each group get materials? Where will they be placed to avoid congestion?

The novice chemistry teacher should perform the laboratory procedures at least one day in advance for three reasons: 1) teachers need to answer student procedural questions, 2) they must anticipate where students may make mistakes in performing experiments, and formulate plans to compensate for these problems (e.g., running out of stock solution in the middle of an experiment), and 3) to determine how difficult it will be for students to perform the experiment.

### Motivation

If students' physical environment is in order, teachers can focus on matters of motivation. Ideally motivation should come from within, but the teacher can provide an external environment designed to foster internal motivation. Use of collaborative groups encourages an atmosphere of support, and creates an environment where students must actively participate thus causing them to realize that the more one knows about something, the more interesting it becomes.

Setting appropriate goals - those that are attainable and worth attaining - helps motivate students. Giving them ample time to practice and be successful not only motivates students but adds to their self-esteem and confidence. Genuine and appropriate amounts of praise also motivates students, and provides them with a model for how to give themselves self praise. Motivation can also be encouraged by linking the subject to constructs students already hold.

### Self Esteem

Self esteem grows when a student feels that he or she is capable. Good management and the exercise of the external motivational techniques listed above produce the environment within which students can be successful. In addition, student successes need to be recognized and celebrated. Traditionally this was done primarily *via* the report card, but teachers can be more creative, using exhibits, debates, contests, *etc*.

## Organization/Implementation Strategies

### Management

*1. Select a fairly complicated experiment from one of the *SourceBook* modules, such as (ENZY) Activity 1: The Effects of Temperature and Inhibitor on the Enzyme Catalase Extracted from Potato. Have preservice teachers mentally walk through the experiment and, without looking at the materials list from the Laboratory Activity Teacher Notes, list all the equipment and supplies needed for a class of 24 students working in groups of two. Have them compare their lists to that in the Teacher's Notes. What conclusions do the preservice teachers come to regarding the need to mentally walk through experiments?

2. Show *SourceView* Episode 15 from 03:28:20 to 03:35:43, an example of an experiment where materials were at desks when the students entered, but the equipment was not the correct equipment. Although this never should have happened, it does show a teacher doing a quick "monitor and adjust." Have preservice teachers discuss the problems and solutions to orchestrating this experiment.

3. Show *SourceView* Episode 10 from 02:06:25 to 02:12:45. Mrs. Herron is able to conduct a novel review of the acids and bases unit because she has spent

considerable time preparing for this review. Have preservice teachers discuss the advantages of reviewing as Mrs. Herron does, and the time commitment involved.

### Motivation and Self Esteem

1. Methods teachers should model good teaching techniques. Since working in collaborative groups increases motivation, yet is not appropriate for all kinds of learning, have preservice teachers work individually and in groups in their methods class. Then ask the preservice teachers to analyze the learning conditions that are best suited for working together and working alone.

*2. Watch *SourceView* Episode 10 (02:12:45 to 02:18:30), showing students building a concept map. Have preservice teachers cite examples of how Mrs. Herron motivates her students and how she is able to maintain their self esteem even if they are wrong.

*3. Show *SourceView* Episode 1 (14:30-14:55) and Episode 15 (03:36:17-03:36:38) where students are told they should know things or be able to figure them out. Have preservice teachers discuss what happens when students ask for help and do not get it.

4. For *SourceView* Episode 11, part or the entire episode can be shown to preservice teachers to emphasize the fact that even in a poorly conducted lesson, a teacher can still show respect for students.

## Identification of Specific Module/Episode Locations

Almost any lesson can be shown for students to evaluate incidences of teachers managing a class well (or poorly), motivating students, or enhancing their self esteem. SV(Overview) lists these on pp. 142-144, #2, 3, 4, 5, 6, 7, 11, and 13. Overviews, references, and coding sheets for the same are located in the Overviews and Inventories Sections:

### Management

SV(Overview), p. 102, Safety in the Laboratory and Classroom.

SV(Overview), p.104, Organization and Management of the Learning Environment.

### Motivation

SV(Overview), p. 106, Pacing of Instruction.

SV(Overview), p.108, Motivating Students.

SV(Overview), p. 112, Obtaining Feedback.

SV(Overview), p. 124, Reinforcement and Review.

### Self Esteem

SV(Overview), p. 110, Enhancing Student Self Esteem.

SV(Overview), p. 120, Peer Learning.

## References

### Management

Collette, A.T. & Chiappetta, E.L. (1994). Classroom management and discipline *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 333-359). Columbus, OH: Merrill.

Ornstein, A.C. & Hunkins, F.P. (1988). *Curriculum foundations, principles, and issues*. (p. 104). Englewood Cliffs, NJ: Prentice Hall.

Trowbridge, L.W. & Bybee, R.W. (1990). The psychology of motivation and learning. *Becoming a secondary school science teacher* (5th ed.). (pp. 63-81). Columbus, OH: Merrill.

Trowbridge, L.W. & Bybee, R.W. (1990). Resolving conflicts in the science classroom. *Becoming a secondary school science teacher* (5th ed.). (pp. 367-384). Columbus, OH: Merrill.

### Motivation and Self Esteem

Kagen, S. (1992). *Cooperative learning*. San Juan Capistrano, CA: Resources for Teachers.

# Unit 6: Beginning the Activity, Lesson, or Unit

## Introduction

Initial impressions are important. Whether seeking a mate, finding a job, or teaching science, getting off on the right foot can spell the difference between success and failure. There are several beginnings in teaching science: 1) We initiate the course at the beginning of each school year, 2) we initiate units several times during the year, and 3) we initiate lessons every day. These various beginnings differ in many ways, but they also have common threads. One common thread is that all three initiating activities have these purposes:

Establish A Need to Know. Whether initiating a course, unit, or lesson, teachers hope to "establish a need to know" for what is to follow. Whether loudly or *sotto voce*, students ask, "Why are we doing all of these weird things?" and the question deserves an answer.

Gain Participation. Convincing students that a subject is worthwhile is part of gaining participation, but that is not enough. Lessons should also be interesting.

Direct Attention Toward Defensible Goals. It is not enough to motivate. Schools are costly institutions meant to educate rather than entertain. The need for participation must not blind us to purpose. We can and should capitalize on student interests to make science enjoyable, but we must be able to defend what we do as worthwhile.

*Beginning the Unit* on p. 86 of *SourceView* Overview describes other functions served by initiating activities.

*SourceBook* modules contain ideas that can be used to introduce lessons. Useful examples are most likely to be found under *Demonstrations*, *Counterintuitive Examples*, *Analogies and Metaphors*, *Humor: On the Fun Side*, or *History: On the Human Side*. Some modules list films or video tapes under *Media* that could be used to introduce a unit or lesson, and others suggest field trips and other activities that could be used. Materials from the four modules suggested for methods courses are listed in Part C.

## Organization/Implementation Strategies

*1. Preservice teachers have been taught for up to sixteen years. They bring a wealth of intuitive knowledge about this topic to your course. *SourceView* Episode 1 provides a suitable stimulus for students to suggest things that they know can be effective in (a) establishing a need to know, (b) gaining participation, and (c) directing attention toward defensible goals. Show Episode 1, ask students to point out weaknesses in the lesson, and have them suggest better ways to introduce the unit. Finally, have students organize the suggestions into a list to which they can refer as they microteach.

*2. Preservice teachers are often able to distinguish effective initiating activities from ineffective ones but are unable to produce and present effective activities themselves. For that reason, some kind of teaching practice (microteaching, peer teaching, mini-lessons in a field setting, *etc.*) related to initiating a lesson should be part of the methods course. What form this practice takes will depend on available equipment and facilities, course organization, and student experiences in other courses. Microteaching as proposed in the original Stanford research (Allen & Ryan, 1969) represents one proven approach.

*3. After students have presented their initial microteaching lesson on beginning a lesson and heard the critique, they should be interested in Episodes 2 and 3 of *SourceView*. Those episodes show experienced teachers initiating a unit and provide ideas that preservice teachers might use. (The critique of their first microteaching lesson might provide a "need to know" and increase student interest in how experienced teachers do what the preservice teachers are just learning.) This viewing could be done by students individually, in small groups, or in a classroom setting.

4. Microteaching provides sufficient time to initiate a lesson or a short unit, but initiating a course or major unit is likely to take longer than microteaching allows. Preparing a lesson plan for "First Day" may be an effective way to get students to think about setting the stage for the course as a whole.

## Identification of Specific Module/Episode Locations

SB(ACID), pp. 16-20, describe demonstrations that could be used to introduce the unit; pp. 21-22 contain counterintuitive examples and discrepant events that could be used to introduce various lessons; ideas presented under environmental science (p. 33), biochemistry (p. 34), geochemistry (p. 34), drugs (p. 34), food (p. 35), and agriculture (p. 35) could be elaborated to initiate the unit.

SB(ENZY), pp. 10-12, describe demonstrations that could be used to introduce the unit or lessons within the unit; class discussion based on the decision making activity at the bottom of p. 14 could be used to introduce the unit; several of the links to the contemporary world found on p. 24 could be used to initiate the unit or lessons within it.

SB(MOLE), pp. 27-30, contain a counterintuitive example and several analogies that could be developed into useful initiating activities.

SB(ROCK), pp. 13-19, describe demonstrations that could be used to initiate the unit or lessons within the unit; the counterintuitive example on p. 19 could be used to initiate a lesson; the videos and films listed on pp. 23-24 could be used to initiate the unit; the links to the contemporary world found on pp. 25-26 could be used to introduce the unit or particular lessons. (Chances are good that a student in the class, a parent, or a teacher in the school is a "rock hound" who would be willing to show a collection and tell about his or her hobby.)

SV(Episode 1) shows Mrs. Walsh give a poor introduction to a unit on acids and bases.

SV(Episode 2) shows Mrs. Walsh using a hands-on activity to introduce a unit on acids and bases.

SV(Episode 3) shows Mr. Lumbley using historical anecdotes to introduce acids and bases.

SV(Overviews), pp. 86-87, deal with beginning the unit.

## References

Allen, D., & Ryan, K. (1969). *Microteaching*. Reading, MA: Addison-Wesley.

Collette, A.T. & Chiappetta, E.L. (1994). *Science instruction in the middle and secondary schools* (3rd ed.). (Chapters 4, 5, 8). Columbus, OH: Merrill.

Herron, J. D. (1978). Establishing a need to know. *Journal of Chemical Education*, 55, 190-191.

McGarvey, B., & Swallow, D. (1986). *Microteaching in teacher education and training*. London: Croom Helm.

McIntyre, D., MacLeod, G., & Griffiths, R. (Eds.). (1977). *Investigations of microteaching*. London: Croom Helm.

SV(Overviews), p. 86 contains references.

Trowbridge, L.W. & Bybee, R.W. (1990). *Becoming a secondary school science teacher* (5th ed.). (Chapters 11, 12, 14). Columbus OH: Merrill.

Turney, C., Eltis, K., Hutton, N., Owens, L., Towler, J., & Wright, R. (1983). *Exploring introductory procedures and closure; advanced questioning*. Sydney: Sydney University Press.

# Unit 7: Ending the Activity, Lesson, or Unit

## Introduction

Ending the unit is too often thought of only as a preparation for an examination which tests a body of knowledge or accumulated materials. In the most common approach to ending a unit, the classroom teacher reviews or summarizes the past unit for the student. The approach seems logical in order for students to study for the examination. However, this strategy mainly fosters short term memory retention, brings about final closure, and encourages rote memory.

Ending the unit needs to be thought of as a spoke in a wheel or piece of a jigsaw puzzle, each having a unique function but also fitting into a larger structure. Thus, ending the unit implies long term retention as well as immediate assessment. Ending a unit or lesson is more than a review of facts or a summary of the unit. The culminating experience must insure student understanding of the unit or lesson. Proper ending of a lesson can determine levels of understanding as well as the quantity of material learned. Feedback needs to be provided for the classroom teachers and the students.

Proper conclusion of a unit or lesson reinforces skills and concepts. However, closure is not limited to such reinforcement. Ending the unit can be used as a beginning. For example, the unit end can be used as a springboard to related topics or possible extensions. Thus, contemporary issues or real life problems can be used to end the unit. Ending the unit gives the classroom teacher the opportunity to use students' artistic talents. Developing and acting out mini dramas, writing poems or songs, or role playing actively involves the students in their own learning. In finishing the unit, the classroom teacher can accommodate all the different learning styles.

Summarizing has an important place in concluding the unit or lesson. Where many ideas or concepts occur, ending the unit may require focusing and organizing the major topics and concepts. If skills are involved, practicing the activity may be necessary. The classroom teacher must properly supervise such time-on-task activities. Finally, students need time for exploration.

## Organization/Implementation Strategies

All varieties of activities, such as using technology, demonstration, or questioning, can be used to bring about closure to a unit or lesson. Your students should be encouraged to use several alternative methods to end a unit. Have your students microteach using the different techniques or strategies. The *SourceView* episodes contain excellent examples of these strategies. The *SourceView* User's Guide is a good resource to clarify the techniques. Have your students look for the section titled "Key Questions" under Concepts/Skills in the *SourceBook* modules. Use some of these ideas to promote discussion on how these ideas can be used to end the unit. Also, have your students look at the sections titled "Common Student Misconceptions" in the *SourceBook*. Have your students determine how these misconceptions can be used to evaluate the level of understanding.

**Teaching Suggestions:**

*1. *SourceView* has excellent examples of ending a unit or lesson. Role playing, discussion of a contemporary issue, concept mapping, and practicing of an activity are different activities in *SourceView* that can be used to end a unit or lesson. Have your students view the four following episodes from *SourceView*:

Episode 8 (01:50:40 - 01:57:15). Role playing by writing letters ends this unit.

Episode 9 (01:57:20 - 02:05:35). A relevant issue discussion ends the unit on acids and bases.

Episode 10 (02:06:25 - 02:23:25). Students make a concept map of acids and bases for review.

Episode 14 (03:22:50 - 03:25:30). Time on task ends a problem solving lesson.

Have your students compare the four strategies in either large or small group discussions. Include as part of the discussion:

a. The different techniques used.

b. For what type of unit and under what conditions would a particular technique be most effective?

c. For what type of unit and under what conditions would a technique be ineffective?

d. How can each technique be used to determine the level of understanding?

As a follow-up to the discussion, have your students microteach using one of the previous strategies to end a lesson.

2. In *SourceView* Episode 20, a Vee diagram is used for post laboratory instruction. Determine how a Vee diagram can be modified for use other than laboratory instruction. Using a *SourceBook* module, have your students modify the Vee diagram for a unit or lesson other than a laboratory activity. Central Concepts can be used for one side of the V, and Links/Extension can be used for the other half of the V.

3. In small groups or individually, have your students write a mini drama, song or poem or create a work of art which summarizes the major concepts in a *SourceBook* module.

## Identification of Specific Module/Episode Locations

SV(Episode 8) 01:50:40 - 01:57:15. Role playing by writing letters ends this unit.

SV(Episode 9) A relevant issue discussion ends the unit on acids and bases.

SV(Episode 10) Students make a concept map of acids and bases for review.

SV(Episode 14) 03:22:50 - 03:25:30. Time on task ends a problem solving lesson.

SV(Episode 20) Post-laboratory instruction uses a Vee diagram.

SV(Episode Questins), pp. 33-35, questions 8.1G, 8.2G, 8.3G, 8.3S, 8.2BG, 9.1G, 9.2G, 9.4G, 9.5G, 9.G, 9.7G, 9.1BG, 10.1G, 10.2G, 10.4G, 10.6S, 10.2BG, p. 46 20.5G, 20.6G, 20.7G.

SV(Overviews), p. 90, a sumary of ending a unit and includes teaching and inquiry references on mapping.

SV(Overviews), p. 112, obtaining feedback strategies.

SV(Overviews), p. 114, questioning skills summary.

SV(Overviews), p. 118, role playing summary.

SV(Overviews), p. 122, using applications summary.

SV(Overviews), p. 124, reinforcement and review summary.

SV(Overviews), p. 126, feedback/informal assessment.

SV(Episode Answers), pp. 58-61, p. 79, suggested answers to questions.

SB possible review questions are present in each content module under Key Questions.

SB performance objectives and central concepts are within each content module.

SB(PEDA), p. 13, a discussion on concept mapping.

SB(PEDA), p. 18, a discussion on assessing the student learning.

### References

SB(PEDA), pp. 26-28.

Collette, A.. & Chiappetta, E.L. (1994). Cognition and learning *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 45-81). Columbus, OH: Merrill.

Novak, J. D. (1984). Application of advances in learning theory and philosophy of science to the improvement of chemistry teaching. *Journal of Chemical Education, 61*, 607 - 612.

Novak, J. D. & Gowin, B. (1984). *Learning how to learn.* Cambridge, England: Cambridge University Press.

## UNIT 8: MODELS AND ANALOGIES

### Introduction

In this unit, for clarification purposes, models will refer to physical structures and analogies will indicate comparisons made to different physical, mental, or imaginary concepts.

Many teachers have discovered that models and analogies are helpful to students in understanding new concepts. Models provide the students with a three dimensional structure which helps them visualize the actual entity rather than relying on only words, flat pictures, or diagrams of the object studied. Models can also represent actual specimens which are far too small to be seen with the most powerful microscope or far too large to actually be brought into the classroom setting. Models are vital to chemistry since chemistry deals with atoms, ions, and particles invisible to the human eye. Analogies are used to point out the resemblance of two similar but different things. Analogies should compare and contrast objects or ideas with which the high school students are already familiar to the new concept being presented.

Models and analogies are wonderfully useful tools for the teacher. Models can simplify the concept and make the actual science object seem more real. After students read and study various topics, models can be used as reminders that objects are three dimensional. Models are also useful because they can be manipulated, examined, and may lead to more inquiring questions which in turn can produce even better models. If students themselves have ever put together a model, like a model car, dinosaur, or doll house, then they will be able to understand why science and scientists utilize models. As students physically assemble the various parts of a model, they learn the names, proper location, and function of that part which is in scale to the actual object. Scientists obtain theories inductively from facts, but models are obtained deductively from theories Cotham and Smith (1981). Models are generated to explain the theory. Over the years models have assisted scientists in predicting more plausible answers to existing questions.

As helpful and useful as models are for the teacher as a learning tool and for the student in visualizing the concepts being taught, there ARE limitations in their use. The teacher's role is to make sure these limitations are pointed out as the model is presented. Students must be made aware that a model represents the actual object; it is NOT the actual entity. Once conceptual understanding is accomplished, students can construct their own models. Students must synthesize the concepts, not just 'learn the model.' Only then will predictions and future discoveries be possible.

When using analogies the teacher must choose carefully those comparisons to which their students are capable of relating. The analogies must be drawn from experiences already familiar to the students. One such analogy example is comparing the structure and function of cell parts to the workings of a factory. It is imperative for the teacher to discuss the limitations of an analogy. Once the new concept has been discussed and compared to more familiar experiences of the students, the students can create original analogies. Having high school students produce and share their own analogies with classmates is helpful for everyone. This activity provides the teacher with feedback as to the students' understanding or their misconceptions. Often the students author analogies that are more useful than the teacher's. By discussing the contrasting dissimilarities as well as the similarities the development of the students' critical thinking skills are stimulated.

Students can become the model when the teacher allows the students to "act like particles" in the "beaker" of the room. [e.g., *SourceView* Episode 6 (01:16:45-01:18:35)]. By actively behaving like solid, liquid, or gaseous states, the students kinetically conceptualize the states of matter through their own movements. If the teacher discusses the similarities of their behavior compared to the behavior of molecules in actual states of matter, then the concepts should become "real" for the students.

## Organization/Implementation Strategies

*1. Have your students create an analogy for a particular concept in their area of study, share these in a small group, and list the limitations of the comparison. As an alternative each student in the group should create a unique analogy for the same concept. This is quite helpful since the greater number of comparisons the teacher can cite for each concept, the broader the high school students' understanding becomes of the science concept presented.

Consider the following questions:

a. Was it difficult to develop an original analogy?

b. Was your own analogy more meaningful than one presented by another? In what ways?

2. Have your students view *SourceView* Episode 1 (00:15:20-00:15:44). What makes the analogy of "ions carry electricity... not like we carry books to class...they just carry electricity" a poor analogy? Devise an analogy for the concept of "ions carry a charge."

*3. Have students select one or more counterintuitive analogies on the mole from *SourceBook* module (MOLE), pp. 27-28 and work through the verification.

*4. Have students complete the activity "Roll-Mole Analogy" from *SourceBook* module (MOLE), p. 28, then discuss the advantages and limitations of the analogy.

5. In *SourceBook* module (ENZY), pp. 12-14, analogies and "pictures in the mind" for enzyme form and function are shown. Have your students work in pairs to create an original analogy for enzyme function. Discuss the value of such an exercise. Consider the following questions:

a. Did the past experiences of each group member help or hinder the development of a new analogy?

b. What are possible pitfalls in having high school students invent analogies?

## Identification of Specific Module/Episode Locations

SB(ACID), pp. 21-22, Analogies and Pictures in the Mind.

SB(ENZY), pp. 12-14, Models, Analogies, and Pictures in the Mind, especially the "Lock and Key" comparison.

SB(MOLE), pp. 27-30, includes a list of analogies to a mole and "Roll-Mole" activity p. 28.

SB(ROCK), pp. 19-20, analogy of fruit stacked and Pictures in the Mind.

SV(Episode 3) 00:40:10-00:42:40 and (Episode 5) 01:10:40-01:11:15. Use of inexpensive models.

SV(Episode 7) 01:23:40-01:26:40. Use of inexpensive models and modeling problem-solving by teacher.

SV(Episode 12) 02:48:55-02:51:20. Use of mental pictures: raisins in beakers.

SV(Episode 19). Use of computer generated models of diluted solutions to develop pH concept.

SV(Overview), pp. 134-135, Using Models and Analogies.

SB(PEDA), pp. 12-13, Using Analogies and Models.

SB(USER), pp. 11 and 13, Modeling.

## References

SB(PEDA), pp. 26-28 (Friedel, *et al.* and Osborne & Cosgrave).

SV(Overview), p. 134 references on models and analogies.

Cotham & Smith. (1981). Development and validation of the conceptions of scientific theories test. *Journal of Research in Science Teaching., 18*(5): 387.

# UNIT 9: DEMONSTRATIONS

## Introduction

Demonstrations of scientific phenomena are a powerful teaching tool, since they can motivate students, help them connect scientific principles with observable phenomena, and enhance retention. Some scientific phenomena are difficult to describe without showing them. For example, the principles of gyroscopic action, oscillating chemical reactions, and the movement of single-celled organisms are much more easily learned if they can be observed. When possible, we want students to have hands-on experiences with science. However, some phenomena involve substances that are too hazardous for students to use on their own, such as toxic chemicals, or equipment that is too expensive or too complicated for students to use. Demonstrations also help prepare students to perform laboratory procedures.

There are important pedagogical benefits associated with the use of well-designed and well-conducted demonstrations. While hands-on activities allow students to model scientific investigations, to explore and discover scientific phenomena, and to develop expertise and confidence, demonstrations allow the class to explore science together, with the ongoing guidance of the instructor. The teacher can use demonstrations to stimulate students to use higher-order thinking skills by involving them in prediction and analysis. Demonstrations are also a good way to introduce discrepant events. When students are actively involved with demonstrations, teachers also obtain useful feedback on student comprehension.

You will give your students a lifetime advantage if you help them to feel comfortable doing demonstrations on a regular basis. Demonstrations can be fun for the teacher as well as for the students and can make it easier to teach science. They do not need to be complicated and may use simple materials. However, it is important to make good pedagogical use of demonstrations, as described in Trowbridge and Bybee (1990). This means the teacher must be well prepared to perform the demonstration, must have preplanned questions and strategies to involve students in the activity, and must be ready to cope with unexpected results. Since it takes time to prepare and conduct demonstrations, some teachers fail to see that instructional time can actually be used more effectively when demonstrations are conducted. The timing of demonstrations is important—both the placement of the demonstration in the lesson plan and the timing of the teacher when conducting the demonstration.

These ideas are illustrated in the *SourceView* videotapes, which include excellent examples of the use of inexpensive and quick demonstrations as well as simulated poorly conducted demonstrations. *SourceBook* contains a wealth of demonstrations in each content module, with detailed descriptions, lists of supplies, safety precautions, explanations of the phenomena, and teaching suggestions. In addition, safety instructions are available in the Safety module and a comprehensive list of demonstration books is included in the Library Resources module.

## Organization/Implementation Strategies

It is important for you to conduct some demonstrations to model their use. Some demonstrations in *SourceBook* that are quick to set up and perform are (ACID), p. 16, "Demonstration 1: Metal-Acid Reactions," and (MOLE), p. 24, "Demonstration 1: A Molar Display."

Performing demonstrations can appear quite intimidating to the novice. Your students will benefit greatly from the opportunity to plan and conduct their own demonstrations under your guidance. Provide opportunities to practice the demonstration before presentation (a necessary preparation and a useful lifetime habit). If no laboratory is available, have students design demonstrations using safe combinations of household items, so they can practice at home. Students should avoid unpredictable or inherently hazardous reactions and be sure not to increase the suggested amounts given in published demonstrations. Students should be prepared for disaster as well as for a variety of possible outcomes—demonstrations do not always work as planned!

Proper safety rules should be followed at all times to help your students develop a disciplined approach to classroom safety. For example, safety goggles should *always* be worn during demonstrations, not only by the teacher, but also by students who could become endangered. Safety equipment should be nearby. Safety information is abundant in the *SourceBook* Safety module, which also contains a list of guidelines for demonstrators developed by the American Chemical Society. Students can be seriously injured by unsafe practices and teachers and their schools can be held liable in court for injuries resulting from the failure to follow accepted safety standards.

**Teaching Suggestions:**

*1. Direct each student to select and conduct an appropriate demonstration as he or she would in a high school classroom, involving the other students as if they were high school chemistry students. Each *SourceBook* content module provides several examples of demonstrations in the Concept/Skills Development section. Have the class critique the demonstration using the *SourceView* demonstration checklist , p. 133.

2. Show *SourceView* Episode 5, which illustrates how an entire class session can be centered on a demonstration, pausing as necessary to discuss the Episode 5 questions pp. 31-32 and safety question S5 p. 49.

3. Show *SourceView* Episode 6 (01:12:20-01:16:00), which has a silent demonstration. After viewing the segment and the interview with Mr. Haines at the end of the episode, in which he discusses why he chose to conduct a silent demonstration, discuss the following Episode 6 questions, p. 32: 6.3G, 6.1S, 6.2S, and 3.1B, and safety question S6, p. 49. Have students discuss in small groups the value of silent demonstrations and under what conditions they might be most effective.

4. Show *SourceView* Episode 1 (00:10:10-00:12:40), an example of poor use of demonstrations. Although the demonstrations are recorded on videodisc rather than conducted live, the teacher makes several common mistakes in conducting the demonstration. Have students critique the presentation using the *SourceView* demonstration checklist on p. 133. Ask students how the presentation could have been improved.

5. Show *SourceView* Episode 10 (02:09:40-02:12:00), which shows a student conducting a demonstration. Discuss the advantages and disadvantages of having students conduct demonstrations and what other techniques can be used to involve students actively in demonstrations.
6. Several *SourceView* episodes show teachers conducting demonstrations on an overhead projector, for example, Episode 19 (04:13:10-04:15:20) and Episode 15 (03:33:00-03:35:05). Show students these episodes and discuss the advantages and disadvantages of using an overhead projector. This is a good opportunity for students to learn that using small amounts of materials reduces safety concerns, but does not make safety precautions unnecessary. Critique each episode shown with respect to safety. Episode 15 shows simulated poor teaching, but includes some desirable teaching characteristics as well. Have students critique the segment using the *SourceView* demonstration checklist on p. 133.
7. Show *SourceView* Episode 17 (03:58:44-04:01:30). Titration procedures are demonstrated by students and by videodisc. Have your students compare the two approaches and discuss when videodiscs are more appropriate and when a live demonstration is better.
8. Have students read a *SourceBook* demonstration description such as "Demonstration 4: Precipitation and Redissolution of Calcium Carbonate" on pp. 17-18 of *SourceBook* module (ROCK) and discuss the following issues:
   a. its appropriate use in the curriculum
   b. how to use the demonstration to stimulate students to use higher-order thinking skills
   c. how to actively involve students in the events.

## Identification of Specific Module/Episode Locations

SB. Each content module contains a selection of demonstrations in the Concept/Skills section, following Laboratory Activities.

SB(SAFE), Appendix, has guidelines for conducting safe chemical demonstrations.

SB(DISB), "Teacher Student Considerations" and "Considerations for the Student Who is Hearing Impaired," have sections on helping disabled students learn from demonstrations.

SB(PEDA), p. 17, gives suggestions for making good use of demonstrations.

The SB Demonstration Index contains a list of all the *SourceBook* demonstrations.

SV(Episode 1) 00:10:10-00:12:40. An example of poor use of demonstrations.

SV(Episode 5) shows a class based on a demonstration.

SV(Episode 6) 01:12:20-01:16:00. A silent demonstration.

SV(Episode 10) 02:09:40-02:12:00. Shows a student conducting a demonstration.

SV(Episode 15) 03:33:00-03:35:05. Shows a poor demonstration, using an overhead projector.

SV(Episode 17) 03:58:44-04:01:30. Shows the use of live and videodisc demonstrations of titration.

SV(Episode 19) 04:13:10-04:15:20. Shows the use of an overhead projector for demonstrations.

SV(Overview), pp. 132-133, has a summary and checklist for using demonstrations.

SV(Skill Sequences), p. 144, lists segments involving demonstrations.

### References


SB(LIBR), Parts I and V contain a comprehensive listing of demonstration books and literature articles.

SV(Overview), p. 132 has references on using demonstrations well.

Collette, A.T. & Chiappetta, E.L. (1994). Demonstrations *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 111-135). Columbus, OH: Merrill.

Trowbridge, L., & Bybee, R. (1990). Demonstration and laboratory work, *Becoming a secondary school science teacher* (pp. 231-250). Columbus, OH: Merrill.


## UNIT 10: QUESTIONING

### Introduction

Probably the most commonly used teaching strategy at the high school level is asking students questions. Teachers ask many questions, seemingly without any purpose in mind. Yet, effective science teachers ask questions as part of an overall instructional strategy designed to achieve a variety of purposes. Questions may be used to gain feedback about student preparation or monitor understanding and concept development during lessons. Questions may be used to arouse interest, set the stage for the lesson, or encourage discussion. Used effectively, questions are used to stimulate thinking, develop new insights, and stimulate the seeking of new knowledge. Teachers may use questions to diagnose student difficulties, particularly in small group and individual settings. When a teacher asks a question, he/she gives an opportunity for students to use their minds in a directed manner.

Learning how to ask the right kind of questions at the appropriate time is a skill that preservice and beginning teachers have difficulty developing unless the formulation of questions is considered in the planning process. Teachers are often criticized for asking too many knowledge level, narrow, convergent, or closed questions in an atmosphere of inquisition rather than one of inquiry. Yet, when individual questions are considered as part of an instructional strategy, this criticism is unfounded. Narrow questions help students know what exists and helps students pull together their learning to develop new meaning or insights. Lessons may start off with an open-ended or divergent question that is followed by a series of convergent questions designed to help students answer the initial divergent question. Assisting preservice teachers in designing questions as part of an overall instructional strategy is an essential part of their development as effective teachers.

How teachers ask questions in the classroom is an important consideration. Too often a *chorus effect* predominates in which a teacher asks a question and the class responds by shouting out the response. Considerable research has shown that the wait-time that teachers use makes a difference in classroom atmosphere and ultimately student achievement. Wait-time occurs when a teacher pauses from three to five seconds after asking a question and again after the student response is given. When teachers employ wait-time (3-5 seconds), the length of student response increases, the failure to respond decreases, the incidence of speculative thinking increases, student-to-student interactions increase and more questions are asked by students. Other considerations include such matters as phrasing questions with words that are familiar to students and avoiding long and complex questions allows students to focus on the content of the question rather than deciphering the meaning.

How a teacher reacts to the student response is critical in providing a smooth flow in the instructional process. A high rate of verbal rewards to the student response or an indication of the correctness of the response serves either to distract from the instructional process or discontinues further thinking about the question. Calling for additional responses serves to invite comparisons and directs the flow of instruction toward consensus.

While the focus of effective teacher questioning techniques lies in the planning process, the nature of instruction often changes by unplanned, spontaneous questions that are formulated as teachers interact with students. Having a direction will allow for formulation of good, unplanned questions that seem to be part of the instructional process. Without clear objectives in mind, the teacher lacks a focus with which to effectively bring these unplanned questions into the process of instruction.

## Organization/Implementation Strategies

All the videotaped episodes contain numerous examples of teachers asking questions. For purposes of enhancing preservice teachers' development, selected videotaped episodes are suggested. The episodes were selected for their clear evidence of an instructional strategy, designed to develop an insight or to produce conceptual change.

1. Convergent and divergent or narrow and broad questions are appropriate for classroom use but for different purposes. From the *SourceView*, show Episode 17 from 03:50:55 to 03:57:38. During the viewing of this episode, have the students write down the questions that are asked. (Mrs. *Herron is attempting to establish a focus question for the laboratory activity. In the lesson, a series of convergent questions are asked to establish the focus question.*) With whole class discussion or small group activity, consider the following questions:
   a. Which questions were convergent and which were divergent?
   b. What is the instructional strategy of the teacher?
   c. How successful was the teacher in accomplishing her instructional objective?

2. From the *SourceView*, show Episode 10 from 02:06:22 to 02:09:38. Mrs. Herron asks the students to tell how the objects on the chair relates to acids and bases. How is the question classified (in terms of being either convergent or divergent)? What is the purpose of this question?

*3. Some questions are designed to encourage conceptual change, particularly if the question is discrepant or counterintuitive. From the *SourceView*, show Episode 4 from 00:50:30 to 00: 59:03. Mrs. Briner asks the question "Is it possible to have a concentrated, weak acid?" and a class discussion begins that lasts about 10 minutes. Consider the following questions:

a. How would you classify the question, "Is it possible to have a concentrated, weak acid?"

b. How was the question finally answered by the class?

c. What conceptual change was produced?

d. What would you say is the teacher's strategy in asking this question? How well did she accomplish her purpose? This approach reveals a new approach to review for testing.

*4. From the *SourceView*, show Episode 5 from 01:04:00 to 01:08:39. Mrs. McKibbin asks what gas is being given off when dry ice is dropped into water. A variety of responses is given. Consider the following questions:

a. How does she respond to the responses given by the students?

b. When students realize that carbon dioxide is a clear, colorless gas and the gas that they see is not clear, what kind of questions does she ask to resolve their cognitive conflict?

c. Describe her strategy of instruction throughout this portion of the episode.

5. When viewing episodes from other units in this *GuideBook*, try to determine the purpose or instructional strategy for the questions that teachers ask.

6. Consider the Group and Discussion Activities of the *SourceBook* module (ACIDS). Choose two questions and determine a context when these questions should be asked.

7. Use the questioning checklist in *SourceView* User's Guide, p. 115 in one of the above activities.

## Identification of Specific Module/Episode Locations

SV(Episode 17) 03:50:55-03:57:38. Pre-lab: Titration of vinegars, STS.

SV(Episode 10) 02:06:22-02:09:38. Ending the Unit: Concept mapping.

SV(Episode 4) 00:50:30-00:59:03. Conducting the Lesson: Identifying misconceptions.

SV(Episode 5) 01:04:00-01:08:39. Conducting the Lesson: Doing a demonstration

SV Overview), pp. 114-115, Questioning.

SB(ACID), p. 20, Group and Discussion Activities, Key Questions.

## References

Collette, A.T., & Chiappetta, E.L. (1994). Lecture, discussion, recitation strategies. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 137-175), Columbus, OH: Merrill.

Hassard, J. (1992). *Minds on science : middle and secondary school methods.* New York, NY: HarperCollins.

Trowbridge, L.T., & Bybee, R.W. (1990). Questioning and inquiry teaching *Becoming a secondary school science teacher* (5th ed.). (pp. 193-206), Columbus, OH: Merrill.

# UNIT 11: PACING INSTRUCTION

## Introduction

Teachers are criticized for covering so much material that students have insufficient time to understand the ideas presented. Teachers are aware of the criticism, but circumstances make it difficult to change. There are individual differences; some students understand quickly, while others catch on slowly if at all. How to pace instruction so that meaningful learning is achieved by most students is an inherent dilemma faced by all teachers. Most often, teachers pace instruction more for rote learning rather than meaningful learning

Rote *versus* Meaningful Learning. *Rote learning* refers to incorporating information into memory without connecting it to other ideas. Rotely learned material is recalled only in contexts that are very similar to those in which it was learned. Students have difficulty in applying rotely learned material in new contexts or remembering the material after a sufficient period of time. In contrast, *meaningful learning* relates what is learned to other ideas so that connections between the new idea and older ones are clear. The more meaningful an idea, the easier it is to use that idea in settings totally removed from the learning environment. "Meaningful" is a relative term. Students continue to add meaning to the terms atom and molecule long after those concepts begin to make sense.

For the teacher there is also difficulty in knowing when ideas are meaningful and when ideas are held rotely. Extensive rote learning by the student can lead to misconceptions. A vast amount of literature documents serious misconceptions held by individuals who have successfully completed several science courses at all level from elementary through college.

For example, most teachers know that correct answers to "What is the definition of mole?" provide little assurance that the concept is meaningful, but they are often surprised that students may answer questions like the following without understanding mole: *How many moles of water will be produced when 12.23 g of methane burn?*

Research on problem solving shows that a *majority* of students solve problems by applying algorithms with little or no understanding of the science implied by the question. For more information about this topic, see *SourceBook* module on Chemical Pedagogy (PEDA) pp. 3, 4, & 19.

The key to pacing instruction to provide for meaningful learning is to utilize the strategies and techniques employed by the teachers viewed in the *SourceView* episodes.

## Organization/Implementation Strategies

1. Ideas in a unit are not equally valued. Have students select a *SourceBook* module and identify (a) "the minimum essentials," *i.e.*, those ideas that every student should understand, regardless of pacing considerations, (b) ideas that should be included if time permits, and (c) ideas that should be totally excluded or used as enrichment for very able students. Students should defend their decisions.

*2. For the selected module, have students examine the questions that are asked in the module and distinguish (a) those that are easily answered on the basis of rote learning from (b) those that are unlikely to be answered rotely. Ask students to rephrase or develop substitute questions for those that are easily answered rotely. (See Part C for relevant pages in the four modules recommended for methods courses.)

3. For the selected module, ask students to pose a question or activity that might be used to detect each of the Common Student Misconceptions listed in the module. [To clarify the assignment, show the *SourceView* segment in Episode 4 (00:48:20-00:59:50) where Mrs. Briner asks whether it is possible to have a concentrated, weak acid. This question is directly related to misconception 3 on p. 27 of (ACID).]

4. Using one of the episodes in *SourceView* or a microteaching lesson taped in your own class, ask students to listen for student comments that suggest incomplete learning (*e.g.*, in reading an equation a student says "two *atoms* of water reacted with..."). For each statement identified, have students suggest how they would follow up the comment to determine whether the student is confused or simply "misspoke" (*e.g.*, the student isn't clear about the meaning of the concepts atoms and molecules rather than just used the wrong word).

5. Fourteen segments of teaching episodes dealing with Pacing of Instruction are identified on p. 142 of Skill Sequences and Suggested Codings in *SourceView*. Show selected sequences to illustrate how experienced teachers pace instruction in varied circumstances.

*6. Show any of the *SourceView* episodes on Conducting the Lesson (Episodes 5, 6, or 7 are likely to be most useful) and ask students to use the *Pacing of Instruction* inventory on p. 107 of the *SourceView* Overview to evaluate the episode. Have students discuss the lesson in small groups. Possible discussion questions are:

   a. Was the pace of the lesson too slow, too fast, or about right? What evidence from the tape supports your judgment?

   b. Was there evidence that the pace of the lesson was dictated by meaningful learning by students? If so, what was the evidence?

   c. If the pace of the lesson was not dictated by meaningful learning, what changes would you make so that it is?

7. Show *SourceView* Episode 12 and point out that the discussion dealing with concentration at the beginning of the lesson is only peripherally related to solving molarity problems, the primary focus of the lesson. In small groups, have students discuss the effect of this diversion on the overall pace of student learning in this lesson.
8. At the conclusion of a 10-minute microteaching lesson, have student pairs discuss what was taught for about two minutes. Their discussion should uncover weaknesses in the lesson.

## Identification of Specific Module/Episode Locations

SB(ACID), p. 22, contains questions for Strategy 2; pp. 27-29 list misconceptions for Strategy 3.

SB(ENZY), pp. 14-16, contain questions under *Problem Solving / Decision Making* that could be used for Strategy 2; pp. 19-20 list misconceptions for Strategy 3.

SB(MOLE) Questions under *Implications and Applications* on pp. 6-7 and p. 18, the worksheets on pp. 14-15 and p. 28, *Key Questions* on p. 26, and *Problem Solving* on pp. 31-32 can be used for Strategy 2; p. 31 lists misconceptions for Strategy 3.

SB(ROCK), p. 19, contains questions for Strategy 2; no misconceptions are listed for this unit.

SV(Overviews), p. 107, contains the inventory, *Pacing of Instruction.*

SV(Skill Sequences), p. 142, contains the sequences on pacing instruction.

SV(Episode 4) 00:48:20-00:59:50. Contains the question, "Is it possible to have a concentrated, weak acid?"

SV(Episode 5) Demonstration of dry ice added to water containing acid-base indicators.

SV(Episode 6) Silent demonstration of Mg added to concentrated and dilute HCl; uses "pictures in the mind."

SV(Episode 7) Lesson on salt character; alternates between whole-class and small-group instruction.

SV(Episode 12) Clarification of concentration and demonstration to distinguish concentration from amount before problem solving on molarity.

## References

Collette, A.T. & Chiappetta, E.L. (1994). Cognition and learning *Science in-struction in the middle and secondary schools* (3rd ed.). (pp. 45-81). Columbus, OH: Merrill.

SV(Overview), p. 107 *Pacing of Instruction*

Trowbridge, L.W. & Bybee, R.W. (1990). Models for effective science teaching. *Becoming a secondary school science teacher* (5th ed.). (pp. 303-323). Columbus, OH: Merrill.

# UNIT 12: PEER LEARNING

## Introduction

Ultimately, anytime learning occurs it is the culmination of student encountered events that produce a conceptual change. Teaching students something certainly does not guarantee that they will learn it. As an instructor you can engage the students in various activities to increase the probability that they may learn the targeted objectives, but in the final analysis, they make the choice, consciously or unconsciously, to learn them or not.

The strategy behind peer learning is that if students are actively engaged in the selection, development, and execution of classroom activities, their vested interest in the unit will manifest itself in the form of content ownership.

The benefits for the high school student participating in peer-learning activities are many. They learn to work as team members. We hear more frequently than ever from the business/industry world the importance placed on group cooperation skills. Students become more sensitive to others' viewpoints when they "put on their shoes" in role-playing activities. Also by teaching their peers in a small group, students' own grasp of the subject is reinforced. Finally, students achieve better on problem solving tasks when they are in small groups since they feel freer to make mistakes and less intimidated about asking questions.

To avoid confusion, a terminology convention needs to be developed. Terms such as cooperative learning and student-centered learning, and activities such as small group discussions and role playing will all fall under the category of "peer learning." The idea behind these activities is that emphasis shifts from teacher to student.

## Organization/Implementation Strategies

Use cooperative group strategies often in your own teaching so that students may experience these techniques and analyze them. As you lead your students through these activities, try to model whenever possible those teaching strategies that maximize the effectiveness of peer learning. Clearly state the objectives and focal points of the activity or discussion. Explicitly indicate when a role-playing activity is about to begin or when one has ended, even if this seems obvious to you. Monitor your students' understanding as the activities progress, but try to refrain from giving them "the answers." Rather, help them to discover "the answers" for themselves. Finally, make sure the activity has closure and all students are "on the same page".

*1. View *SourceView* Episode 7, (01:23:30-01:36:30). Use the Episode 7 questions, p. 33, to launch a discussion on teacher responsibilities to maximize peer learning. These questions may be particularly helpful:

   a. Mrs. Dillon makes extensive use of peer learning. How does her attitude towards her students guarantee success in the peer learning process?

   b. (01:24:00) What evidence do you have that Mrs. Dillon uses small groups often in her classroom?

   c. (01:26:45) In order to monitor the progress of her students, Mrs. Dillon moves around from group to group. What does Mrs. Dillon do to encourage her students to provide the correct answers and what are rewards for a "job well done"?

d. (01:26:55) How do you know that Mrs. Dillon was actively monitoring her students?

e. (01:30:55) You are shown an example of the interaction between two students as one explains the process of determining the parent acid and base to the other. Comment on the explanation given by the young man to his partner.

f. (01:34:20) What are some possible reasons Mrs. Dillon invited her students to work in groups of four for the last activity rather than in pairs?

*2. Break up your class into small groups to discuss the logistics and dynamics of small group activities. Help them focus using these possible questions:

a. What criteria would you use to form small groups in your class?

b. How do you evaluate small group performance? group grades? individual grades?

c. What student behaviors constitute successful small group peer learning activities? engaged students? 100% participation? critical thought? teacher objectives met?

d. How do you ensure equal participation? How do you deal with non participants?

e. What types of activities are appropriate for small groups?

f. When is peer learning not appropriate?

After 15-20 minutes, pool your students' ideas and add some of your own formulated from your past experience.

3. Using the cartoon on p. 21 of the *SourceBook* module (ENZY), have students role play the various components of the enzyme, substrate, reactants, and products to visualize enzyme function. Have them discuss problems in organizing the group, ensuring participation, and completing the task.

4. Have the students read the section on Collaborative Learning, pp. 15-16 in the *SourceBook* module (PEDA). Then use the jig-saw technique referenced therein to research the topic of Animals in Research. How does this technique expedite the research process? What are some of its disadvantages?

5. Give each of your students a copy of the Peer Learning check list on p. 121 of *SourceView* Overview. Direct them to read through the check list before viewing *SourceView* Episode 14 (03:09:50-03:25:30) during and after which they can check off the appropriate categories. Follow up with a discussion of effective use of peer-learning activities.

6. Divide your class into groups of 3-4. Have each group generate ideas on why peer learning is important. After several ideas are pooled, have the students read the abstracts on peer learning and role playing on pp. 120 and 118, respectively, of the *SourceView* Overview. Were their ideas reinforced? refuted? Were other useful ideas found in the text?

## Identification of Specific Module/Episode Locations

SV(Skill Sequences), p. 144, Using Discussions episode list.

SV(Skill Sequences), p. 143, Peer learning episode list.

SV(Skill Sequences), p. 143, Decision making and role-playing episode list.

SV(Overview), pp. 120-121, Peer learning abstract and checklist.

SV(Overview), pp. 118-119, Decision making and role-playing abstract and checklist.

SV(Episode 7). Students work in groups on products of neutralization.

SV(Episode 14). Students solve molarity problems in groups.

SV(Episode Questions), p. 33, Episode 7 Questions.

SV(Episode Questions), pp. 41-42, Episode 14 Questions.

SB[Group and Discussion Activities (Every content module) show specific group activities related to the module topic.]

SB(PEDA), pp. 15-16, Gives a brief pedagogical rationale for using collaborative learning.

SB(ENZY), p. 21, Cartoon that brings an enzyme to life using familiar objects.

## References


SV(Overview), p. 120

SV(Overview), p. 118

SV(Overview), p. 136

Collette, A.T. & Chiappetta, E.L. (1994). Inquiry *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 102-106). Columbus, OH: Merrill.

Johnson, D.W., & Johnson, R. (1975). *Learning together and alone: cooperation, competition, and individualization.* Englewood Cliffs, NJ: Prentice Hall

Slavin, R.E. (1983). *Cooperative learning.* New York: Longman.


# Unit 13: Laboratory Learning

## Introduction

Science and science teaching must be an active process. The laboratory activity is a "hands-on" way for the student to learn and a vital part of all *good* science teaching. Laboratory activities are an integral part of science in which students make observations, think about what is occurring, formulate conclusions, manipulate materials and gain an appreciation for the scientific method of solving problems.

Laboratory exercises allow students to experience the joy of discovery. Laboratories are activities in which facts of science are used. Laboratory activities are the doing part of science. They should engage students' minds as well as stimulate their senses. Learning science without a laboratory is like learning music without the instruments, learning to dribble without a basketb-ll, or experiencing life without our senses.

Laboratory activities are of various types requiring many roles of the teacher and involving many practical considerations in running the laboratory. These areas will be examined in three separate topics.

### Various Types of Laboratory Activities

There are several types of laboratory activities you can introduce depending on the desired outcomes to be achieved. Specific types include:

1. deductive laboratories which are used to verify the concepts presented prior to the laboratory experience.
2. inductive laboratories which introduce concepts through observations and data analysis prior to any discussion of the concept in the classroom or the text.
3. manipulative skill laboratories where the student learns the proper use of equipment, hand-eye coordination, physical manipulation, and respect for safety.
4. open ended or exploratory laboratories which present students with a problem and allow them to design experiments and test their ideas with little or no structure from the teacher.

### Role of the Teacher in Laboratory Activities

All laboratory activities, no matter what the type of laboratory, should have three parts: the pre-laboratory, the laboratory activity, and the post-laboratory.

Pre-laboratory sets the stage for action. The high school teacher may demonstrate the correct use of equipment or model new manipulative techniques. The teachers should check for understanding by asking questions before the laboratory begins. At the end of the pre-laboratory discussion, the high school students should be able to state how, why, and what they will specifically be doing in the laboratory experience. Through pre-laboratory dialogues the students learn the value of planning for the experimental operations and thinking about the question to be answered before the actual laboratory begins. Pre-laboratory discussion is the appropriate time to go over safety procedures and proper disposal of materials to be used. Another facet of pre-laboratory planning includes incorporating cooperative laboratory groups with each group member assigned a specific role to fulfill in the investigation.

In student-centered, inquiry-based classrooms the pre-laboratory discussions may simply begin with a question the class wishes to answer. The discussion can lead students to develop a procedure to follow, consider safety factors, and decide on group and individual responsibilities. The success of the activity depends on (1) the high school student's previous experience with inquiry laboratories, (2) the students' interest and "ownership" in solving the question, (3) the procedures to be utilized that are familiar to students, and (4) how secure the teacher feels having students explore areas unfamiliar to the teacher as well as the students. See references at the end of this unit for specific methods textbooks that include inquiry teaching and suggestions for success.

During the laboratory activity, the teacher's role is to monitor all activity in the laboratory. The teacher as manager should provide a safe working environment, encouragement, and assistance if problems arise. The teacher must keep the students "on task," keep them thinking, and keep track of time especially for safe clean-up.

The post-laboratory activity portion has the students share and analyze the data and relate the information to the unit content. Under the direction of the teacher, collected data are interpreted, evaluated, and possible limitations of the data are discovered. These limitations may lead to new questions resulting in student creation of new laboratory activities to search for solutions. The post-laboratory discussion provides opportunities to expand on the concepts presented, deal with higher level questions, solve problems, make value judgments, look at related societal issues, and search for reasons that errors arose.

### Practical Considerations of Laboratory Activities

It is important to be aware of the practical aspects of laboratory activities. These factors include the amount of time needed for preparation of materials and equipment; the time required to carry out the laboratory; the availability of facilities, space, and supplies; and the practical manner in which the laboratory will be evaluated after completion.

Modern trends that aid the teacher include use of small-scale laboratories which take less time, are safer, and produce less waste. Computer simulations may serve as practice and drill laboratories or as experiments where data are collected and analyzed as a group, serving as a basis for discussions. Further assistance to the teacher may include technical equipment and instruments coupled with computers that allow measurements to be made more easily, measured over periods of time beyond the class period, and even grade the data collected by students.

## Organization/Implementation Strategies

### Various Types of Laboratory Activities

You should have your students decide: the type of laboratory needed to produce a desired outcome; the frequency of laboratories to be performed based on time and budget availability; and how to ensure the safety of the students. Each *SourceBook* module provides a source of laboratory activities and demonstrations that may be used as laboratories.

*1. Have your students view *SourceView* Episode 18, Conducting the Laboratory, and speculate on the type of laboratory being demonstrated in the serial dilution experiment. Could this laboratory be used:

    a. deductively? how?

    b. inductively? how?

    c. as a manipulative skill develr ɔment laboratory? how?

    d. as an open-ended laboratory?

2. Is it possible for a single laboratory activity to serve more than one purpose? Explain.

3. Have your students read the laboratory from the *SourceBook* module (MOLE), pp. 4-7. What type or types of laboratory are presented?
4. Have your students read the laboratory from the *SourceBook* module (ROCK), pp. 6-7. What type of laboratory is presented?

**Role of the Teacher in Laboratory Activities**

Each of the *SourceBook* modules offer pre- and post-laboratory discussion suggestions as well as expected results from the students.

1. Have students view *SourceView* Episode 15 (03:28:28-03:31:25) and Episode 16 (03:40:05-03:50:04). Compare the episodes and include at least two differences in the pre-laboratory sessions. What information should be included in ALL pre-laboratory discussions (list at least three)?

*2. After viewing *SourceView* Episode 15 (03:28:20-03:39:20), list inappropriate behavior demonstrated by Ms. McKibbin followed by more appropriate behavior that could be utilized (list at least three modeled errors and their corrections). Show *SourceView* Episode 18 (04:02:45-04:10:50) for comparison.

3. From *SourceView* Episode Questions, have your students answer questions 19.1G, 19.4S, 19.7S, and 19.1B pp. 45-46.
4. You may want to have your students fill out the coding sheets on Pre-Laboratory Instruction, Supervising Laboratory Instruction, and Post-Laboratory Instruction found in the Overview section of *SourceView* pp. 94-99.

**Practical Considerations of Laboratory Activities**

These *SourceBook* module laboratories include approximations of time required for teacher preparation and student performance, safety concerns, expected results from students, and suggested assessments for the laboratories.

You need to make your students aware that there is limited time for preparing, conducting, and grading laboratory activities. Yet laboratories are an integral part of science. When your pre-service teachers begin teaching, they may be further restricted if the facilities or resources of their school are limited. But creative uses of common, inexpensive materials can be utilized.

*1. Have your students view *SourceView* Episode 15. Problems arise in the laboratory with the use of the students' wells. What does this reveal about Ms. McKibbin's preparation prior to the students doing the laboratory? (*Could be done with #2 on Role of Teacher*)

*2. Have your students watch *SourceView* Episode 16 in which Mrs. Dillon discusses small-scale laboratories and their many advantages. Answer questions 16.3S and 16.4S regarding micro-scale laboratories.

3. Some classroom teachers do not conduct laboratory activities because of the time required to grade all the students' laboratory reports. Have your students discuss possible ways to keep the grading process manageable. View *SourceView* Episode 16 (03:47:15-03:50:10), in which Mrs. Dillon uses cooperative learning and has decreased dramatically the number of laboratory write-ups to be turned in and graded.

4. Have your students watch *SourceView* Episode 17 and discuss the types of materials, equipment, and prior preparation Mrs. Herron utilized in order to prepare her students.
5. After viewing *SourceView* Episodes 15 and 18, have your students compare the teacher's role as manager in the laboratory setting. What do they envision as their role in a laboratory activity?

## Identification of Specific Module/Episode Locations

### Various Types of Laboratory Activities

SB(ACID), pp. 8-9, inductive and manipulative laboratory with exploratory components.

SB(ROCK), pp. 10-11, deductive and manipui :ive laboratory.

SB(ENZY), pp. 4-5, deductive laboratory.

SB(MOLE), pp. 16-18, deductive laboratory: exploratory laboratory could be performed by the high school student with question #6 on p. 18.

### Role of the Teacher in Laboratory Activities

SV(Overview), pp. 94-95, definition and coding sheet for pre-laboratory instruction.

SV(Overview), pp. 96-97, definition and coding sheet for supervising laboratories.

SV(Overview), pp. 98-99, definition and coding sheet for post-laboratory instruction.

SV(Episode 15) Poor pre-laboratory, laboratory, and post-laboratory skills are modeled.

SV(Episode 16) Pre-laboratory demonstrates techniques, use of small scale, cooperative learning, and the importance of safety.

SV(Episode 17) Pre-laboratory discussion clarifies purpose and techniques needed.

SV(Episode 18) Supervising a small-scale serial dilution laboratory.

SV(Episode 19) Post-laboratory discussion develops more complex concepts.

SV(Episode 20) Post-laboratory discussion involving value judgment and use of a Vee diagram.

SV(Episode 21) Post-laboratory discussion to resolve discrepancies in collected data.

### Practical Considerations of Laboratory Activities

Specific Laboratory Activities in *SourceBook* Modules

SB(ACID), pp. 8-11 and pp. 15-16

SB(ENZY), pp. 4-7

SB(MOLE), pp. 4-7 and pp. 16-18

SB(ROCK), pp. 6-7 and pp. 10-11

**Assessment of Laboratory Learning found in *SourceBook* under:**

SB(ACID), p. 14

SB(ENZY), p. 10

SB(MOLE), pp. 12-13 and p. 23

SB(ROCK), p. 13

## References


SB(INTR), pp. 4-14 Measurement in the laboratory; pp. 15-16 Tips on ordering chemicals; pp. 18-23, Uncertainty in measurement.

SB(PEDA), pp. 26-28

SB(USER), p. 6

Collette, A.T. & Chiappetta, E.L. (1994). Laboratory work. *Science instruction in the middle and secondary schools*, (3rd ed.). (pp. 197-223). Columbus, OH: Merrill.

Hassard, J. (1992). Models of teaching. *Minds on science: middle and secondary school methods.* (pp. 210-226). New York, NY: HarperCollins.

Hassard, J. (1992). Facilitating learning in the science classroom. *Minds on science: middle and secondary school methods* . (pp. 357-360). New York, NY: HarperCollins.

Trowbridge, L.W. & Bybee, R.W. (1990). Demonstration and laboratory work. *Becoming a secondary science teacher, (5th ed.).* (pp. 231-252). Columbus, OH: Merrill.

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# Unit 14: Safety

## Introduction

No issue is more important than the total safety of the student. Likewise, personal liability is too great to ignore safety issues. A secondary science teacher can not afford the financial burdens of a personal injury lawsuit. A serious permanent injury to a student can be mentally damaging to a teacher. Once an accident occurs, there is no "second chance."

A science teacher may be responsible for a total safety program for the department, school, or district. At a minimum, a science teacher is responsible for the purchasing, handling, storage and disposal of chemicals and equipment. Therefore, knowledge of state and local regulations is necessary for reasonable and prudent practice. Many science teachers are called upon by the community for their knowledge and experience in handling safety issues. Any lesson must balance its educational value with the risks involved in doing the activity.

An immediate priority for any science teacher is to develop a workable classroom and laboratory safety policy. This policy needs to stress the danger of carelessness and "horse play" in a science classroom and laboratory. The consequences of violating the safety policy needs to be written out. Also, a safety contract for the students needs to be written, signed and enforced. No room for "second chances" exists where laboratory safety is concerned.

## Organization/Implementation Strategies

Because of the unique hands-on experience in science, teachers need constantly to be aware of safe classroom practices. Both legal and ethical liabilities and responsibilities fall upon the classroom teacher. With increased hands-on activities, increased risks also occur. However, such hands-on experiences need not be reduced if safe practices are observed. A safe hands-on program is the responsibility of the science teacher.

**Teaching Suggestions:**

*1. Have your students examine Episodes 15 and 16 from *SourceView*. Consider the consequences if an accident had occurred in either sequence. Discuss the following questions:

   a. What possible accidents could occur?

   b. How does small-scale equipment reduce risks in this laboratory activity?

   c. What could be considered as prudent practice in each episode? What could be considered as imprudent practice in the episodes?

2. Obtain for your students records of actual court cases involving litigation of accidents occurring in a science laboratory. Remove from the case the final settlement or outcome. Have your students make a ruling on each case. Have the students compare their ruling with the actual ruling and the justifications behind the ruling. As a methods instructor, you need to emphasize the variety of cases involved. Documents and information can be obtained from the American Chemical Society, Division of Chemical Health & Safety, Committee on Chemical Safety, 1155 Sixteenth Street N.W., Washington, D.C. 20036. In addition if still available, NSTA's publication *Science Teaching and the Law* is an excellent resource containing court cases.

3. From a *SourceBook* module, have your students read a safety section from one of the laboratory activities. Consider "whether the information is sufficient to be considered prudent. What, if any, changes should be made?"

*4. Have your students design a student safety contract. Have them determine what factors need to be included in a contract to be considered reasonable. The students should consider what parties need to sign this contract.

5. From the *SourceBook* module (SAFE), pp. 14-18, use the safety list of facilities, to assign each student to make a safety checklist of a local secondary school science laboratory.

*6. Students need to consider what information is included on an MSDS sheet, manufacturer's label and a handbook of chemistry (*i.e.*, The Merck Index) about a particular chemical. Have your students obtain a copy of each and compare the information available on each. An actual MSDS sheet or label may be obtained from the stockroom. The *SourceBook* module (SAFE) does have examples of information provided on a label (p. 25-26) or an MSDS sheet (p. 32-34) if no other source is available to the student.

7. Bring in an official from a regulatory agency like EPA, OSHA or the state health department to give local regulations dealing with the transportation, storage, disposal of chemicals, and the regulations pertaining to facilities.
8. For a demonstration, mix incompatible household chemicals under controlled conditions. Show that the labels may not be adequate to predict the results. Emphasize that household chemicals do not necessarily mean safe chemicals. [*SourceBook* module (ACID), p. 24 lists both battery acid and bleach. In a 250-ml Erlenmeyer flask, place 75 ml of water then add 25 ml of household bleach (5% sodium hypochlorite). *Under a hood*, add 5 drops of battery acid. After the green gas is well expelled, loosely stopper the flask to prevent further dispersion of chlorine gas. Be extremely careful since the gas is now in a closed system. Also, chlorine and battery acid are extremely corrosive. For disposal make the solution basic with sodium hydroxide to absorb excess chlorine. Adjust the pH to 12 which is the normal pH of bleach. Safety goggles should be worn at all times. Since this demonstration is extremely dangerous, use extreme caution including hood, safety shield, and goggles. Also, although battery acid and bleach will not likely be mixed, some toilet cleaners contain hydrochloric acid which will give the same results when mixed with bleach.] Discuss with your students that a little knowledge is a dangerous thing when working with chemicals.

## Identification of Specific Module/Episode Locations

SB(SAFE) is a complete module on safety. Included in this module are a hazardous materials list (carcinogens, extremely toxic chemical and flammable), pp. 38-41, a laboratory safety check list, pp. 7-19, and chemical storage design and facilities, pp. 15-26. Also included are information on a chemical label with codes, pp. 25-26 and 58-60, information on an MSDS sheet, pp. 32-34, and a reference list, pp. 61-73.

SB includes a safety section with each laboratory activity or demonstration within each content module. However, there are no disposal recommendations for chemicals. This omission should be discussed with the students.

SV(Episode Questions), p. 49, has specific safety questions. Reference to individual episodes and times are given.

SV(Overview), pp. 102-103, Safety in the Laboratory and Classroom contains a brief statement on safety. These pages contain several references and a teacher check list.

SV(Skill Sequences), p. 149, sequences on safety.

## References

SV(Overview), p. 102

SB(SAFE), pp. 61-73

American Chemical Society, Division of Chemical Health & Safety, Committee on Chemical Safety, 1155 16th St. N.W. Washington D.C. 20036.

Brown, B.W. & Brown, W.R. (1969). *Science teaching and the law*. Washington D.C.: National Science Teachers Association.

Collette, A.T. & Chiappetta, E.L. (1994). Safety in the laboratory and classroom. *Science instruction in the middle and secondary schools*, (3rd ed.). (pp. 225-257). Columbus, OH: Merrill.

*Flinn chemical catalog reference manual, "The science instructor's safer source"* (1992). Annual Publication. Batavia, IL: Flinn Scientific. An excellent reference for the storage and disposal of chemicals and for safety equipment and facilities.

# UNIT 15: PROBLEM SOLVING

## Introduction

Problems exist in many forms: We can't balance our checkbook, we can't get the car started, or we can't get students to be quiet. All of these are problems, and they appear to have little in common except that there is some goal that we are temporarily prevented from reaching. *Problem solving*, then, is the process of overcoming some apparent or real impediment and proceeding to a goal. Said another way, "Problem solving is what you do when you don't know what to do."

Routine problems. Problems exist along a continuum from well-defined to ill-defined and along another continuum from routine to nonroutine. *Routine problems* are frequently encountered, and because they are common, experts develop well-defined procedures for solving them without much thought. Such well-defined procedures that are carried out with a minimum of conscious attention are called *algorithms*. We refer to routine tasks as *exercises* and refer to nonroutine tasks as *problems*.

Traditionally, science courses have included only tasks that are exercises for experts, and instruction has consisted of drill on algorithms that experts use to do them. Unfortunately, those tasks represent *problems* to beginners, and the algorithms that are taught bear little or no resemblance to what experts do when they encounter *problems* (*i.e.*, novel tasks). Consequently, the procedures outlined in most textbooks are of little help if one's goal is to teach problem solving as defined here.

What has been said should not be taken to mean that algorithms have no place in science teaching. Indeed, the complexity of real problems is such that no person is likely to solve them unless they complete routine aspects of the problems algorithmically.

Ill-Defined Problems. The area in which science courses have traditionally dealt with tasks that are problems for experts as well as novices is social issues with a strong science component, *e.g.*, acid rain, water and air pollution, nuclear energy, food additives, and synthetic pesticides. Such problems seldom have one solution if they have a solution at all. Furthermore, today's "correct" solutions may prove disastrous as additional information becomes available. Problems with these characteristics are said to be *ill-defined*. We call the "solution" to these ill-defined problems *decision-making* to distinguish it from solution of complex but well-defined tasks such as identifying a chemical in the school stockroom whose label has disappeared. The latter is described as a *well-defined* problem because, unlike most social problems, there is a single "correct" answer and the goal of the task is quite clear. However, there may be many ways to solve the problem. *Virtually all problems, whether well-defined or ill-defined, can be solved in many ways. Implying that the efficient procedure presented in the textbook or advocated by the teacher is the only way to solve a problem is misleading and does students a disservice.*

Important Considerations. A great deal has been learned about problem solving since 1980, and information from recent research may not be reflected in science courses taken by your students. Consequently, preservice teachers may be unfamiliar with the distinctions made in the preceding section, they may have experienced no models of teaching aimed at developing problem solving skills, their own problem-solving skills may be weak, and existing textbooks may provide little help in teaching problem solving to high school students. Until preservice teachers understand the distinction between exercises and problems and develop skills to solve problems, they are unlikely to be effective in teaching high school students to do so.

## Organization/Implementation Strategies

There are four *SourceView* Episodes 11 through 14 dealing with mathematical problem solving, the kind most science teachers bring to mind when problem solving is mentioned. Episode 11 is provided as a "poor" example of problem solving, but many "good" things can be seen in this episode and some "bad" things can be seen in the other three.

If your students have little background in problem solving, you may want to involve them in some problem-solving activity before they analyze the teaching episodes suggested below. (See suggestion 6.)

*1. Show two of the four episodes on problem solving and ask students which approach they like better and why. (If Episodes 11 and 12 are used, skip the student comments at the end of Episode 11. Students indicate that they are accustomed to better teaching.)

    In the first half of Episode 12, Mr. Cardulla is clarifying the concept of concentration rather than teaching problem solving. If you are contrasting Episodes 11 and 12, you may want to begin Episode 12 at 02:52:00 where the first molarity problem is introduced. After students have compared the two episodes, you might then go back and show the first half of Episode 12 and consider whether the time used to clarify concepts *before* taking up problems was well spent.

    Many of the Episode Questions on mathematical problem solving (pp. 35-42) will be useful in directing discussion.

2. Research provides no clear-cut answer to the question of whether structured or unstructured approaches to problem solving are better[1], and both are used. In Episode 14 Mr. Haines presents a structured approach. This could be contrasted with the less structured approach illustrated in Episode 12. Mr. Haines' use of "pictures in the mind" to make the problem-solving procedure meaningful is particularly interesting. (In Episode 6, beginning at 01:20:25, Mr. Haines develops the mathematical expression for molarity using "pictures in the mind." That segment could be substituted for the one in Episode 14.)

3. Episode 8 is described as "role playing...to illustrate how science relates to students' everyday world," but it can be contrasted with the episode(s) on mathematical problem solving (11 through 14) to show (a) differences in skills used to solve well-defined, routine problems and those used in decision making, (b) differences in teaching strategies used for the two kinds of problems, and (c) differences in what constitutes a "solution" to these problems.

   Since Episode 8 was not designed to focus on problem solving, the Episode Questions will be less useful to you than those for Episodes 11-14. Possible questions that do focus on problem solving are:

   a. Could a structured problem solving approach like the one illustrated in Episode 14 be applied to the problem presented in Episode 8? Do you think it would help or hinder the problem-solving process? Why?

   b. What kinds of skills are students learning in Episode 8? Would you describe these skills as "problem-solving skills?" Why? How do the skills learned in this kind of problem-solving activity differ from the skills learned in the kind of activity shown in Episodes 11-14?

   c. Solving any complex problem requires a number of procedures that are performed "algorithmically." Name procedures used by students in their decision making about the "fish kill" that were sufficiently well-practiced that they required little conscious attention.

   d. Do decision-making tasks like "fish kill" have a place in the science curriculum? Why? What are potential problems with this kind of activity? Potential benefits?

4. Problem solving need not be mathematical or involve decisions about social issues. In Episode 7 Mrs. Dillon poses the problem of deducing the formulas of the parent acid and parent base from the formula of a salt. The problem solving begins at 01:29:50 and continues to 01:32:25 where Mrs. Dillon models problem solving behavior as she writes the solutions to the problems on the board while thinking through the process out-loud.

   This segment of Episode 7 might be contrasted with problem solving seen in other episodes. What problem-solving skills seem to be common to the various kinds of problems? What skills appear to be content specific?

*5. Episode 21 provides an excellent example of a teacher modeling scientific inquiry. The material beginning at 04:47:30 where Mr. Cardulla leads students to consider possible explanations for their discrepant laboratory results is particularly instructive. The thinking exhibited in this segment is common in effective problem solving, and Mr. Cardulla uses several techniques to encourage students to engage in analytical thought while monitoring their thinking processes. (Among the techniques illustrated are brainstorming and Socratic dialogue.)

   Discussion of this episode is likely to be spontaneous. Episode Questions 21.2G, 21.1S, and 21.5S through 21.9S can be used to focus on issues related to reasoning required for problem solving.

6. Explain to students that the purpose of this activity is to learn as much as possible about what people do when they solve problems. Whether the problem is actually solved matters little, since it is the thought processes used rather than the problem itself that interests us. One of the best ways to get an idea of how people solve problems is to have them "think aloud" as they solve a problem, and that is what everyone should do in this activity.

   Demonstrate the think-aloud technique by talking aloud while you solve a problem. (If you are brave enough to make the demonstration authentic, allow a student to suggest the problem that you attempt to solve.) Then, as a group, select a problem that each class member will solve as she or he thinks aloud.

   Virtually any novel task can be used for this activity, but the most effective tasks will meet these conditions: (i) The student "owns" the problem; *i.e.*, it is one for which the student honestly wants a solution. (ii) The problem can be solved using information that the student knows and understands (or information that the student can easily obtain). (iii) There is no algorithm (or at least the student knows no algorithm) for solving the problem.

   It is difficult to predict what problem will meet the first condition, but the other two conditions would be met by asking students to verify one of the analogies illustrating the size of Avogadro's number found on p. 29 of the *SourceBook* module (MOLE). Have students verify one of these analogies or select another task that interests them.

   At this point you may proceed in a number of ways, but you will reduce student anxiety and have more data for analysis if each student solves the problem at home while "thinking aloud" into a tape recorder. Students should listen to and analyze their own recording, but they should not be forced to share with others if they are uncomfortable in doing so.

   There are many ways that students could analyze the recordings of their problem solving. Some of the analyses can be done alone, but others require several students to compare what they did. These questions suggest useful things to do:

   a. One of the first tasks in problem solving is deciding what the problem says. Did you have any trouble deciding what that was? If so, why? If not, what did you do to understand the problem? Get together with three or four other students and compare your approaches to the problem. Did everyone have exactly the same understanding of the problem? If not, what were the differences? What seems to account for the observed differences?

   b. Once a problem is understood, it is represented in some way. Are there differences in the way you represented the problem and the way others represented it? [This question will not be sensible unless the difference between problem understanding and problem representation Newell & Simon (1972) have been discussed.]

   c. When faced with novel problems, it is common to make several false starts before hitting on a strategy that leads to a solution. Did you make any false starts? If so, why? How did you decide to change directions?

d. There are several questions that good problem solvers ask themselves as they solve problems; questions like "What should I do next?" "What knowledge might I try using?" "Does it apply? How?" "What can I conclude from it?" Listen to your tape to see whether you asked such questions.

e. Typically, there are numerous ways to solve any problem. Compare your solution to that of others. What differences do you observe? Are some strategies "better" than others? If so, what makes them better?

f. "Silly " mistakes like writing down the wrong number, misreading, quitting before you get to the answer called for, or using the wrong information in a calculation are common during problem solving. Did you make "silly" errors? If so, did you catch and correct them? If not, why not? If so, how did you catch the errors?

g. Textbook problems often have answers at the back of the book, but real problems don't. Is your answer correct? How do you know?

7. Repeat Activity 6, but this time have students work together in groups as they solve the problem. Contrast the results of the group-problem-solving session with that of individual problem solving. What are advantages and disadvantages of each procedure?

## Identification of Specific Module/Episode Locations

Many *SourceBook* modules contain a section on problem solving. Most tasks within that section are exercises rather than problems as defined here. For the four modules recommended for use in a methods course, these sections may be of interest:

SB(ACID), pp. 21-22, contain counterintuitive examples and discrepant events that would be problems for many students in a methods course.

SB(ENZY), pp. 14-16, contain a variety of exercises and problems involving reaction rates, effect of temperature and foreign substances on enzymes, *etc.*

SB(MOLE), pp. 31-32, contain exercises involving mole calculations; Confirming that the analogies presented on pp. 27-30 are actually true would involve problem solving for many students in a science methods course; Other Laboratory Activities 1, 3, and 4 on p. 23 would be problems for some methods students.

SB(ROCK), p. 22, contains one exercise on percent composition.

SV(Episode 6) 01:20:25-end, shows "pictures in the mind" being used to make molarity problems meaningful.

SV(Episode 7) 01:29:50-01:32:25, shows Mrs. Dillon engage students in group problem solving to deduce the parent acid and parent base from the formula of the salt (non-mathematical problem solving).

SV(Episode 8) shows Mr. Escudero engaging students in decision making about a "fish kill."

SV(Episode 11) is an example of a "poor" problem solving lesson.

SV(Episode 12) is an example of a "good" problem solving lesson.

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SV(Episode 13) is an example of a problem solv g lesson.

SV(Episode 14) presents a structured approach to problem solving.

SV(Episode 21) 04:47:30-end. Shows Mr. Cardulla engaging students in analytical thinking aimed at explaining discrepancies in class data (scientific inquiry; developing analytical skills).

SV(Overview), pp. 92-93, contains an inventory for evaluating problem solving lessons.

## References

SV(Overview), p. 92.

SB(PEDA) Research Perspectives on Concept Learning and Problem Solving, pp. 3-4; Views on Learning, pp. 6-9; Collaborative Learning, pp. 15-16; and Enhancing Problem Solving, pp. 18-20 all provide excellent background material on problem solving.

Collette, A., & Chiappetta, E. (1994). Inquiry *Science instruction in the middle and secondary schools*, (3rd ed.). (pp. 85-109), Columbus, OH: Merrill.

Hassard, J. (1992). *Minds on science: Middle and secondary school methods*. (pp. 14-15, 20-23, 210-224, & Chapter 8). New York: HarperCollins.

Herron, J. D. (1990). Research in chemical education: Results and directions. *Toward a scientific practice of science education*. (pp. 31-54). Hillsdale, NJ: Lawrence Erlbaum.

Herron, J. D. (in press). *It's all about teaching chemistry*. (Chapters 7 & 8). Washington, DC: ACS Books.

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Newell, A., & Simon, H. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Trowbridge, L.W., & Bybee, R.W. (1990). *Becoming a secondary school science teacher*, (5th ed.). (Chapters 11-13). Columbus, OH: Merrill.

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# UNIT 16: EDUCATIONAL TECHNOLOCY

## Introduction

Educational technologies include all electronic learning media, such as television, VCRs, computers, telecommunications, radio, even overhead projectors. Knowing how and when to use these technologies has become an essential part of the education of science teachers. Not only do they make it possible to design truly new ways of teaching and new cognitive approaches, but they also help teachers prepare students for life in a society increasingly dependent on technology. Many schools now expect teachers, especially science and mathematics teachers, to be familiar with a variety of educational technologies and to be able to use them well.

The applications of technology to science teaching are numerous [See Moore (1989)]. Videotapes, videodiscs, and CD-ROM technology provide sophisticated animations of the invisible concepts of chemistry that are based on calculations using actual data. Instructional software provides opportunities to have students working independently or in small groups on simulations or tutorials, freeing the instructor to spend more time with individual students. Microcomputers can allow students to model industrial processes or simulate experiments and natural processes. Microcomputers interfaced with laboratory equipment make it possible for students to quickly collect large amounts of data, plot it as it is being generated, and pool their results. Electronic networks allow students and teachers to communicate with each other, with students at other schools, or with national experts.

Videotapes, videodiscs, and interactive CD-ROM computer lessons containing video images can integrate discussions of theory with visible examples [See Smith and Jones (1989)]. The use of computer-controlled video allows science students to explore microscopic realms such as cell components or to work with systems not possible to include in the laboratory, such as explosive mixtures, toxic chemicals, and processes carried out at remote sites (for example, auto collisions or moon landings). Since lengthy setup and cleanup procedures are eliminated, students can repeat experiments as often as they want, trying different strategies each time. The computer makes many more reactions accessible to students and allows more attempts to be made than would be possible in a hands-on laboratory. It also provides opportunities for students to introduce (and be forced to cope with) experimental errors before conducting related laboratory experiments [See Jones and Smith (1990)].

One of the most difficult problems in teaching science is conveying to students the three-dimensional structure of crystals and the structure and dynamic interactions of molecules. Molecular modeling software allows students to explore electronic structures, molecular skeletons, and molecular motions from many viewpoints. Other software programs make it possible for students to construct, rotate, and compare different crystal lattices.

The use of microcomputers has had a profound effect on many science classrooms because of the opportunities they provide for active student involvement with learning. However, since software varies widely in quality you will need to review software before purchasing it and to obtain information on effectiveness from publishers, from colleagues, or from published reviews and articles.

## Organization/Implementation Strategies

Critical to learning about educational technology is hands-on experience. The primary reason teachers with access to microcomputers do not use them is lack of training and familiarity. Thus, science methods courses should devote several laboratory periods to the uses of instructional software and at least one to the interfacing of microcomputers to laboratory equipment. Students should have ample opportunity to examine available software packages, videotapes, and videodiscs for science teaching. You will find the *SourceView* video tapes invaluable in helping you model the uses of educational technology as well as teach their applications.

**Teaching Suggestions:**

*1. Have students perform a computer-interfaced experiment from the *SourceBook* module (COMP) in the laboratory, then critique and revise the laboratory for use in their own teaching.

*2. Assign students to review and compare several software programs. In groups, students then discuss how the materials can be managed and integrated into the curriculum. This activity can be repeated with videotapes or videodiscs.

*3. Show the sections of *SourceView* Episode 1 in which the videotape and videodisc are used. Then show the sections of *SourceView* Episode 9 and *SourceView* Episode 17 in which video is used. (See Part C for time codes). Ask students to comment on the different strategies used by the teachers, using the audio-visual checklist *SourceView* User's Guide p. 141 to focus the discussion. Ask small groups to find ways of turning the normally passive video medium into an active learning experience.

*4. Assign students to compare and contrast the strengths of the various educational technologies and debate the place of technology in the curriculum.

5. Invite guest speakers such as developers, teachers making use of technology, or vendor representatives to speak to the class. Provide time for discussion and hands-on experiences for students.

6. Assign students to choose a topic from a *SourceBook* module, such as the dilution of HCl in *Activity 1: Classifying Substances Based on Their Reactions* in the module (ACID) and devise a means of using any chosen technology to enhance the teaching of it.

7. Arrange for students to have computer accounts and encourage them to use BITNET or INTERNET to subscribe to free discussion lists such as SciNet and ChemEd-L.

8. Challenge students to find and record a broadcast television or radio program useful in teaching science, secure information on obtaining rights for classroom use, and demonstrate how they would use it in teaching.

## Identification of Specific Module/Episode Locations

SB(COMP) is devoted to the use of the microcomputer as a tool. Rather than focusing on instructional software, it describes a variety of microcomputer tools for the science teacher (for example, word-processing, electronic gradebooks, and spreadsheets). It introduces the interfacing of laboratory equipment to microcomputers and describes several laboratory activities in detail.

SB(DISB) includes a comprehensive discussion of how technological aids can be used to help students with disabilities learn chemistry.

SB(LIBR), Part IV, includes a list of technology-based materials.

SB(PEDA), pp. 17-18, discusses the pedagogical impact of technology.

SB: Each module has a Media section listing relevant films, videotapes, videodiscs, and instructional software programs. These are not complete lists and additional materials may be discovered by your students.

SV: Using the *SourceView* episodes in class models effective use of videotapes in teaching.

Episode 1 - inappropriate use of videotape (00:06:35-00:09:05) and videodisc (00:09:30-00:12:40).

Episode 9 - using a videotape to introduce acid rain, a controversial issue (02:01:20-02:02:45).

Episode 17 - using a videodisc to show experimental titration procedures (04:01:00-04:02:25).

Episode 19 - using simulations on a microcomputer as a lecture aid (04:18:35-04:24:30).

SV(Overview) includes discussions of appropriate uses of technology in teaching science:

pp. 138-139, Microcomputers in the Classroom and Laboratory

pp. 140-141, Using Audio-visual Resources

## References


SB(COMP), pp. 33

SB(DISB), pp. 19-22

SV(Overview), p. 138

SV(Overview), p. 140

Collette, A.T. & Chiappetta, E.L. (1994). Computers and electronic technology. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 287-303). Columbus, OH: Merrill.

Jones, L. L., & Smith, S. G. (1990). Using interactive video courseware to teach laboratory science. *Tech Trends, 35* (6), 22-24.

Moore, J. W. (1989). Tooling up for the 21st century. *Journal of Chemical Education, 66* (1), 15-19.

Smith, S. G. & Jones, L. L. (1989). Images, imagination, and chemical reality. *Journal of Chemical Education, 66* (1), 8-11.

Trowbridge, L.W. & Bybee, R.W. (1990). Computers in science classes. *Becoming a secondary school science teacher* (5th ed.). (pp. 169-191). Columbus, OH: Merrill.


# UNIT 17: CONTEMPORARY ISSUES AND DECISION MAKING

## Introduction

Contemporary issues are "The Real World." They are inescapable and color every aspect of life, including science. Some of the most productive discussions you will have in your classroom can stem from exploring these topics. You will find no difficulty eliciting responses and opinions from your students as these discussions progress.

Due to the volatile nature of some of these subjects, if not properly facilitated, discussions could quickly escalate to arguments or confrontations. Thus, practice with this teaching methos is important. You will soon begin to identify clear opportunities to develop critical thinking/informed decision-making skills in your students and yourself. You will see that students become interested and motivated, and by integrating science and technology with societal issues they will see the relevance of what they are learning.

Please note that many of these issues can be very controversial - strong feelings, whether well thought out or not exist on both sides. Some school districts even have policies on how teachers should deal with many of these subjects. Sensitivity, responsibility, and common sense are important to model and encourage. It is especially critical (unless role playing a deliberately hostile atmosphere) to foster a classroom atmosphere of personal safety and acceptance regardless of one's position on a particular topic.

The topic of contemporary issues and decision-making in science is a large one. Familiarity with and interest in each subject will vary with student background. Thus, a plethora of opportunities exists for you to incorporate these topics into other teaching strategies as well as to explore many of these topics for their own sake. Some of the topics you may want to explore include: Global Warming; Ozone Depletion; Acid Rain; AIDS in Society; Nuclear Energy; Logging/Deforestation; Environment vs Jobs; Mining Practices; Genetic Engineering; Animals in Research; Politics of Science; Origins of the Universe; Superconductor Application; Computer Technology; Space Exploration; Evolution; Advertising Claims vs Scientific Fact and many others.

## Organization/Implementation Strategies

In developing a unit on contemporary issues and decision-making for your pre-service teachers, realize that they see you as a model for their own future teaching. While your students may or may not be intimidated by you, *their* high-school students will typically be swayed by teacher opinions and their presentation.

It is important to plan how class discussion is allowed to proceed. Care should be taken to ensure that each student's opinions are held to be valuable, regardless of personal differences. It is suggested that you take the initiative at the beginning of the unit to lay down "ground rules" for discussion. Respectful consideration of one another's views, courteous etiquette during conversation (one speaker at a time), and even voice levels are important. Be sure, also, to make it clear when you are about to role-play or play the "*Devil's Advocate*".

Try to develop activities specifically related to several of these topics, rather than simply developing generic activities that would be applicable to all "contemporary issues". You will find students appreciate the opportunity to explore many of these issues individually and spend time developing their own philosophies and positions. Inevitably, they will discover many things about themselves, some possibly unexpected.

*1. Watch *SourceView* Episode 8, directing the students to focus on logistics, objectives, and teacher responsibilities when conducting a "town meeting".

Before, during, and after viewing this episode, generate discussion using these suggested questions and/or others taken from *SourceView* Episode 8 Questions, pp. 33-34:

a. What student skills are developed through the use of role-playing?

b. Develop a scenario other than a "fish kill" that would lend itself to the use of role-playing.

c. Describe the role of the teacher throughout this lesson.

d. (01:39:39) What is the purpose of the town council meeting? Is that purpose clearly stated by Mr. Escudero?

e. (01:48:53) After the town council meeting, several of the participants were dissatisfied with the outcome. Describe the actions of Mr. Escudero. If you were the teacher, what would you have done?

f. (01:54:50) In your opinion, was Mr. Escudero justified in assuming some responsibility for the lack of consensus at the town meeting?

*2. Watch *SourceView* Episode 8 to see a model of a "town meeting." Brainstorm as a class the types of activities that went into holding such a meeting. When sufficient activities are on the board, assign similar activities to your students so that a town meeting on logging vs environmental protection can be held a week later.

3. Divide the class into groups of 3-4 students. Have each group review state guidelines regarding public school AIDS policies. Direct the students to discuss implications of having a student with AIDS in their classroom. Possible springboard questions:

Knowing many states have strict laws regarding AIDS related information,

a. does the possibility of having a student with AIDS in your classroom change how you might conduct labs?

b. would it be valuable as a teacher to know how the student contracted the disease?

c. would anything change depending on the method of infection?

d. how do you weigh privacy, safety, and student rights issues?

Have each group pool some ideas, strong feelings, and/or other questions to bring before the class.

4. Use the cartoon regarding "recombinant life forms" in the *SourceBook* module (ENZY), p. 29 to initiate discussion centering on ethical responsibilities of scientists, specifically genetic engineers.

5. Use contemporary books or movies to generate discussion. Choose some current examples that raise science ethics questions and show how science relates to contemporary issues, or promote particular science/political viewpoints.

*6. Devote part of a class session to discuss dealing with contemporary issues on a spontaneous basis. Possible discussion questions:

a. Under what circumstances can you expect students to be preoccupied with contemporary issues?

b. To what extent do you deal in class with issues seemingly unrelated to science?

c. How can you make these discussions most productive?

d. What are the possible consequences if you ignore these issues?

7. Have students role play having a particular "politically-incorrect," very small minority view, or a view with which they personally disagree. Have them sincerely attempt to defend their position against a deliberately aggressive opposition. After 5-10 minutes, discuss how they felt having an unpopular "public" position.
8. Have your students locate and interview persons of local importance regarding contemporary/controversial issues and report their findings to the class. Direct them to begin compiling a list of local resources.
9. Discuss with your students what the teacher roles are in using contemporary issues to develop decision-making skills. After the students have listed some ideas give them a copy of both the *Decision making and role playing* and *using applications* checklists, the *SourceView* Overview, pp. 119 & 123, respectively. Compare/contrast the lists.
10. As a class, develop another list of student objectives for using contemporary issues in class.

## Identification of Specific Module/Episode Locations

SB[Links and Connections (every content module)] integrates many contemporary issues with specific science topics, e.g., SB(ENZY), p. 24 #2 enzymes are used to dissolve blood clots for heart disease patients. SB(MOLE), p. 41 #3 knowing how to calculate moles is related to $SO_2$ production and acid rain. SB(ACID), pp. 32-35 topics such as acid rain, drugs, foods, agriculture, and insects are related to acids and bases.

SB(ENZY), p. 29, cartoon illustrating ethical questions of current biochemical research.

SV(Episode 8) Using a "fish-kill" incident as the theme, a "town meeting" is held to discuss causes of the kill and ramifications of certain policies.

SV(Episode 9) A discussion of acid rain is used to end a unit on acids and bases.

SV(Episode 10) The instructor uses common objects placed around the classroom to evaluate student understanding of acids and bases and their ability to relate acids and bases to contemporary society.

SV(Episode Questions), pp. 33-34, Episode 8 Questions (All). SV(Episode Questions), pp. 34-35, Episode 9 Questions (9.4G, 9.5G, 9.3S).

SV(Episode Questions), p. 35, Episode 10 Questions (10.1S).

SV(Overview), p. 119, Decision making and role playing checklist.

SV(Skill Sequences), p. 143, Decision making and role playing episode list.

SV(Overview), p. 123, Using applications checklist.

SV(Skill Sequences), pp. 143-144, Using applications episode list.

## References

SV(Episode Outlines), p. 16 *About Acid Rain*

SV(Overview), pp. 118-119 *Decision Making and Role Playing*

SV(Overview) pp. 122-123 *Using Applications*

Collette, A.T. & Chiappetta, E.L. (1994). Science, technology, and society. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 177-195). Columbus, OH: Merrill.

Tanis, D., & Dombrink, K. (Eds.). (1983). Checking out acids and bases. *ChemMatters, 1*(2), 4-16.

Trowbridge, L.W. & Bybee, R.W. (1990). Science-technology-society (STS): a vision for science teachers. *Becoming a secondary school science teacher* (5th ed.). (pp. 417-436). Columbus, OH: Merrill.

Viola, V.E. (1990). Formations of the chemical elements and the evolution of our universe. *Journal of Chemical Education, 67*, 723-730.

# How Do We Know We Have Arrived?

## UNIT 18: ASSESSMENT

### Introduction

Through the assessment process teachers analyze whether the instructional goals have been attained with respect to individual students, teacher effectiveness, and the class curriculum. Thus, for the preservice teacher, assessment skills cannot be overemphasized, for without them, how will one know if they have "gotten there"?

Assessment skills are defined here as any process, either formal or informal, that allows the teacher to determine how well the students are progressing and if the instruction is appropriately meeting the students' needs. Assessment may be anything from listening to student conversation in small groups to formal, standardized testing. Evaluation, on the other hand, is making a judgment about that assessment. This unit will deal specifically with assessment.

The preservice teacher should be encouraged to select assessment methods that clearly show what their students know and can do. Preservice teachers, raised on traditional paper-and-pencil tests, often find it difficult to see that other forms of assessment, such as laboratory performance assessments, may be more appropriate tools and may "count" for evaluation purposes. Now that many states incorporate science performance assessment tasks in their high-stakes testing (testing developed to evaluate entire school districts or schools) teachers can help their students prepare for these tests by using alternative assessment methods in their classrooms.

Alternative assessment methods should not be employed simply because they are novel. Careful consideration should be given to selecting the method that most clearly demonstrates whether the goal has been achieved. If the goal is for students to be able to balance equations, a traditional paper-and-pencil test would be more appropriate than asking the children to come up with a rap song to demonstrate their understanding. A mock town council meeting is appropriate for open-ended, decision-making skills, and a laboratory performance test is appropriate for assessing process skills.

Self assessment is also important. Rather than the teacher being the only one to decide how the student shall be evaluated, teachers and students can work together to determine the goals, the methods of reaching those goals, and what behavior or product would show evidence that the student has met those goals. The student becomes a co-appraiser, and assessment of the student's progress becomes an on-going activity by both the teacher and the student. The distinction between learning and assessment blurs as the two processes build on each other.

Although assessment skills are often taught toward the end of preservice training, preservice teachers should be encouraged to see that when goals and objectives are developed, in essence the assessment is being delineated. Asking the question "What do I want my students to be able to do and know" is like setting a target for the students. If the target is clear and it is not moving, students can hit it. Instruction becomes more powerful and learning more focused if the final assessment tool is decided upon before instruction begins: the students can see where they are going, the level of performance they are expected to achieve, and the teacher can provide models of expert performance to achieve the target.

## Organization/Implementation Strategies

1. A good model showing informal assessment taking place in the mind of both teacher and students is seen in *SourceView* Episode 4 (00:46:54-00:57:45). Show students the clip where high school students are struggling with the idea of strength and concentration of acids, ending with the segment when a student metacognitively realizes her definitions of the terms "strength" and "concentration" are not sufficient for her to answer the questions. The teacher's assessment informs her that more work needs to be done to differentiate these terms. The student's assessment informs her where the "holes" are in her understanding. Ask preservice teachers the following questions:

   a. How is the teacher assessing whether the students fully comprehend the differences between strength and concentration of acids and bases?

   b. What leads her to her judgments?

   c. How are the students assessing their own learning during this discussion?

   d. How could the teacher foster more metacognitive skills at this point?

   e. What other decisions could the teacher make about the next lesson to give to these students?

   f. What might be her next step if all students had shown a thorough understanding of strength and concentration at this point?

   g. How could she quickly do an evaluation of students at this point in time?

   h. How could she involve the students in their own evaluation at this time?

*2. Ask preservice teachers to develop a number of different types of assessment tools for this lesson or develop directions that they would give high school students when asking them to assess their own learning.

   a. Assume it is your high school students who have just completed the lesson on acid strength and concentration. Working in groups of three, come up with an example of each of the following question or assessment types which would help you evaluate their understanding:

      1) A true-false question

      2) A multiple-choice question

      3) A completion question

      4) A short answer question

      5) A 10-minute laboratory performance test

      6) An interview question

      7) A list of at least five alternative ways they could assess their students (*e.g.*, asking students to create a poem, song, collage, analogy, model, or picture describing the difference between the two).

b. Pretend you are the teacher who has just finished the lesson on strength and concentration. Script a statement to your students which directs them to determine for themselves whether they understand the concept of strength and concentration.

3. Show *SourceView* Episode 4 and discuss the differences between formative and summative assessments. Formative assessments can be either informal monitoring of students' progress or formal testing which helps show teachers the students' progress, but is not used for evaluative (grading) purposes. Pre-testing, which allows a teacher to determine the students' entry level understanding, should be stressed as an important part of formative assessment. Ask preservice teachers the following:

   a. What entry level knowledge and conceptions would you have expected these students to have upon entering the classroom?

   b. How would you develop a pre-test (this may be a lab performance test) for these students to allow you to quickly assess their entry level knowledge and conceptions?

   c. Assume these students enter with no understanding of concentration or strength. Determine what you want the students to be able to know and do by the end of this unit, and then develop a list of formative questions which would help you assess how well your students are learning as the lesson progresses.

## Identification of Specific Module/Episode Locations

1. In the Topic Overview, each *SourceBook* module lists Central Concepts, Related Concepts, Related Skills, and Performance Objectives from which preservice teachers can develop formative and summative assessment and evaluation instruments.
2. SV(Episode 10) The entire episode shows Mrs. Herron's method of assessing student understanding through group sharing and group concept mapping.
3. SV(Overview), p. 144 lists numerous segments showing instances of teacher feedback and informal assessment. Pages 126-127 give an overview, references, and coding sheets for preservice teachers to use in viewing these instances and other segments. Included are 00:32:15 - 00:32:50: assessing prior knowledge, and 00:51:40 - 00:58:10: allowing students to assess their own knowledge.

## References

Brandt, R. (Ed.) (1992). *Performance assessment: readings from educational leadership*. Alexandria, VA: Association of Supervision and Curriculum Development.

Collette, A.T. & Chiappetta, E.L. (1994). Evaluation in science teaching. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 429-449). Columbus, OH: Merrill.

Collette, A.T. & Chiappetta, E.L. (1994). Constructing and administering science tests. *Science instruction in the middle and secondary schools* (3rd ed.). (pp. 451-485). Columbus, OH: Merrill.

Herman, J., Aschbacher, P., & Winters, L. (1992). *A practical guide to alternative assessment.* Alexandria, VA: Association of Supervision and Curriculum Development.

Mitchell, R. (1992). *Testing for learning.* New York, NY: Free Press.

Perrone, V. (1991). *Expanding student assessment.* Alexandria, VA: Association of Supervision and Curriculum Development.

Stiggins, R. (1992). *In teachers' hands: investigating the practices of classroom assessment.* Albany, NY: State University of New York Press.

Trowbridge, L.W. & Bybee, R.W. (1990). Evaluating classroom performance. *Becoming a secondary school science teacher* (5th ed.). (pp. 345-365). Columbus, OH: Merrill.

# UNIT 19: PROFESSIONAL DEVELOPMENT

## Introduction

Continual self assessment leads to professional growth if the teacher conscientiously seeks standards by which to measure his or her classroom performance. Three general methods may be employed: self appraisal, peer coaching, and association with professional organizations and institutes.

Self appraisal can take many forms, but the teacher who reflects daily on the lesson and student progress - and writes these reflections down - will be more cognizant of personal development, have references when teaching the same material again, and have a list of areas for needed improvement.

Many teachers employ some form of peer coaching. Often districts will offer staff development classes in professionally developed courses [such as TESA (Teacher Expectations, Student Achievement) Peer Coaching, Clinical Supervision]. Preservice teachers should be encouraged to seek out these courses, or find a mentor teacher in the same building with whom to develop their own form of peer coaching.

Experienced teachers will attest that the most rewarding professional growth comes from the interaction with other teachers. This "networking" can be accomplished at local, regional, national, and international professional meetings, at summer workshops and institutes, and through continuing education classes. Preservice science teachers should be encouraged to join, at least, the National Science Teachers Association, NSTA and one organization in their specific area (e.g., the American Chemical Society, ACS, the National Association of Biology Teachers, NABT, the Association of Physics Teachers, APT). They should also be made aware that many other organization can contribute to their professional development, such as National Association for Research in Science Teaching, NARST, American Educational Research Association, AERA, Association for Supervision and Curriculum Development, Phi Delta Kappa, and related subject organizations, such as School Science and Mathematics.

## Organization/Implementation Strategies

1. Break preservice teachers into groups. Assign a professional organization to each group. Have them go to the library and look up the following:

a. Information about the organization, including how long it has existed, its home base, whether it has local, regional, national, and/or international meetings, membership costs, etc.

b. If the organization publishes a journal, have the students list the titles of the articles appearing within the last year and then categorize these. Students should share their findings with other groups.

2. Request formal evaluation sheets from several school districts. Have students compare and contrast the evaluative criteria. Discuss methods specific to science teaching that would cause a new teacher to score high on his or her first formal evaluation.

3. Supply students with several copies (from several editions) of the NSTA newspaper. Have them peruse these and share opportunities for professional development they found of which they were unaware.

## Identification of Specific Module Locations

SB(PROF) lists a number of professional organizations for chemistry teachers.

SB(LIBR) lists a variety of books, computer programs, and media resources for science teachers.

## References

Collette, A., & Chiappetta, E. (1994). Growing professionally *Science instruction in the middle and secondary schools*, (3rd ed.). (pp. 489-501), Columbus, OH: Merrill.

Trowbridge, L.W., & Bybee, R.W. (1990). Student teaching and professional growth *Becoming a secondary school science teacher*, (5th ed.). (pp. 385-402). Columbus, OH: Merrill.

[1] There is some evidence that structured approaches are effective when teaching students to solve well-defined, routine problems, but they are less useful for ill-defined, novel tasks (Herron, 1990).

# Appendices: Teacher Resources

## Resource 1: Episode Running Time

**Part 1**

| | |
|---|---|
| Episode 1 | |
| 0:00:00 - 0:04:43 | Introductory comments by students and teachers |
| 0:04:45 - 0:19:30 | Running time |
| 0:19:30 - 0:20:00 | Final comments by teacher |
| Episode 2 | |
| 0:20:00 - 0:30:40 | Running time |
| 0:30:40 - 0:31:06 | Final comments by teacher |
| Episode 3 | |
| 0:31:15 - 0:45:50 | Running time |
| 0:45:57 - 0:46:45 | Final comments by teacher |
| Episode 4 | |
| 0:46:45 - 0:59:50 | Running time |
| 0:59:59 - 1:00:50 | Final comments by teacher |
| Episode 5 | |
| 1:00:50 - 1:11:15 | Running time |
| 1:11:20 - 1:12:00 | Final comments by teacher |
| Episode 6 | |
| 1:12:00 - 1:22:30 | Running time |
| 1:22:40 - 1:23:20 | Final comments by teacher |
| Episode 7 | |
| 1:23:20 - 1:36:30 | Running time |
| 1:36:35 - 1:37:11 | Final comments by teacher |
| Episode 8 | |
| 1:37:42 - 1:56:45 | Running time |
| 1:56:50 - 1:57:14 | Final comments by teacher |
| Episode 9 | |
| 1:57:20 - 2:05:35 | Running time |
| 2:05:42 - 2:06:15 | Final comments by teacher |
| Episode 10 | |
| 2:06:25 - 2:18:26 | Running time |
| 2:18:32 - 2:18:57 | Final comments by teacher and students |

## Part 2

Episode 11

| | |
|---|---|
| 2:21:59 - 2:23:22 | Introductory comments by students |
| 2:22:35 - 2:37:25 | Running time |
| 2:37:33 - 2:37:10 | Final comments by teacher |

Episode 12

| | |
|---|---|
| 2:38:15 - 2:55:55 | Running time |
| 2:55:59 - 2:57:00 | Final comments by teacher |

Episode 13

| | |
|---|---|
| 2:57:05 - 3:08:55 | Running time |
| 3:09:01 - 3:09:40 | Final comments by teacher |

Episode 14

| | |
|---|---|
| 3:09:50 - 3:25:30 | Running time |
| 3:25:36 - 3:26:18 | Final comments by students |

## Part 3

Episode 15

| | |
|---|---|
| 3:26:35 - 3:28:17 | Introductory comments by students |
| 3:28:20 - 3:39:20 | Running time |
| 3:39:29 - 3:39:57 | Final comments by students |

Episode 16

| | |
|---|---|
| 3:40:05 - 3:50:10 | Running time |
| 3:50:14 - 3:50:43 | Final comments by students |

Episode 17

| | |
|---|---|
| 3:50:53 - 4:01:55 | Running time |
| 4:02:58 - 4:02:34 | Final comments by students |

Episode 18

| | |
|---|---|
| 4:02:45 - 4:10:50 | Running time |
| 4:10:53 - 4:12:00 | Final comments by teacher |

Episode 19

| | |
|---|---|
| 4:12:10 - 4:24:35 | Running time |
| 4:24:39 - 4:25:27 | Final comments by students |

Episode 20

| | |
|---|---|
| 4:25:40 - 4:37:00 | Running time |
| 4:37:03 - 4:37:59 | Final comments by teacher and students |

Episode 21

| | |
|---|---|
| 4:38:10 - 4:54:30 | Running time |
| 4:54:36 - 4:56:26 | Final comments by students and teacher |

## Resource 2: Unit Introduction Handouts

### Philosophy of Instruction

*"What am I going to teach?"* and *"How am I going to do it?"* are two questions foremost in teachers' minds. The decisions teachers make with regard to these two questions are influenced by the philosophy of instruction they possess at that moment. All teachers have a viewpoint about the nature of science, the nature of teaching and learning, the nature of students, the goals and directions of science education, and what is a good teaching style. Points of view about these and other issues go into making up a teacher's individual philosophy of instruction. A teacher's philosophy may or may not change with experience and exposure to other forms of learning.

Beginning or preservice teachers bring a philosophy of instruction to the methods course. This philosophy has been built as a result of all their previous experiences in science courses throughout their academic careers. They have viewed models of teaching and learning, experienced science as a learner, have formulated views about what they believe is important to accomplish, identified teaching styles they think are effective, and pinpointed what they wish to avoid in teaching. Most often, this initial philosophy of preservice teachers is amorphous or ill defined because they have never been put into positions where they were forced to "think-it-through".

In general, preservice teachers have experienced science taught in a lecture/recitation format in which learning knowledge for the next level was important. Laboratory experiences were of a verification variety. Learning consisted of rote memorization. The nature of science that was experienced presented an image of science as a collection of facts, principles, laws and algorithms to be applied. The view of science as a process of inquiring into the world was not experienced. Learning how science can meet personal, societal, and career needs was lacking. These and a variety of other concerns go into making up a view about a modern philosophy of instruction of science teaching.

The concern of science educators is to invite preservice teachers to construct or reconstruct a philosophy of instruction that incorporates a modern view about what is the nature of science, the goals and directions of science education, the nature of teaching and learning, and the nature of students. The initial construction of this philosophy must occur early in the methods course and will continue throughout the balance of the methods course. These *GuideBook* materials are designed to assist with the development of a philosophy of instruction among preservice teachers.

### Instructional Objectives

"If you're not sure where you're going, you're liable to end up someplace else - and not even know it"! (Mager, 1962) The science teacher must have a clear understanding of the objectives of the science classes being taught. Students must also know what is expected of them ; and have some knowledge of how to achieve the objectives.

It is customary to group instructional objectives in three categories - cognitive, psychomotor, and affective. Cognitive objectives refer to knowledge, information and understandings. These objectives have received primary attention in traditional science teaching. Psychomotor objectives are those that emphasize skills of movement, muscular coordination, hand and eye coordination, balance, and the tactile senses. Affective objectives pertain to attitudes, feelings, interests, appreciations, and values.

Effective science teaching should give attention to all of the above objectives. Students bring to their classes their whole being, encompassing all aspects of learning. The teacher must consider all aspects of their education as well.

When considering objectives for science teaching, several criteria can be used for their selection:

1. They should be understandable for all parties concerned - students, teachers, administrators and parents.
2. They should be relatively few in number, but comprehensive for any lesson, unit, or program.
3. They should be challenging but attainable by teachers and students.
4. They should be relevant and appropriate for the subject being taught.

## Daily Lesson Planning

Instruction in lesson planning in a methods class in science is important for many reasons. One practical reason is that many school districts require it. They must be prepared to give direction to a substitute teacher if the need arises. They wish to insure that the curriculum objectives are being met when the regular teacher is not there.

Beginning science teachers find daily lesson planning to be an essential component of good instruction. It assists in classroom management and organization. Teachers must think through the kinds of potential problems that might arise and prepare some preventive strategies. Good plans will provide a measure of confidence for the beginning teacher. Two elements of teaching are of primary concern for new teachers. One is having enough plans and materials to insure a full class period and another is managing the class so as to minimize discipline problems. Thoughtfully prepared daily lesson plans can help to alleviate the new teacher's concerns on both of these elements.

Well prepared lesson plans can help meet instructional goals and objectives, both for the teacher and the students. They provide organization and focus for the class period. They provide a solid basis for evaluation and assessment of content, process, and attitude objectives.

A lesson plan should provide for two or three varied activities within the class period to maintain high motivation and interest. An effective lesson plan will clarify what the objectives are for each activity and insure that all needed materials are available. In addition the lesson plan provides a record of what transpires in the class and gives a basis for necessary modifications for future classes.

The *SourceBook* and *SourceView* materials provide several examples of daily lesson plans for specific topics. [See *SourceBook* module (USER), pp 10-12] These examples can be useful in developing lesson plans. It is important to recognize that lesson planning is broader than just preparing a written plan. Much preliminary thought is needed to identify objectives, organize the plan, determine how you will know if the objectives were met, and gather necessary materials.

## Longterm Planning

Long term lesson plans consist of at least two forms - yearly plans and unit plans. Each requires consideration of goals and objectives for the teacher and the students. The yearly and unit objectives may differ in scope and degree of specificity, with unit objectives being subsumed under yearly plans.

Teacher objectives take the form of overall expectations for the year. Student objectives are usually more specific and should generally be formulated in performance terms to permit teachers to observe and evaluate academic progress and changes in the behavior of their students.

Long term plans must include a time framework, content and process skills to be covered, materials required and methods of evaluation. They are used to set the direction, pace, and expectations of the class.

1. Yearly Plans
   a. Content

      Topics to be covered during the year are frequently determined by a school curriculum guide or the textbook. It is important to recognize that the textbook in itself is not the curriculum but only a part of it. The *SourceBook* and *SourceView* materials as well as current newspaper and popular journal articles can be useful ancillary resources. Teachers usually have considerable freedom to decide on the order of topics and may wish to take into consideration student interests and preferences. Current teaching in science is tending to de-emphasize coverage of many topics and is concentrating on fewer topics at greater depth. This permits more attention to the development of inquiry skills and understanding of the nature of science.

   b. Materials and Facilities

      Planning for a year's work requires attention to procurement of materials when needed and availability of equipment and facilities for maximum teaching effectiveness. This usually entails ordering supplies and working within certain budgetary constraints.

2. Unit Plans

   Unit plans fall into two categories - teaching units and resource units. The first of these is a planned sequence of teaching for a period of several weeks (See *SourceView* User's Guide, p.10). The second is an organized file of materials on a specific topic that can be drawn upon as the need arises. Good examples are found in the *SourceBook* modules.

a. Content

A unit usually refers to a content topic such as "Weather," "Global Warming" or "Acids and Bases." If matched to a textbook or curriculum unit, general objectives will have been suggested by the author of the unit. Specific student objectives may also be suggested, but the classroom teacher may wish to refine these objectives to apply to the particular students in his or her class.

b. Materials and Facilities

Teachers making unit plans are concerned with making materials and resources available to their students to carry out the study of the unit. These may include resource books, textbooks other than the primary one chosen for the class, films, film strips, computer programs, video tapes, video discs, newspaper articles, popular journal articles, speakers from local businesses and industries, and many other resources. The success in effective teaching of a topical unit depends on the availability of a variety of resource materials.

c. Time Framework

The resource unit is relatively free of time constraints, other than making sure the collected materials are fairly current and relevant. In the teaching unit, time becomes a highly relevant factor. The number of required class periods for completion of the unit must be estimated. This must include introduction, body of the unit, and time for evaluation. Also note that class interruptions may occur that will interfere with completion of the planned schedule.

d. Evaluation

The teaching unit should contain diagnostic, formative, and summative evaluation plans.

## Management, Motivation, and Self Esteem

### Management

It is the teacher's job to provide an environment in which all students have the opportunity to succeed. Maslow's hierarchy of needs (Ornstein & Hunkins, 1988) tells us that 1) physical and 2) safety needs must be met before one can attend to 3) belonging, 4) self esteem, and 5) self-actualization needs. Since self-actualization is what we wish our students to achieve, we must help them meet their other needs through appropriate classroom management and by building a climate for success.

Good science classroom management does not differ substantially from good generic classroom management, but the inclusion of laboratories and demonstrations adds another dimension to management problems. Laboratories require that teachers plan for rapid and safe dissemination of equipment and supplies, the inevitable problems of breakage and solution shortages, and the rapid restocking, replacing, and possible rethinking between class periods.

Pre-service teachers should think through a laboratory activity as if they were a student performing each step, writing down all the supplies, consumables, and ancillary items they will need. Often minor but significant items are left out of teacher's guides (*e.g.*, test tube brushes, waste disposal containers). Having everything available allows high school students to concentrate on learning and prevents wasted time.

Teachers should also visualize how materials will be disseminated. Will materials be on la oratory desks, requiring teachers to restock between classes? Will a student from each group get materials? Where will they be placed to avoid congestion?

The novice chemistry teacher should perform the laboratory procedures at least one day in advance for three reasons: 1) teachers need to answer student procedural questions, 2) they must anticipate where students may make mistakes in performing experiments, and formulate plans to compensate for these problems (e.g., running out of stock solution in the middle of an experiment), and 3) to determine how difficult it will be for students to perform the experiment.

### Motivation

If students' physical environment is in order, teachers can focus on matters of motivation. Ideally motivation should come from within, but the teacher can provide an external environment designed to foster internal motivation. Use of collaborative groups encourages an atmosphere of support, and creates an environment where students must actively participate thus causing them to realize that the more one knows about something, the more interesting it becomes.

Setting appropriate goals - those that are attainable and worth attaining - helps motivate students. Giving them ample time to practice and be successful not only motivates students but adds to their self-esteem and confidence. Genuine and appropriate amounts of praise also motivates students, and provides them with a model for how to give themselves self praise. Motivation can also be encouraged by linking the subject to constructs students already hold.

### Self Esteem

Self esteem grows when a student feels that he or she is capable. Good management and the exercise of the external motivational techniques listed above produce the environment within which students can be successful. In addition, student successes need to be recognized and celebrated. Traditionally this was done primarily *via* the report card, but teachers can be more creative, using exhibits, debates, contests, *etc.*

## Beginning the Activity, Lesson, or Unit

Initial impressions are important. Whether seeking a mate, finding a job, or teaching science, getting off on the right foot can spell the difference between success and failure. There are several beginnings in teaching science: 1) We initiate the course at the beginning of each school year, 2) we initiate units several times during the year, and 3) we initiate lessons every day. These various beginnings differ in many ways, but they also have common threads. One common thread is that all three initiating activities have these purposes:

Establish A Need to Know. Whether initiating a course, unit, or lesson, teachers hope to "establish a need to know" for what is to follow. Whether loudly or *sotto voce*, students ask, "Why are we doing all of these weird things?" and the question deserves an answer.

Gain Participation. Convincing students that a subject is worthwhile is part of gaining participation, but that is not enough. Lessons should also be interesting.

Direct Attention Toward Defensible Goals. It is not enough to motivate. Schools are costly institutions meant to educate rather than entertain. The need for participation must not blind us to purpose. We can and should capitalize on student interests to make science enjoyable, but we must be able to defend what we do as worthwhile.

*Beginning the Unit* on p. 86 of *SourceView* Overview describes other functions served by initiating activities.

*SourceBook* modules contain ideas that can be used to introduce lessons. Useful examples are most likely to be found under *Demonstrations*, *Counterintuitive Examples*, *Analogies and Metaphors*, *Humor: On the Fun Side*, or *History: On the Human Side*. Some modules list films or video tapes under *Media* that could be used to introduce a unit or lesson, and others suggest field trips and other activities that could be used. Materials from the four modules suggested for methods courses are listed in Part C.

## Ending the Activity, Lesson, or Unit

Ending the unit is too often thought of only as a preparation for an examination which tests a body of knowledge or accumulated materials. In the most common approach to ending a unit, the classroom teacher reviews or summarizes the past unit for the student. The approach seems logical in order for students to study for the examination. However, this strategy mainly fosters short term memory retention, brings about final closure, and encourages rote memory.

Ending the unit needs to be thought of as a spoke in a wheel or piece of a jigsaw puzzle, each having a unique function but also fitting into a larger structure. Thus, ending the unit implies long term retention as well as immediate assessment. Ending a unit or lesson is more than a review of facts or a summary of the unit. The culminating experience must insure student understanding of the unit or lesson. Proper ending of a lesson can determine levels of understanding as well as the quantity of material learned. Feedback needs to be provided for the classroom teachers and the students.

Proper conclusion of a unit or lesson reinforces skills and concepts. However, closure is not limited to such reinforcement. Ending the unit can be used as a beginning. For example, the unit end can be used as a springboard to related topics or possible extensions. Thus, contemporary issues or real life problems can be used to end the unit. Ending the unit gives the classroom teacher the opportunity to use students' artistic talents. Developing and acting out mini dramas, writing poems or songs, or role playing actively involves the students in their own learning. In finishing the unit, the classroom teacher can accommodate all the different learning styles.

Summarizing has an important place in concluding the unit or lesson. Where many ideas or concepts occur, ending the unit may require focusing and organizing the major topics and concepts. If skills are involved, practicing the activity may be necessary. The classroom teacher must properly supervise such time-on-task activities. Finally, students need time for exploration.

## Models and Analogies

In this unit, for clarification purposes, models will refer to physical structures and analogies will indicate comparisons made to different physical, mental, or imaginary concepts.

Many teachers have discovered that models and analogies are helpful to students in understanding new concepts. Models provide the students with a three dimensional structure which helps them visualize the actual entity rather than relying on only words, flat pictures, or diagrams of the object studied. Models can also represent actual specimens which are far too small to be seen with the most powerful microscope or far too large to actually be brought into the classroom setting. Models are vital to chemistry since chemistry deals with atoms, ions, and particles invisible to the human eye. Analogies are used to point out the resemblance of two similar but different things. Analogies should compare and contrast objects or ideas with which the high school students are already familiar to the new concept being presented.

Models and analogies are wonderfully useful tools for the teacher. Models can simplify the concept and make the actual science object seem more real. After students read and study various topics, models can be used as reminders that objects are three dimensional. Models are also useful because they can be manipulated, examined, and may lead to more inquiring questions which in turn can produce even better models. If students themselves have ever put together a model, like a model car, dinosaur, or doll house, then they will be able to understand why science and scientists utilize models. As students physically assemble the various parts of a model, they learn the names, proper location, and function of that part which is in scale to the actual object. Scientists obtain theories inductively from facts, but models are obtained deductively from theories Cotham and Smith (1981). Models are generated to explain the theory. Over the years models have assisted scientists in predicting more plausible answers to existing questions.

As helpful and useful as models are for the teacher as a learning tool and for the student in visualizing the concepts being taught, there ARE limitations in their use. The teacher's role is to make sure these limitations are pointed out as the model is presented. Students must be made aware that a model represents the actual object; it is NOT the actual entity. Once conceptual understanding is accomplished, students can construct their own models. Students must synthesize the concepts, not just 'learn the model.' Only then will predictions and future discoveries be possible.

When using analogies the teacher must choose carefully those comparisons to which their students are capable of relating. The analogies must be drawn from experiences already familiar to the students. One such analogy example is comparing the structure and function of cell parts to the workings of a factory. It is imperative for the teacher to discuss the limitations of an analogy. Once the new concept has been discussed and compared to more familiar experiences of the students, the students can create original analogies. Having high school students produce and share their own analogies with classmates is helpful for everyone. This activity provides the teacher with feedback as to the students' understanding or their misconceptions. Often the students author analogies that are more useful than the teacher's. By discussing the contrasting dissimilarities as well as the similarities the development of the students' critical thinking skills are stimulated.

Students can become the model when the teacher allows the students to "act like particles" in the "beaker" of the room. [e.g., *SourceView* Episode 6 (01:16:45-01:18:35)]. By actively behaving like solid, liquid, or gaseous states, the students kinetically conceptualize the states of matter through their own movements. If the teacher discusses the similarities of their behavior compared to the behavior of molecules in actual states of matter, then the concepts should become "real" for the students.

## Demonstrations

Demonstrations of scientific phenomena are a powerful teaching tool, since they can motivate students, help them connect scientific principles with observable phenomena, and enhance retention. Some scientific phenomena are difficult to describe without showing them. For example, the principles of gyroscopic action, oscillating chemical reactions, and the movement of single-celled organisms are much more easily learned if they can be observed. When possible, we want students to have hands-on experiences with science. However, some phenomena involve substances that are too hazardous for students to use on their own, such as toxic chemicals, or equipment that is too expensive or too complicated for students to use. Demonstrations also help prepare students to perform laboratory procedures.

There are important pedagogical benefits associated with the use of well-designed and well-conducted demonstrations. While hands-on activities allow students to model scientific investigations, to explore and discover scientific phenomena, and to develop expertise and confidence, demonstrations allow the class to explore science together, with the ongoing guidance of the instructor. The teacher can use demonstrations to stimulate students to use higher-order thinking skills by involving them in prediction and analysis. Demonstrations are also a good way to introduce discrepant events. When students are actively involved with demonstrations, teachers also obtain useful feedback on student comprehension.

Demonstrations can be fun for the teacher as well as for the students and can make it easier to teach science. They do not need to be complicated and may use simple materials. However, it is important to make good pedagogical use of demonstrations, as described in Trowbridge and Bybee (1990). This means the teacher must be well prepared to perform the demonstration, must have preplanned questions and strategies to involve students in the activity, and must be ready to cope with unexpected results. Since it takes time to prepare and conduct demonstrations, some teachers fail to see that instructional time can actually be used more effectively when demonstrations are conducted. The timing of demonstrations is important—both the placement of the demonstration in the lesson plan and the timing of the teacher when conducting the demonstration.

These ideas are illustrated in the *SourceView* videotapes, which include excellent examples of the use of inexpensive and quick demonstrations as well as simulated poorly conducted demonstrations. *SourceBook* contains a wealth of demonstrations in each content module, with detailed descriptions, lists of supplies, safety precautions, explanations of the phenomena, and teaching suggestions. In addition, safety instructions are available in the Safety module and a comprehensive list of demonstration books is included in the Library Resources module.

## Questioning

Probably the most commonly used teaching strategy at the high school level is asking students questions. Teachers ask many questions, seemingly without any purpose in mind. Yet, effective science teachers ask questions as part of an overall instructional strategy designed to achieve a variety of purposes. Questions may be used to gain feedback about student preparation or monitor understanding and concept development during lessons. Questions may be used to arouse interest, set the stage for the lesson, or encourage discussion. Used effectively, questions are used to stimulate thinking, develop new insights, and stimulate the seeking of new knowledge. Teachers may use questions to diagnose student difficulties, particularly in small group and individual settings. When a teacher asks a question, he/she gives an opportunity for students to use their minds in a directed manner.

Learning how to ask the right kind of questions at the appropriate time is a skill that preservice and beginning teachers have difficulty developing unless the formulation of questions is considered in the planning process. Teachers are often criticized for asking too many knowledge level, narrow, convergent, or closed questions in an atmosphere of inquisition rather than one of inquiry. Yet, when individual questions are considered as part of an instructional strategy, this criticism is unfounded. Narrow questions help students know what exists and helps students pull together their learning to develop new meaning or insights. Lessons may start off with an open-ended or divergent question that is followed by a series of convergent questions designed to help students answer the initial divergent question. Assisting preservice teachers in designing questions as part of an overall instructional strategy is an essential part of their development as effective teachers.

How teachers ask questions in the classroom is an important consideration. Too often a *chorus effect* predominates in which a teacher asks a question and the class responds by shouting out the response. Considerable research has shown that the wait-time that teachers use makes a difference in classroom atmosphere and ultimately student achievement. Wait-time occurs when a teacher pauses from three to five seconds after asking a question and again after the student response is given. When teachers employ wait-time (3-5 seconds), the length of student response increases, the failure to respond decreases, the incidence of speculative thinking increases, student-to-student interactions increase and more questions are asked by students. Other considerations include such matters as phrasing questions with words that are familiar to students and avoiding long and complex questions allows students to focus on the content of the question rather than deciphering the meaning.

How a teacher reacts to the student response is critical in providing a smooth flow in the instructional process. A high rate of verbal rewards to the student response or an indication of the correctness of the response serves either to distract from the instructional process or discontinues further thinking about the question. Calling for additional responses serves to invite comparisons and directs the flow of instruction toward consensus.

While the focus of effective teacher questioning techniques lies in the planning process, the nature of instruction often changes by unplanned, spontaneous questions that are formulated as teachers interact with students. Having a direction will allow for formulation of good, unplanned questions that seem to be part of the instructional process. Without clear objectives in mind, the teacher lacks a focus with which to effectively bring these unplanned questions into the process of instruction.

## Pacing Instruction

Teachers are criticized for covering so much material that students have insufficient time to understand the ideas presented. Teachers are aware of the criticism, but circumstances make it difficult to change. There are individual differences; some students understand quickly, while others catch on slowly if at all. How to pace instruction so that meaningful learning is achieved by most students is an inherent dilemma faced by all teachers. Most often, teachers pace instruction more for rote learning rather than meaningful learning.

Rote *versus* Meaningful Learning. *Rote learning* refers to incorporating information into memory without connecting it to other ideas. Rotely learned material is recalled only in contexts that are very similar to those in which it was learned. Students have difficulty in applying rotely learned material in new contexts or remembering the material after a sufficient period of time. In contrast, *meaningful learning* relates what is learned to other ideas so that connections between the new idea and older ones are clear. The more meaningful an idea, the easier it is to use that idea in settings totally removed from the learning environment. "Meaningful" is a relative term. Students continue to add meaning to the terms atom and molecule long after those concepts begin to make sense.

For the teacher there is also difficulty in knowing when ideas are meaningful and when ideas are held rotely. Extensive rote learning by the student can lead to misconceptions. A vast amount of literature documents serious misconceptions held by individuals who have successfully completed several science courses at all level from elementary through college.

For example, most teachers know that correct answers to "What is the definition of mole?" provide little assurance that the concept is meaningful, but they are often surprised that students may answer questions like the following without understanding mole: *How many moles of water will be produced when 12.23 g of methane burn?*

Research on problem solving shows that a *majority* of students solve problems by applying algorithms with little or no understanding of the science implied by the question. For more information about this topic, see *SourceBook* module on Chemical Pedagogy (PEDA) pp. 3, 4, & 19.

The key to pacing instruction to provide for meaningful learning is to utilize the strategies and techniques employed by the teachers viewed in the *SourceView* episodes.

## Peer Learning

Ultimately, anytime learning occurs it is the culmination of student encountered events that produce a conceptual change. Teaching students something certainly does not guarantee that they will learn it. As an instructor you can engage the students in various activities to increase the probability that they may learn the targeted objectives, but in the final analysis, they make the choice, consciously or unconsciously, to learn them or not.

The strategy behind peer learning is that if students are actively engaged in the selection, development, and execution of classroom activities, their vested interest in the unit will manifest itself in the form of content ownership.

The benefits for the high school student participating in peer-learning activities are many. They learn to work as team members. We hear more frequently than ever from the business/industry world the importance placed on group cooperation skills. Students become more sensitive to others' viewpoints when they "put on their shoes" in role-playing activities. Also by teaching their peers in a small group, students' own grasp of the subject is reinforced. Finally, students achieve better on problem solving tasks when they are in small groups since they feel freer to make mistakes and less intimidated about asking questions.

To avoid confusion, a terminology convention needs to be developed. Terms such as cooperative learning and student-centered learning, and activities such as small group discussions and role playing will all fall under the category of "peer learning." The idea behind these activities is that emphasis shifts from teacher to student.

## Laboratory Learning

Science and science teaching must be an active process. The laboratory activity is a "hands-on" way for the student to learn and a vital part of all *good* science teaching. Laboratory activities are an integral part of science in which students make observations, think about what is occurring, formulate conclusions, manipulate materials and gain an appreciation for the scientific method of solving problems.

Laboratory exercises allow students to experience the joy of discovery. Laboratories are activities in which facts of science are used. Laboratory activities are the doing part of science. They should engage students' minds as well as stimulate their senses. Learning science without a laboratory is like learning music without the instruments, learning to dribble without a basketball, or experiencing life without our senses.

Laboratory activities are of various types requiring many roles of the teacher and involving many practical considerations in running the laboratory. These areas will be examined in three separate topics.

### Various Types of Laboratory Activities

There are several types of laboratory activities you can introduce depending on the desired outcomes to be achieved. Specific types include:

1. deductive laboratories which are used to verify the concepts presented prior to the laboratory experience.
2. inductive laboratories which introduce concepts through observations and data analysis prior to any discussion of the concept in the classroom or the text.
3. manipulative skill laboratories where the student learns the proper use of equipment, hand-eye coordination, physical manipulation, and respect for safety.
4. open ended or exploratory laboratories which present students with a problem and allow them to design experiments and test their ideas with little or no structure from the teacher.

### Role of the Teacher in Laboratory Activities

All laboratory activities, no matter what the type of laboratory, should have three parts: the pre-laboratory, the laboratory activity, and the post-laboratory.

Pre laboratory sets the stage for action. The high school teacher may demonstrate the correct use of equipment or model new manipulative techniques. The teachers should check for understanding by asking questions before the laboratory begins. At the end of the pre-laboratory discussion, the high school students should be able to state how, why, and what they will specifically be doing in the laboratory experience. Through pre-laboratory dialogues the students learn the value of planning for the experimental operations and thinking about the question to be answered before the actual laboratory begins. Pre-laboratory discussion is the appropriate time to go over safety procedures and proper disposal of materials to be used. Another facet of pre-laboratory planning includes incorporating cooperative laboratory groups with each group member assigned a specific role to fulfill in the investigation.

In student-centered, inquiry-based classrooms the pre-laboratory discussions may simply begin with a question the class wishes to answer. The discussion can lead students to develop a procedure to follow, consider safety factors, and decide on group and individual responsibilities. The success of the activity depends on (1) the high school student's previous experience with inquiry laboratories, (2) the students' interest and "ownership" in solving the question, (3) the procedures to be utilized that are familiar to students, and (4) how secure the teacher feels having students explore areas unfamiliar to the teacher as well as the students. See references at the end of this unit for specific methods textbooks that include inquiry teaching and suggestions for success.

During the laboratory activity, the teacher's role is to monitor all activity in the laboratory. The teacher as manager should provide a safe working environment, encouragement, and assistance if problems arise. The teacher must keep the students "on task," keep them thinking, and keep track of time especially for safe clean-up.

The post-laboratory activity portion has the students share and analyze the data and relate the information to the unit content. Under the direction of the teacher, collected data are interpreted, evaluated, and possible limitations of the data are discovered. These limitations may lead to new questions resulting in student creation of new laboratory activities to search for solutions. The post-laboratory discussion provides opportunities to expand on the concepts presented, deal with higher level questions, solve problems, make value judgments, look at related societal issues, and search for reasons that errors arose.

### Practical Consideration of Laboratory Activities

It is important to be aware of the practical aspects of laboratory activities. These factors include the amount of time needed for preparation of materials and equipment; the time required to carry out the laboratory; the availability of facilities, space, and supplies; and the practical manner in which the laboratory will be evaluated after completion.

Modern trends that aid the teacher include use of small-scale laboratories which take less time, are safer, and produce less waste. Computer simulations may serve as practice and drill laboratories or as experiments where data are collected and analyzed as a group, serving as a basis for discussions. Further assistance to the teacher may include technical equipment and instruments coupled with computers that allow measurements to be made more easily. measured over periods of time beyond the class period, and even grade the data collected by students.

## Safety

No issue is more important than the total safety of the student. Likewise, personal liability is too great to ignore safety issues. A secondary science teacher can not afford the financial burdens of a personal injury lawsuit. A serious permanent injury to a student can be mentally damaging to a teacher. Once an accident occurs, there is no "second chance."

A science teacher may be responsible for a total safety program for the department, school, or district. At a minimum, a science teacher is responsible for the purchasing, handling, storage and disposal of chemicals and equipment. Therefore, knowledge of state and local regulations is necessary for reasonable and prudent practice. Many science teachers are called upon by the community for their knowledge and experience in handling safety issues. Any lesson must balance its educational value with the risks involved in doing the activity.

An immediate priority for any science teacher is to develop a workable classroom and laboratory safety policy. This policy needs to stress the danger of carelessness and "horse playing" in a science classroom and laboratory. The consequences of violating the safety policy needs to be written out. Also, a safety contract for the students needs to be written, signed and enforced. No room for "second chances" exists where laboratory safety is concerned.

## Problem Solving

Problems exist in many forms: We can't balance our checkbook, we can't get the car started, or we can't get students to be quiet. All of these are problems, and they appear to have little in common except that there is some goal that we are temporarily prevented from reaching. *Problem solving*, then, is the process of overcoming some apparent or real impediment and proceeding to a goal. Said another way, "Problem solving is what you do when you don't know what to do."

Routine problems. Problems exist along a continuum from well-defined to ill-defined and along another continuum from routine to nonroutine. *Routine problems* are frequently encountered, and because they are common, experts develop well-defined procedures for solving them without much thought. Such well-defined procedures that are carried out with a minimum of conscious attention are called *algorithms*. We refer to routine tasks as *exercises* and refer to nonroutine tasks as *problems*.

Traditionally, science courses have included only tasks that are exercises for experts, and instruction has consisted of drill on algorithms that experts use to do them. Unfortunately, those tasks represent *problems* to beginners, and the algorithms that are taught bear little or no resemblance to what experts do when they encounter *problems* (*i.e.*, novel tasks). Consequently, the procedures outlined in most textbooks are of little help if one's goal is to teach problem solving as defined here.

What has been said should not be taken to mean that algorithms have no place in science teaching. Indeed, the complexity of real problems is such that no person is likely to solve them unless they complete routine aspects of the problems algorithmically.

Ill-Defined Problems. The area in which science courses have traditionally dealt with tasks that are problems for experts as well as novices is social issues with a strong science component, *e.g.*, acid rain, water and air pollution, nuclear energy, food additives, and synthetic pesticides. Such problems seldom have one solution if they have a solution at all. Furthermore, today's "correct" solutions may prove disastrous as additional information becomes available. Problems with these characteristics are said to be *ill-defined*. We call the "solution" to these ill-defined problems *decision-making* to distinguish it from solution of complex but well-defined tasks such as identifying a chemical in the school stockroom whose label has disappeared. The latter is described as a *well-defined* problem because, unlike most social problems, there is a single "correct" answer and the goal of the task is quite clear. However, there may be many ways to solve the problem. *Virtually all problems, whether well-defined or ill-defined, can be solved in many ways. Implying that the efficient procedure presented in the textbook or advocated by the teacher is the only way to solve a problem is misleading and does students a disservice.*

Important Considerations. A great deal has been learned about problem solving since 1980, and information from recent research may not be reflected in science courses taken by your students. Consequently, preservice teachers may be unfamiliar with the distinctions made in the preceding section, they may have experienced no models of teaching aimed at developing problem solving skills, their own problem-solving skills may be weak, and existing textbooks may provide little help in teaching problem solving to high school students. Until preservice teachers understand the distinction between exercises and problems and develop skills to solve problems, they are unlikely to be effective in teaching high school students to do so.

## Educational Technology

Educational technologies include all electronic learning media, such as television, VCRs, computers, telecommunications, radio, even overhead projectors. Knowing how and when to use these technologies has become an essential part of the education of science teachers. Not only do they make it possible to design truly new ways of teaching and new cognitive approaches, but they also help teachers prepare students for life in a society increasingly dependent on technology. Many schools now expect teachers, especially science and mathematics teachers, to be familiar with a variety of educational technologies and to be able to use them well.

The applications of technology to science teaching are numerous [See Moore (1989)]. Videotapes, videodiscs, and CD-ROM technology provide sophisticated animations of the invisible concepts of chemistry that are based on calculations using actual data. Instructional software provides opportunities to have students working independently or in small groups on simulations or tutorials, freeing the instructor to spend more time with individual students. Microcomputers can allow students to model industrial processes or simulate experiments and natural processes. Microcomputers interfaced with laboratory equipment make it possible for students to quickly collect large amounts of data, plot it as it is being generated, and pool their results. Electronic networks allow students and teachers to communicate with each other, with students at other schools, or with national experts.

Videotapes, videodiscs, and interactive CD-ROM computer lessons containing video images can integrate discussions of theory with visible examples [See Smith and Jones (1989)]. The use of computer-controlled video allows science students to explore microscopic realms such as cell components or to work with systems not possible to include in the laboratory, such as explosive mixtures, toxic chemicals, and processes carried out at remote sites (for example, auto collisions or moon landings). Since lengthy setup and cleanup procedures are eliminated, students can repeat experiments as often as they want, trying different strategies each time. The computer makes many more reactions accessible to students and allows more attempts to be made than would be possible in a hands-on laboratory. It also provides opportunities for students to introduce (and be forced to cope with) experimental errors before conducting related laboratory experiments [See Jones and Smith (1990)].

One of the most difficult problems in teaching science is conveying to students the three-dimensional structure of crystals and the structure and dynamic interactions of molecules. Molecular modeling software allows students to explore electronic structures, molecular skeletons, and molecular motions from many viewpoints. Other software programs make it possible for students tc construct, rotate, and compare different crystal lattices.

The use of microcomputers has had a profound effect on many science classrooms because of the opportunities they provide for active student involvement with learning. However, since software varies widely in quality you will need to review software before purchasing it and to obtain information on effectiveness from publishers, from colleagues, or from published reviews and articles.

## Contemporary Issues and Decision Making

Contemporary issues are "The Real World." They are inescapable and color every aspect of life, including science. Some of the most productive discussions you will have in your classroom can stem from exploring these topics. You will find no difficulty eliciting responses and opinions from your students as these discussions progress.

Due to the volatile nature of some of these subjects, if not properly facilitated, discussions could quickly escalate to arguments or confrontations. Thus, practice with this teaching method is important. You will soon begin to identify clear opportunities to develop critical thinking/informed decision-making skills in your students and yourself. You will see that students become interested and motivated, and by integrating science and technology with societal issues they will see the relevance of what they are learning.

Please note that many of these issues can be very controversial - strong feelings, whether well thought out or not exist on both sides. Some school districts even have policies on how teachers should deal with many of these subjects Sensitivity, responsibility, and common sense are important to model and encourage. It is especially critical (unless role playing a deliberately hostile atmosphere) to foster a classroom atmosphere of personal safety and acceptance regardless of one's position on a particular topic.

The topic of contemporary issues and decision-making in science is a large one. Familiarity with and interest in each subject will vary with student background. Thus, a plethora of opportunities exists for you to incorporate these topics into other teaching strategies as well as to explore many of these topics for their own sake. Some of the topics you may want to explore include: Global Warming; Ozone Depletion; Acid Rain; AIDS in Society; Nuclear Energy; Logging/Deforestation; Environment vs Jobs; Mining Practices; Genetic Engineering; Animals in Research; Politics of Science; Origins of the Universe; Superconductor Application; Computer Technology; Space Exploration; Evolution; Advertising Claims vs Scientific Fact and many others.

## Assessment

Through the assessment process teachers analyze whether the instructional goals have been attained with respect to individual students, teacher effectiveness, and the class curriculum. Thus, for the preservice teacher, assessment skills cannot be overemphasized, for without them, how will one know if they have "gotten there"?

Assessment skills are defined here as any process, either formal or informal, that allows the teacher to determine how well the students are progressing and if the instruction is appropriately meeting the students' needs. Assessment may be anything from listening to student conversation in small groups to formal, standardized testing. Evaluation, on the other hand, is making a judgment about that assessment. This unit will deal specifically with assessment.

The preservice teacher should be encouraged to select assessment methods that clearly show what their students know and can do. Preservice teachers, raised on traditional paper-and-pencil tests, often find it difficult to see that other forms of assessment, such as laboratory performance assessments, may be more appropriate tools and may "count" for evaluation purposes. Now that many states incorporate science performance assessment tasks in their high-stakes testing (testing developed to evaluate entire school districts or schools) teachers can help their students prepare for these tests by using alternative assessment methods in their classrooms.

Alternative assessment methods should not be employed simply because they are novel. Careful consideration should be given to selecting the method that most clearly demonstrates whether the goal has been achieved. If the goal is for students to be able to balance equations, a traditional paper-and-pencil test would be more appropriate than asking the children to come up with a rap song to demonstrate their understanding. A mock town council meeting is appropriate for open-ended, decision-making skills, and a laboratory performance test is appropriate for assessing process skills.

Self assessment is also important. Rather than the teacher being the only one to decide how the student shall be evaluated, teachers and students can work together to determine the goals, the methods of reaching those goals, and what behavior or product would show evidence that the student has met those goals. The student becomes a co-appraiser, and assessment of the student's progress becomes an on-going activity by both the teacher and the student. The distinction between learning and assessment blurs as the two processes build on each other.

Although assessment skills are often taught toward the end of preservice training, preservice teachers should be encouraged to see that when goals and objectives are developed, in essence the assessment is being delineated. Asking the question "What do I want my students to be able to do and know" is like setting a target for the students.

If the target is clear and it is not moving, students can hit it. Instruction becomes more powerful and learning more focused if the final assessment tool is decided upon before instruction begins: the students can see where they are going, the level of performance they are expected to achieve, and the teacher can provide models of expert performance to achieve the target.

## Professional Development

Continual self assessment leads to professional growth if the teacher conscientiously seeks standards by which to measure his or her classroom performance. Three general methods may be employed: self appraisal, peer coaching, and association with professional organizations and institutes.

Self appraisal can take many forms, but the teacher who reflects daily on the lesson and student progress - and writes these reflections down - will be more cognizant of personal development, have references when teaching the same material again, and have a list of areas for needed improvement.

Many teachers employ some form of peer coaching. Often districts will offer staff development classes in professionally developed courses [such as TESA (Teacher Expectations, Student Achievement), Peer Coaching, Clinical Supervision]. Preservice teachers should be encouraged to seek out these courses, or find a mentor teacher in the same building with whom to develop their own form of peer coaching.

Experienced teachers will attest that the most rewarding professional growth comes from the interaction with other teachers. This "networking" can be accomplished at local, regional, national, and international professional meetings, at summer workshops and institutes, and through continuing education classes. Preservice science teachers should be encouraged to join, at least, the National Science Teachers Association, NSTA and one organization in their specific area (e.g., the American Chemical Society, ACS, the National Association of Biology Teachers, NABT, the Association of Physics Teachers, APT). They should also be made aware that many other organization can contribute to their professional development, such as National Association for Research in Science Teaching, NARST, American Educational Research Association, AERA, Association for Supervision and Curriculum Development, Phi Delta Kappa, and related subject organizations, such as School Science and Mathematics.

# Resource 3: What Do I Need to Know

## What Do I Need to Know to Become an Effective Science Teacher?

**Conceptual Views**
Why Teach Science
What is Teaching and Learning

**Teaching For ?**
Meaningful Learning
Background of Knowledge
Inquiry Skills
Thinking Skills
Concept Development
Creativity
Positive Attitudes
Personal Needs
Career Awareness
Society and Technology
Misconceptions

**Instructional Strategies**
Inquiry
Lecture
Recitation
Discussion
Laboratory
Drill and Review
Demonstrations
Field Trips
Projects
Reading

**Instructional Skills**
Lecturing
Questioning
Leading Inquiry
Achieving Closure
Giving Directions
Blackboard
Using Media
Set Induction
Interpersonal Interaction

**Laboratory**
Types of Laboratories
Safety

**Planning**
Stating Goals and Objectives
Daily Lesson Plans
Unit or Chapter Plans
Course Plans
Redesigning Materials

**Materials**
Textbook Series
Curriculum Projects
Other Teaching Materials
Computer Software
Laboratory Materials
Facilities

**Evaluation**
Achievement
- Quizzes
- Summative Tests
- Formative Tests

Thinking Processes
Laboratory Skills
Affective

# Resource 4: Sample Student Assignments

*Example*

## Initial Planning Assignment

**Directions:** This assignment is about planning. Effective teaching involves careful planning. To develop good planning skills, a series of steps are necessary on your part. Below are a series of activities with due dates attached.

1. Obtain a science textbook at the junior or high school level for the primary area (chemistry, biology, physics or earth science) you will be teaching. It makes no difference whether the book is recent or of an earlier vintage. It must be a recognized high school textbook. Check with me if you are uncertain.

2. From that textbook, choose a chapter as the basis of your instruction planning for this assignment and the ones to come. You might scan the book to find a chapter that offers possibilities for utilization of a variety of instructional techniques.

3. For **Monday**, write 10 behavioral objectives for your chosen chapter. The first eight objectives must have the performance and the conditions components. The last two objectives must have the performance, condition, and criterion components. When you submit your objectives, please identify the textbook (title, publisher, and year) and the chapter you have chosen. Write a one paragraph summary of the chapter.

4. For **Wednesday**, using the intermediate lesson plan form and the expansions to it discus ed in class, write a lesson plan for a daily lesson for your chapter using one o two objectives. Illustrate a least two teaching strategies in your lesson plan.

5. For **Friday**, submit a lesson plan that incorporates an inquiry strategy. Again, utilize the intermediate lesson plan form and the chapter you have chosen.

*Example*

## Demonstration Assignment

You are to prepare a demonstration, either from the *SourceBook* module or another source. You will turn in a written description of the demonstration, with a list of materials and safety precautions. You will also present your demonstration to others as if you were teaching a class.

Your demonstration can be designed to achieve one of the following objectives:

1. initiate thinking
2. illustrate a concept, principle, or point
3. answer a student question
4. review ideas previously taught
5. introduce or conclude a unit

Your demonstration is not to exceed 15 minutes.

You will be evauated according to the following:

Economy

Ease of preparation

Appropriateness of the demonstration for its purpose

Ease with which students can see/hear the demonstration

Ability to involve students in the demonstration

*Example*

## Test Construction Assignment

**Directions:** This assignment is about constructing a test. This will give you an opportunity to experience the steps necessary from beginning to end in constructing a classroom test.

For the chapter in which you have written objectives and constructed lesson plans or another chapter of your choice, you will construct a short chapter test of the summative variety. Your test should contain the following elements:

1. Multiple choice questions
2. True false questions
3. Short answer questions

Prepare this test as if you would actually give it in class to your students (typed). Assume that the test will be given during a time span of 30-40 minutes.

*Example*

## Test Assignment Feedback

Below are a number of critical elements concerning the construction of a test that should be present. For an examination of your assignment, those elements checked indicate that their presence or modification will enhance your test from the perspective of the student taking the test or of the teacher who must grade this test.

### Critical Elements

1. Test Identification - course, year, test #, topic.
2. Student Name.
3. Place for Total Points and Grade.
4. Directions for whole test.
5. Directions for each part of the test.
6. Space on test for response to Multiple Choice and True False questions.

**Or**

7. Separate response sheet for Multiple Choice and True False questions.
8. Like questions grouped together.
9. Space conservation used on multiple choice responses.
10. Appropriate space for short answer and problem responses.
11. Point value given for short answer and problem questions.

**Comments:**

*Example*

## Assignment in Unit Planning

**Objective**: Each student should be able to demonstrate competency in effectively planning for both long term instruction and concept building.

Constructing the Science Unit

1. Choose from chapter from your area of specialization. It could the one your have already work with in the initial planning assignment. Your chapter should be narrow in scope yet broad enough to allow for a variety of learning experiences, activities, sequences, and materials.
2. Write your instructional unit so that it covers a period of approximately two weeks, with science periods of 50 minutes per day, five days per week.
3. Write your instructional unit according to the following format:
   a. Title Page
   b. Overview of the Unit

      what is the purpose of the unit

      what concepts do you intend to teach

      what are your overall objectives

      how do you intend to initiate the unit

      how do you intend to evaluate what is learned
   c. Daily Activities

      objectives

      materials and equipment

      concepts

      description of teacher and student activities

(You need not write detailed, specific, extensive lesson plans. The main objective is planning, not writing lesson plans. Just describe what you intend to do, include evaluation techniques—where appropriate)

d. Concept Map

e. Sources of activities utilized in this assignment.

Evaluation of the Science Unit

Your unit will be evaluated according to how well your planning unit demonstrates evidence of:

Does it follow logically step-by-step in building concepts within your topic?

Does it provide for hands-on activities?

Do the activities agree with the objectives of the unit?

Does it appear teachable?

Suggestions for the Science Unit

The purpose of the science unit is to enable the teacher to plan for learning of a particular area of study in a logical fashion in which the sequence of learning objectives and activities has coherence. The day-by-day learning should develop objectives which develop a basic concept. A unit is not a hodgepodge of unintegrated lessons.

## Resource 5: Sample Course Syllabus

*Sample Syllabus Starting Point*

### Teaching of Science in Secondary Schools

**Course Description**

A study of theory, research, issues, trends and modern approaches of teaching science in secondary schools. Competencies that reflect effective science teaching practices will also be developed.

**Course Topics**

Emphasis in the course will be placed on the following topics:

- Nature of Science and Relationship to Technology and Society
- Goals and Objectives of Science Education
- Inquiry Learning and Teaching
- Application of Learning Theory to the Science Classroom
- Constructivism in Science

- Concept Mapping and Concept Development
- Effective Teaching Practices in Science
- Teaching for Conceptual Understanding, Critical Thinking and Problem Solving Skills
- Role of Explanation
- Teaching for Individual Needs and in Culturally Diverse Settings
- Curriculum Approaches
- Trends of Science Teaching
- Resources and Materials
- Planning
- Evaluation Procedures
- Educational Statistics
- Instructional Technology
- Safety in the Science Classroom

## Course Objectives

Upon completion of this course, Teaching of Science in Secondary Schools, you should possess knowledge of or be able to:

1. Discuss the relationship between the nature of science, technology, and society and its importance to modern goals of science education, curriculum materials, and future directions of science teaching and learning.
2. Develop content-based lessons for various topics that promote the goals and objectives of science instruction in the junior high and senior high school (career awareness, science, society, and technology issues, and the development of personal interests).
3. Distinguish between various cognitive learning theories and their application to science teaching and learning.
4. Describe the role of contructivism in science teaching and learning and its importance to curriculum materials and science teaching and learning.
5. Distinguish between science as inquiry and teaching and learning by inquiry.
6. Describe inquiry teaching and learning. Contrast it with non-inquiry learning approaches.
7. Devise and conduct inquiry oriented laboratory exercises, discussions, demonstrations, and lectures.
8. Discuss the research associated with inquiry teaching and learning.

9. Demonstrate appropriate pre-instructional strategies and focusing strategies before, during, and after instruction through the use of communicating the objectives of instruction to the student, set induction techniques, and advance organizers.

10. Identify and illustrate teaching strategies of other cognitive approaches to promote learning of science concepts.

11. Identify and use a variety of strategies for developing conceptual understanding of science topics such as: the use of scientifically correct explanations or representation, use of appropriate examples in lessons, use of questions to clarify understanding and to evoke explanation of various phenomena on the part of the student, and the use of appropriate concreteness or realism in choice of materials.

12. Identify and use strategies that provide for opportunities for students to engage in non-routine problem solving activities.

13. Select and use questions, problems, unknown elements, and activities designed to develop higher-order thinking, problem solving skill, and curiosity.

14. Identify and use evaluation techniques designed for students to apply what they have learned in different contexts, draw conclusions from data, and to explain various phenomena.

15. Describe and construct various discussion activities: Morphological analysis, pictorial riddles, counterintuitive events, inquiry development sessions, synectics, etc.

16. Demonstrate appropriate planning procedures (both long and short term) in an effort to prepare students for instruction and to maximize learning outcomes through selecting materials and learning experiences to stimulate student curiosity and support student investigation or activities and preparing for a broad range of alternative ideas and situations which students may raise questions related to a central topic.

17. Describe major characteristics of science curriculum materials appropriate for area of certification.

18. Develop familiarity with commercial textbook series and other support software.

Identify and discuss curricular patterns that currently exist in area of certification and any emerging trends.

19. Describe the nature of current science instruction in the secondary school in terms of how teachers teach and current levels of student achievement.

20. Identify trends in secondary science education and determine their importance to various education settings.

21. Identify instruction strategies based on research which will result in effective teaching practices.

22. Describe the specific safety precautions to be taken relative to your particular teaching field.

23. Identify the legal responsibilities with regard to safety in the science classroom.
24. Prepare a lesson plan for teaching laboratory safety, skills, and techniques in your teaching area.
25. Identify and develop laboratory experiences to accomplish the various roles the laboratory 26 can provide.
27. Identify, describe and demonstrate effective classroom management techniques for conducting all phases of science instruction.
28. Identify facilities and materials needed to conduct a modern inquiry oriented science program.
29. Demonstrate procedures to inventory, store, order, and maintain laboratory materials and supplies.
30. Illustrate how individual differences can be provided for in science programs in general and in culturally diverse classrooms in particular.
31. Identify techniques and devise science activities that promote the development of creative thinking skills in students.
32. Construct evaluation devices which assess student's understanding of the processes of science, subject matter competency and achievement, scientific attitudes, laboratory skills, and work attitudes.
33. Write a comprehensive summative test for a unit of work in a science class of your choice. Identify and use measures of frequency distribution, central tendency, variability, correlation, and regression.
34. Identify and apply tests of differences between means, analysis of variance, chi square and other non-parametric measures.
35. Analyze and interpret educational research in terms of research design, hypothesis generation and testing, and degrees of significance.
36. Identify various instructional approaches involving the use of emerging technologies for secondary science classrooms.

**Textbook**

**Requirements of the Course**

1. Read the textbook, articles, and materials handed out in class.
2. Prepare and give a 15-minute lecture.
3. Present daily lesson plans illustrating a variety of teaching strategies.
4. Teach one demonstration, either a verification or inquiry type to the class.
5. Construct a classroom test in your area according to the assignment sheet.
6. Prepare a two week instructional unit using a variety of teaching techniques.
7. Complete a written analysis of science materials according to the assignment sheets.

8. Write a major paper on topics to be assigned in class.
9. Write a series of short papers on topics designed to reflect and integrate course content and readings.
10. Complete homework assignments given periodically throughout the term.
11. Complete the midterm and final examinations designed to measure understanding of pedagogy.

**Course Grade**

Your final grade will be a combination of the above and the experiences of this course. The distribution will be announced during class at a later date.

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