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ABSTRACT

Based on the idea that reading instruction in science means teaching simultaneously the science content and the reading and reasoning processes by which that content is learned, this booklet offers practical and theoretical suggestions for science teachers to help students improve their content area comprehension. Chapters discuss the following areas: (1) learning from science text, (2) diagnosis in teaching science, (3) prereading strategies for teaching science, and (4) the use of guided materials in teaching science. The booklet also contains a statement on the need for collaboration between reading teachers and science teachers in the best interest of students. Appended are an informal study skills inventory on a physical science textbook and an essay for students on expanding their thinking abilities. (HTH)

reading aids series

IMPROVING READING IN SCIENCE, Second Edition

Judith N. Thelen

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CONTENTS

ERRATA

The foreword for Improving Reading in Science, Second Edition, by Judith N. Thelen was set incorrectly. The foreword which is shown on page v varies in a number of ways from the foreword which was intended for the second edition of this publication. Future printings of Improving Reading in Science, Second Edition, will include the correct version.

Figure 24, shown on page 44 of Improving Reading in Science, Second Edition, by Judith N. Thelen, has an incorrect caption. The caption should read: Figure 24: Variation of the Every-Pupil Response.

FOREWORD

In this second edition of *Improving Reading in Science*, Judith Thelen presents a good mix of the practical and the theoretical in her message to science teachers. Her recommendations are both experientially and experimentally based. Importantly, her message is not a set of exhortations but rather a set of examples and suggestions.

To some, teaching reading in science means to bring into the science classroom instruction which is usually done in the reading class. Time is set aside from the curriculum for the direct teaching of reading and a dichotomy is created between science and reading.

This monograph is based on the idea that reading instruction in science means to teach simultaneously the science content and the reading and reasoning processes by which that content is learned. The reading taught in the science classroom is the reading that is required by the curriculum. Science teachers can teach their students how to read required materials as needed.

Science teachers who use Dr. Thelen's ideas will find them helpful in the science classroom. Students will find the instruction helpful in their learning. And that is the ultimate test.

Improving Reading in Science, second edition is a welcome addition to the International Reading Association's growing list of publications.

Harold L. Herber
Syracuse University

Chapter 1

LEARNING FROM SCIENCE TEXT

The textbook plays a dominant role in science learning. How much reading is done in science classes? Stuart (1982) quoted a U.S. Government document citing that 93 percent of all secondary school science classes (grades 7-12) utilized one or more textbooks. Science teachers are constantly complaining that students can't read the assigned textbooks and as a result are not learning. Science educators Santesteban and Koran (1977) wrote: "Students with low verbal ability and low motivation remain the largest segment of the school population to which we are attempting to teach science. At the same time, written materials, in the form of science texts, laboratory guides, and worksheets, still occupy a major place in science instruction" (p. 56).

Reading teachers, feeling guilty about the reported reading levels of the students, often shift the responsibility back to the content teachers with the old cliche, "Every teacher is a teacher of reading."

Both positions place the responsibility for learning on the textbook. The primary source of information should be the science teacher, not the textbook. Textbooks should be used to reinforce and expand on the concepts learned in class. Publisher William Jovanovich defended the use of textbooks as a tool by asking, "Is it not futile to decry textbooks when it need only be said that the wise teacher uses a text at his own pace and in his own way? One does not blame the adze if a shipwright is lazy or incompetent" (Broudy, 1975, p. 15). Good shipwrights would hardly blame the quality of their work on a deficient tool. Why, then, should science teachers blame the quality of their work on textbooks, or on the students' ability to learn from them? Science educator Jill Wright (1983, p. 3) wrote: ". . .much science content knowledge must be gained through reading. As with most academic subjects, reading is a vital tool for the successful science student."

The textbook is a tool, just like the microscope is a tool. It is not the intent of this monograph to make reading teachers out of science teachers but to give the science teachers some strategies to make the textbook an effective tool. Textbooks should be used by science teachers, not in place of them.

• Suggested Uses of the Textbook

Some authors suggest that teachers rewrite the content material at a lower level of difficulty. Teachers will say they don't have time to rewrite the material, and they are correct. Besides, rewriting the material may make it more difficult to read (Pearson, 1974-1975).

Others advise multilevel content textbooks so the teacher can assign students materials on their proper reading levels. However, research by Daugs (1977) showed no statistically significant differences in cognitive achievement gains among classrooms using multilevel science texts and those using one level of material.

Then there are those who believe we should go back to the basics. "Basics" to them means teaching reading skills; particularly word attack, decoding, and/or phonics. They feel that once students have learned to sound out the words they will be able to read the textbook. If students already know the words, this is true. Unfortunately, knowing how to pronounce a word does not guarantee that students will know the *meaning* of the word. There is nothing more basic to reading than comprehension. Students are failing because they can't comprehend assigned reading from textbooks.

Reading comprehension is a process. It means understanding printed language, and it means using prior experiences to make sense of that printed language. Smith (1979) said that comprehension was making sense out of what one reads and that "A common characteristic of poor readers in high school is that they read as if they do not expect what they read to make sense, as if getting every individual word right were the key to reading" (p. 36).

• Language

It goes without saying that the first requirement for understanding what one reads is that one must understand the language in which the book is written. By the time they enter school, most students are very adept in listening to and speaking their language.

For example, when asked to complete the following sentence, "I went swimming in the ____ ," most youngsters will respond with "pool," "pond," "ocean," "water," "morning," or any other noun that makes sense. They won't be able to tell us the word they replaced was a noun. They put in a word that makes sense because they have been users of their language for a long time. And as users they also have the ability to generate their own rules and respond correctly to questions on material even if the material makes absolutely no sense to them.

To illustrate, students were asked to read the first stanza of Lewis Carroll's *Jabberwocky* and answer the questions that follow:

> Twas brillig, and the slithy toves
> Did gyre and gimbel in the wabe;
> All mimsy were the borogoves,
> And the mame raths outgrabe.

1. What were the toves doing?
2. Where were they doing it?

Most of the students answered "The toves were gyring and gimbling in the wabe." Notice that even when they didn't understand the vocabulary, they changed the tense of the words to match the tense expected by the question, "What were the toves doing?" "The toves were gyring and gimbling." The students do that because they are successful users of their language. They have learned to respond to their language. Often teachers are fooled by students who respond correctly to literal level questions without understanding most of what they read.

Here is another example from a science class. Some physical science students were given the following sentence to read from their text (PSNS, 1969): "In the melting process, ions of the melt collide with ions in the crystals and give these ions enough energy so that they can escape from their potential wells; those ions enter the melt" (p. 410). Two questions were then asked: "What happened in the melting process?" and "What did the collision of the ions in the melting process do to the ions in the crystal?" The students answered, "The ions of the melt collided with the ions in the crystal." and "The ions in the crystal were given enough energy to enable them to escape from their potential wells." Yet, when asked what that meant, they could not explain it (gyring and gimbling!).

Although those physical science students used their language skills they still didn't comprehend. The thought expressed in that language did not make sense to the students because they had no meaning for, or prior experience with, the terms used by the authors.

• Prior Knowledge

Prior knowledge or prior experience with some aspect of the new material to be learned is essential for comprehension of the printed word. If students don't have anything in their prior experience that is relevant to the new material to be learned, they often attempt to memorize it. Vachon and Haney (1983) call this "survival by memorizing and this is not what we should be seeking."

This is not just a concern of reading educators. Science educators acknowledge that one of the most important variables to influence science learning is the learner's relevant background knowledge. Novak (1976) said, "There is a growing body of evidence to indicate that some reasonable degree of learning for most any concept can take place if proper instructional sequences are provided, and examples and activities are used that will relate to the prior experience of the learner" (p. 504).

West and Fensham (1976) state that if students were assigned a chapter on "potential energy," those students lacking knowledge of "energy" would have difficulty relating the new chapter to what they already know. It probably would not make much sense to them. Learning should be meaningful. Relating what is read to what is already known helps make sense out of printed text and thus, makes it meaningful.

If the text doesn't make sense, students become bored. Bored students gradually withdraw from the learning situation by refusing to do classroom assignments, missing classes, and/or becoming discipline problems in class.

When students are required to use reading as a tool, science teachers must have ideas that will assist students in comprehending what is read. It is the purpose of this monograph to provide science teachers with suggestions on how to help students make sense out of what they are expected to read.

One suggestion is to change the way materials are assigned. Most teachers follow the model in Figure 1.

Students are told to read the next chapter, often as they are rushing out the door. Some will, some won't, some can't. During the next class meeting, quite a bit of time is spent discussing the assignment with those who read it, clearing up misconceptions for those who did not understand it.

Most science teachers agree that their primary responsibility is to teach the concepts of their subjects. When the above method is used, the textbook becomes the primary source of information and replaces the teacher.

In the next model the textbook is used by the teacher and not in place of the teacher (see Figure 2).

Figure 1. Model developed by Margaret Early, Syracuse University, 1980.

ASSIGNMENT: OLD STYLE

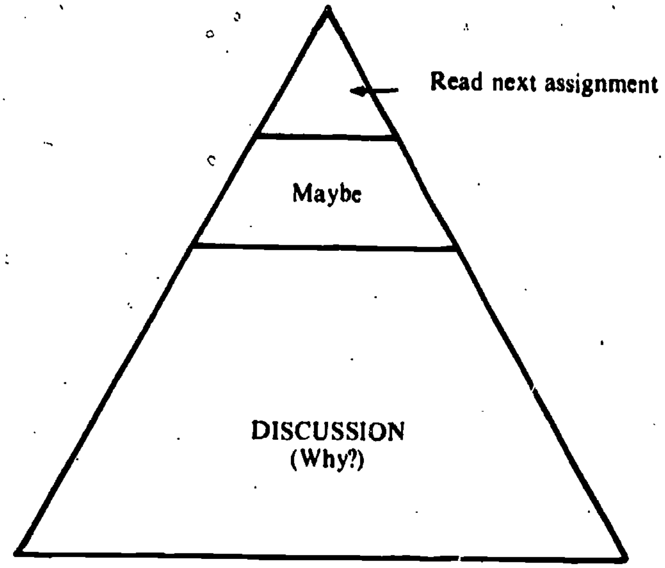
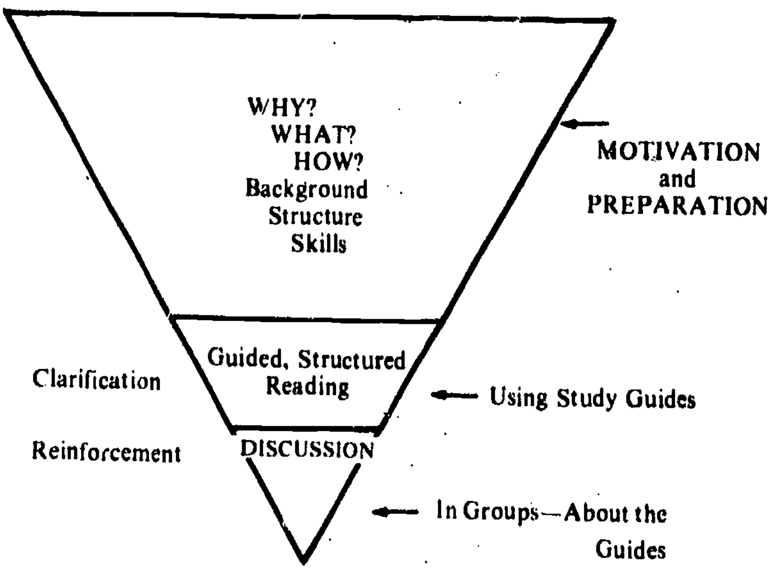


Figure 2. Model developed by Margaret Early, Syracuse University.

ASSIGNMENT: NEW STYLE



In the first part of this model, the teacher 1) aids the students in organizing what they already know, 2) provides relevant background knowledge if it isn't present, and 3) relates those experiences to the new material to be learned. Again taking potential energy as an example, it would be to the teacher's advantage to find out what the students already know about energy and teach them accordingly.

There are many prereading strategies designed for teachers to aid their students. These strategies will be discussed in Chapter 3 of this monograph.

Using preparation techniques is an important step in facilitating learning from assigned reading but it may not be enough. Many students need guidance to comprehend the material. The second stage in the new style model involves guidance. Guidance is the procedure of helping students through the concept forming processes and can be accomplished by the use of reading guides. It's not enough to tell students what to look for when assigning reading from a textbook. If students with low verbal ability and low motivation are not provided with some guidance, they may learn a few key terms or sentences by rote without trying to understand what they mean. Chapter 4 contains some suggestions for the use of guided material.

Discussion is the last stage of the new style model. It is during this time the teacher and the students actively attempt to relate the new material to material already learned.

There is some scholarly research on a quick and efficient test that measures a reader's ability to use prior experiences in dealing with the language of the text. Chapter 2 will include this test and a study skills test. Chapter 3 contains prereading activities that science teachers have used with some success. In Chapter 4, activities for guidance are presented and in Chapter 5 activities for reinforcement of vocabulary and comprehension are presented. Chapter 6 contains ideas for evaluating teaching and learning in science.

Chapter 2

DIAGNOSIS IN TEACHING SCIENCE

The science teacher, whose goal is to teach a student rather than a textbook, wants first to determine the student's ability to handle a given textbook. Two methods of diagnosing are suggested here: the cloze technique and an informal study skills inventory to evaluate skills necessary for reading the text.

• The Cloze Technique

Science teachers often report that reading difficulty levels in many textbooks in all areas of science are too advanced for the students for whom they are written. The cloze method developed by Taylor (1953) can be used to accurately and quickly screen each student's ability to understand the language of the text.

Cloze Reliability and Validity

Levels of individual learners have been classified by reading authorities (Betts, 1946, in particular) as independent, instructional and frustration. For all practical purposes, the independent level is the highest level at which learners can read on their own. The highest level at which learners can read *with teacher guidance* has been labeled the instructional level. The frustration level is that plateau where learners are frustrated in their attempts to comprehend and decode. Materials are considered suitable for use in learners' independent study if they can correctly respond to 90 percent of the questions constructed on those materials, and suitable for guided instruction when they respond to only 75 percent of those questions.

Studies were conducted by Bormuth (1967, 1968) and Rankin and Culhane (1969) to establish a frame of reference for interpreting cloze test scores when they are used to measure the comprehension difficulties of passages. They established this frame of reference by determing comparable scores on cloze and multiple-choices tests. Rankin and Culhane's study was a replication of Bormuth's 1968 study. Conclusions indicate that if students receive cloze scores of 61 percent on a passage, they would probably answer 90 percent of the multiple-choice items that can be written on that passage. A cloze score of 41 percent would compare to a 75 percent multiple-choice score.

If the percentages established by the research of Bormuth and Rankin and Culhane are to be used, it follows that the criteria for construction, administration, and scoring must be followed. Any variety in the criteria would violate the standardization process which is as basic as reliability and validity.

Cloze Description and Construction

A cloze test is constructed by mutilating, or deleting, words from a selected passage from the text one intends to use for instruction. Mutilation is accomplished by randomly deleting every fifth word and replacing those words with 50 blanks of equal length (about 1½ inches). The test should start and end with a complete sentence. An example of a cloze test can be seen in Figure 3.

Figure 3. Cloze Test on the Introduction to Physical Science for Nonscience Students.*

Why does a person become a scientist? Ask _____ and he will probably _____ you that he gets _____ enjoyment, excitement, and intellectual _____ from working in science _____ from anything else he _____ think of doing. Nature _____ a great mystery that _____ him. Like a detective _____ to solve a crime, _____ scientist tries to understand _____ by piecing together his _____ and the observations of _____ into a coherent whole. _____ many students not majoring _____ science find these courses _____ and not all _____. Must this be true? _____ don't think so. We _____ that it is possible _____ the scientist to impart _____ of the fun he _____ in his work to _____ nonscience students.

In this _____ we hope that you _____ experience some of the _____ and enjoyment we find _____ science by joining us _____ we undertake a scientific _____. We hope that you _____ encounter the thrill of _____ and discovery, the disappointment _____ things don't seem to _____ together properly, and the _____ of success when they _____. We also expect you _____ share in the hard _____ of interpreting your own _____ about nature. You will _____ able to make sense _____ of your observations only _____ you have some background; _____ this depends, in large _____, on you. It will _____ that you study and _____ important material. As the _____ proceeds, you will gain _____ familiarity with this material _____ will be able to _____ more deeply in the _____.

In science, as in the rest of life, interpretations are subjective.

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*From *An Approach to Physical Science*. Reprinted by permission of John Wiley & Sons, Inc., Publishers.

Cloze Administration and Scoring

Cloze tests are distributed to each student with oral instructions to read the mutilated passage and fill in all blanks, one word per blank, by guessing from the context of the remaining words what the missing words should be. Time limits should not be imposed on the tests.

Perhaps the greatest feature of this test is the facility with which it is scored. Two points credit is given only when the exact word deleted is supplied. Research by Taylor (1953) and Bormuth (1967) indicates that when cloze tests are used as measures of individual differences in reading ability, scores obtained by counting exact replacements and not synonyms, more often yield valid scores. Rankin and Culhane note that counting synonyms makes scoring cumbersome and could lead to arbitrary decisions regarding the worth of the synonym as a replacement. Words spelled incorrectly should not cause a correct response to be counted as wrong.

A score between 41 and 60 percent usually means the material is at the student's instructional reading level; that is, materials at this level are suitable *if the student has guidance from a teacher*. Some methods of guidance are suggested later in this monograph.

Papers with scores that fall below 40 percent should be carefully reexamined by the teacher. The cloze test is merely a screening device to separate levels of learners. Scores above 40 percent indicate that students have supplied appropriate replacements for deleted words and probably will not have much difficulty reading the book at the literal level. Scores below 40 percent do not necessarily mean the student will have difficulty reading the material. On the contrary, the examiner may discover the student has chosen better or more appropriate synonyms than the author of the passage. It is appropriate, at this time, to read for synonyms; additional points for synonyms may not be given but a subjective judgment can be made. If the student has not written appropriate or relevant synonyms, the teacher can expect the student to have difficuly reading the textbook. A cloze score above 60 percent usually indicates that the material is easy enough for the student to read without assistance.

• The Informal Study Skills Inventory

Spiegel and Wright (1984) discovered that in selecting textbooks for their students the characteristics biology teachers rated high in importance for their students were locational aids such as figures, graphs, and diagrams. Therefore, once teachers have determined that the text material is suitable for their students by using a cloze test, it would be to the teacher's advantage to discover whether the students have the necessary study skills for the successful use of that text. Some of the study skills useful in science are included in Figure 4. An informal study skills inventory is an instrument classroom teachers can use to determine which skills need to be taught.

Informal Study Skills Inventory Description and Construction

An informal test should be used with the text. Using the list of skills in Figure 4 as a guide, teachers should determine which of these skills will be needed by the students to facilitate the understanding of the text and to complete assignments.

The next step is to construct items that require students to use the whole text and the particular skill to be measured. For example, when measuring locational skills, the following questions might be asked:

Number the following in the order they will be dealt with in the textbook

_____ Molecular motion
_____ Solubility and solvents
_____ Characteristic properties
_____ Quantity of matter, mass
_____ Sizes and masses of atoms and mulecues

The answers to the above questions were found in

_____ Index
_____ Table of Contents
_____ Looking through the book
_____ Epilogue
_____ Introduction

For ease in scoring the tests later, each item should be labeled to indicate which skills it measures. For example, the above sample should be labeled *Locational Skills.* An example of an informal test (developed by Scott L. Shablak of Syracuse University) on a science textbook is provided in Appendix A.

Figure 4. Study Skills Needed to Aid in the Understanding of Scientific Materials.

Vocabulary Skills

Using context
Using prefixes, suffixes, and roots as aids to meaning

Locational Skills

Using graphs, charts, tables, figures, scales, and diagrams
Using a glossary
Using table of contents and index
Using appendixes
Using chapter headings and subtitles

Comprehension Skills

Following directions
Locating main ideas, supporting details
Following sequence
Organizing
Using problem solving techniques in
- formulating hypothesis
- collecting data
- organizing data
- forming a conclusion
- testing a conclusion

Others

Observing
Gaining knowledge of labs and apparatus

Informal Study Skills Inventory Administration and Scoring

The informal study skills inventory should be given early in the semester so that the teacher can use the results for long range planning. Students should be told why they are being given the test. No more than one class period should be needed to administer the test, but students should be informed that the test will not be timed.

Scoring is not so easy as in determining the level of difficulty of the textbook but is similar to, and will probably take as much time as, the scoring of a content test. When all of the items have been scored, the results should be recorded on a class analysis chart (see Figure 5). Each chart is constructed by filling in those skills the inventory measures. Niles and Early (1955) suggest that pupils' scores be recorded as follows:

a. Leave the space blank if the students have demonstrated acceptable competence in a given skill.
b. Use a single check if they are having some difficulty.
c. Use a double check if they are having extreme difficulty.

Thus, an indication of those skills that need to be taught to the class as a whole can be seen by reading the chart vertically. Suggestions on teaching the relevant skills in the science classroom are discussed in later chapters.

Figure 5. Class Analysis Chart.*

Textbook ____________________ Subject ____________________ Grade __________

Name	Skills from Informal Inventory										Comments
	Vocabulary		Locational			Comprehension					
	Using Affixes	Using Content	Graphs	Figures	Tables	Following Directions	Sequence	Organizational	Main Ideas	Supporting Details	

*Reprinted from Olive Niles and Margaret Early. Adjusting to individual differences in English. *Journal of Education*, 1955, 138.

Chapter 3

PREREADING STRATEGIES FOR TEACHING SCIENCE

In developing the concept of preparation, we have to assume two principles: the students' existing cognitive structures and the material they must learn.

Student preparation for learning new material is essential to the learning process. If students are forced to learn new material (for example, the concept of potential energy) before they master the necessary backlog of experience for the concept of energy, they may become frustrated and resort to memorization of definitions and trivia. Student preparation is an important but neglected area of teaching. The following section presents a brief explanation of the theory behind the activities suggested later in this chapter.

• Cognitive Structure

Cognitive structure may be defined as all of an individual's *existing* knowledge. It may be likened to an ideational filing system. Individuals have their own ways of organizing existing knowledge hierarchically into their personal "filing cabinet." For example, most students understand the concept, *animal*, and may include in a personal filing system smaller concepts such as *dog*, *horse*, and *cat*. Have you seen the look of surprise on students' faces when they discover that *they* are animals? This situation results when the cognitive structure does not have the necessary attributes for a particular concept to enable learners to relate new material to what they already know. This may not happen, for example, if their concept of animal includes attributes such as living organisms having hair, eyes, nose, mouth, and legs.

As students encounter new ideas, they need appropriate filing systems for storing the information. Meaningful learning takes place when two things are properly organized: students' existing cognitive structures and material to be learned.

If students have nothing in their cognitive structure that can be related to new material they often attempt to memorize the material.

Ausubel and Robinson (1969, p. 58) warned us of this with the following admonition.

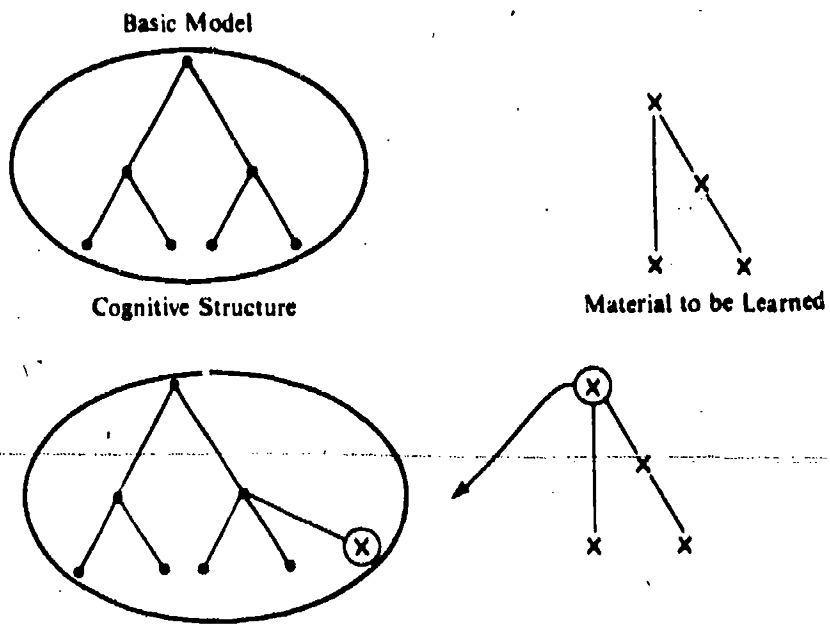
> One reason why pupils may develop a rote learning set in relation to potentially meaningful subject matter is because they have learned from sad experience that substantially correct answers, which are, however, lacking in verbatim correspondence

to what they have been taught, receive little credit from certain teachers. If we require verbatim answers and judge others to be inaccurate, then rote memorization obviously is being encouraged and rewarded. Another reason for a rote learning set may be that because of a generally high level of anxiety, or because of chronic failure in a given subject, some students lack confidence in their ability to learn meaningfully and hence perceive no alternative to panic, apart from rote learning. Finally, some pupils may develop a rote learning set if they are under excessive pressure to exhibit glibness, or to conceal rather than admit, and gradually remedy, an original lack of understanding. Under these circumstances it seems easier and more important to create a spurious impression of facile comprehension by rotely memorizing a few key terms or sentences than to try to understand what they mean.

Rather than observe, apply concepts, interpret, interrelate to larger concepts, and solve problems, Novak (1976) says the sequence becomes: observe, memorize, test, and forget!

Robinson (1970) prepared an excellent schematic representation of cognitive structure and its relationship to material to be learned. He represented cognitive structure as an oval (see Figure 6) and the existing ideas within as a series of dots. The material to be learned—also organized and exhibiting some structure represented outside the cognitive structure—is characterized by Xs.

Figure 6. Schematic Representation of Cognitive Structure and Its Relationship to New Materials to Be Learned.



(new idea incorporated into existing cognitive structure by relating the new idea to ideas already present)

If the cognitive structure is organized, and/or if the student is told where and how the new material "fits," the new idea should become part of the student's cognitive structure. Raths (1967) contends that, if this theory describes the way a student learns new material, teachers must organize their teaching to insure that their students possess in their cognitive structures, general concepts under which they can incorporate new material. The general concepts should be organized and presented to students before they are confronted with new learning tasks. Ausubel (1968) labels these aids as advance organizers.

• Receptive/Discovery Learning

There has been some concern expressed, especially by science teachers, about Ausubel's theory (referred to as receptive learning). So many of our students appear to utilize only concrete thoughts and are not ready for formal operational thoughts. Therefore, they must engage in discovery learning as opposed to receptive learning. In discovery learning, the learners must act on the material in order to be led to the final form of the concept. In receptive learning the concepts to be learned are given to students in the final form. In both instances the material in its final form must be related to cognitive structure. Concept attainment models presented in this chapter can be used by teachers to ascertain what the learners already know and to teach them, using both receptive and discovery learning techniques.

• Advance Organizers

Ausubel suggested that students be presented with passages containing an orderly arrangement of highly generalized concepts needed in their cognitive structure *before* they try to learn new concpets. Called *advance organizers*, Ausubel's passages were given in advance of the new material to be learned. The intent was to organize students' cognitive structures and prepare them for the new material by providing very generalized concepts which would later provide hooks for grasping new knowledge. In that way, the new materials could readily be incorporated into students' existing cognitive structures.

In 1960, Ausubel experimented with a passage on the properties of steel as an alloy and the relation of its internal structure to 1) temperature, 2) carbon content, and 3) rate of cooling. In the experiment, one group of college students read a short introductory passage (advance organizer) on the more abstract material explaining that, because of its limited grain structure, pure metal should be alloyed with other metals or nonmetals to create a wider variety of metals; and that to know the grain structure of an alloy one must know 1) the temperature, 2) its principle metal component, and 3) its cooling rate. The control group of students read a historical passage describing methods used in processing iron and steel. Both groups then studied the steel passage and took a multiple-choice test on it three days later. The group which had studied the advance organizer did significantly better. That is really not too difficult to understand when you compare the information in the organizer with the passage; it actually relates the steel passage to something and sets a purpose for reading the steel passage.

Ausubel suggests that teachers consider presenting fairly general and abstract introductory material before assigning difficult, detailed information. However, advance organizers are difficult to construct and Ausubel has not set down rules or instructions for constructing them. Robinson (1970) offers some directions for creating organizers:

> Possibly the only coherent advice that can be offered is that the teacher begin by attempting to construct a map or diagram of the interrelationship of the concepts to be learned and a second map of the interrelationship of these concepts in the learner's cognitive structure which might be used for anchorage. With this visual representation

in front of him, the teacher will probably then be able to ascertain which ideas, because of their superordinate position with respect to the most general notions in each map... should be included in the organizer. (p. 50)

Barron (1969) recognized that the absence of directions for constructing advance organizers would pose a serious problem for the overburdened classroom teacher. Thus, he developed a preparatory technique which, in theory, is similar to an advance organizer but, in use, is more practical. The technique bears resemblance to Robinson's visual representation of content and cognitive structures. Barron's organizers are different from advance organizers in that they are not written in prose form and do not have to be read by the learners. In addition, Barron's organizers attempt to structure both the cognitive structure and the material to be learned.

Barron's graphic organizers are called structured overviews and are defined by Estes (1969) as "visual and verbal representation of the key vocabulary of a learning task in relation to more inclusive or subsuming vocabulary concepts that previously have been learned by the student." Estes explains the construction of a structured overview as a graphic arrangement of words relevant to the important concepts in the learning passage. It illustrates how the concept to be learned relates to the concept in its hierarchy.

The creation of this visual representation depends on two things: how well science teachers have internalized their subject as a science and how structured the subject matter is.

• Structured Overview

One of the most difficult tasks in building a structured overview is the selection of important concepts. So often, teachers are more concerned with teaching books than with teaching concepts. Hurd (1970) suggests that this mad pace to cover the textbook by the end of the school year results in students' learning by rote and acquiring concepts which are shells of verbalism. He goes on to say that the majority of textbooks contain too many concepts and teachers should select representative concepts, preferably those which provide a sense of direction within a science and which open doors to future learning.

Once the concepts of teaching have been selected, the construction of a structured overview is relatively easy. Barron (1969) presents the following six steps:

1. Analyze the vocabulary of the learning task and list all the words that you feel are important for the student to understand.
2. Arrange the list of words until you have a scheme which depicts the interrelationships among the concepts particular to the learning task.
3. Add to the scheme vocabulary terms which you believe are understood by the students in order to depict relationships between the learning task and the discipline as a whole.
4. Evaluate the organizer. Have you clearly depicted major relationships? Can the overview be simplified and still effectively communicate the idea you consider to be crucial?
5. Introduce the students to the learning task by displaying the scheme and informing them why you arranged the terms as you did. Encourage them to contribute as much information as possible.
6. During the course of the learning task, relate new information to the organizer where it seems appropriate.

Finley (1983) concedes that a common and implicit assumption in assigning reading materials in science class is that most students will recall approximately the same propositions they have read. However, a teacher cannot assume that the cognitive structures of any two students will be identical with respect to relevant background knowledge. The interaction between learn- and teacher, using a structured overview, allows the teacher to evaluate the appropriateness of a structured overview in relation to the student's existing background of knowledge and to make adjustments in the overview when it is presented.

Figure 7. Structured Overview of Concept *Angiosperms*.

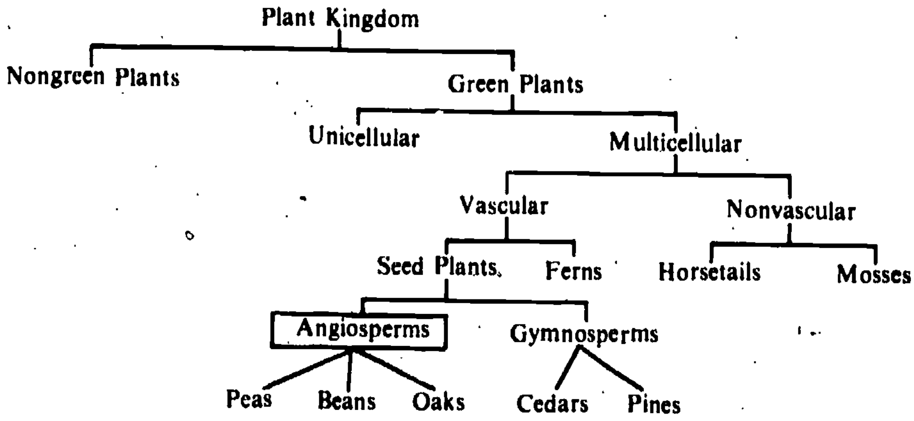


Figure 7 shows an example of a structured overview used in a biology class. This was developed by Kent Graves, a teacher in the Pittsburgh school system. Graves wanted to teach the concept *Angiosperms* and show his students how the concept related to other concepts in that hierarchy.

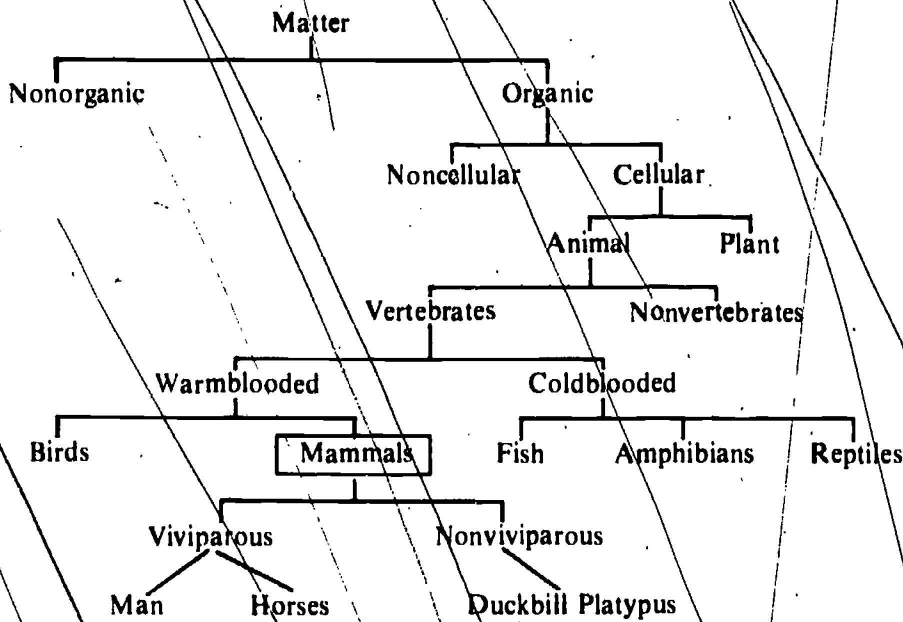
Figure 8 illustrates a less complicated overview of the concept *Mammals*. Students developed this overview with the teacher. Students were divided into working groups with three members in each group. The teacher told them they had five minutes to write down as many animals as they could think of. At the end of five minutes the teacher asked the students to count the number of animals they had listed. The group with the longest list dictated their list to the teacher who then put the terms on the board in categories (warmblooded, coldblooded, birds, mammals). By asking students to list animals, the teacher was attempting to discover what the students already had in their cognitive structures. By categorizing them, the teacher was trying to illustrate their relationship to one another.

• Frayer Model

A major goal of science education, according to Wallman (1983, p. 419), is that students will be able to apply what they have learned to novel situations. He states that learning "...should go beyond memorizing or paraphrasing. Teachers should teach for transfer."

Showing students how new concepts relate to other concepts in a structured overview is a step in facilitating concept attainment, but it may not be enough. For example, if the science teacher is concerned about teaching students the difference between hurricanes and cyclones, a structured overview illustrating that they are both examples of spiralling winds may not be effective in enabling students to discriminate between the two.

Figure 8. Structured Overview of Concept *Mammals.*



Indeed, if a student can identify a previously not taught example as belonging to a known concept we can truly say the student has learned that concept. Failure to generalize a concept has been attributed by Herron and others (1976) to poorly designed lessons. Markle and Tiemann (1970, p. 2) define generalization as "making the *same* response [giving the same name] to a *new* example which *differs* in some way from previously met examples."

We cannot possibly list or teach all of the examples of a concept in a structured overview, so we must provide students with something more than a hierarchy. Another prereading strategy, developed by Frayer (1969), appears to be an extension of the structured overview model. This paradigm also recommends clarifying concepts by showing students how the new concepts relate to other concepts in a hierarchy but suggests that teachers clarify concepts even further by giving students many examples and nonexamples of the new concepts as well as the essential and nonessential attributes of that concept.

By examining the examples of the concept, both teachers and students can identify those characteristics, or attributes, that are common to every example of that concept. These characteristics are called the relevant attributes. Characteristics which occur only in particular examples and which can be varied without changing the example to a nonexample are called irrelevant attributes.

The test that students really understand concepts, wrote Markle and Tiemann, is their ability to go beyond our teaching to new examples and nonexamples. They can do this when they discriminate between members and nonmembers of a concept and generalize to different examples.

For example, after showing students the structured overview on angiosperms, the teacher could put the information contained in Figure 9 on the board or on a transparency.

Figure 9. Concept *Angiosperms* (flowering plants).

Essential Attributes	1. Produce flowers 2. Produce fruit 3. Produce covered seeds
Nonessential Attributes	1. Color of flower 2. Number of seeds 3. Size of plant, seed, or flower 4. Structure of flower 5. Where it grows 6. Kind of fruit produced
Examples	1. Peas 2. Coleus 3. Roses 4. Maples 5. Grass
Nonexamples	1. Pines 2. Cedars 3. Moss 4. Ferns

Notice that the nonexamples in the hierarchy come from the coordinate concept, *Gymnosperms*.

In the previously mentioned list of animals, teachers ask their students to list all of the common characteristics of the *mammals*. After a specified period of time, the teacher asked the group with the longest list to dictate those characteristics while the teacher transcribed the list on the board. The rest of the class were free to add to that list.

Up to this point, the teacher was discovering what the students already knew about mammals. The teacher then began the lesson on mammals by teaching the students what characteristics, or attributes, were essential for a particular

Figure 10. Concept *Mammals*.

Essential Attributes	1. Have hair on their bodies 2. Give live birth 3. Have four chambered hearts 4. Are warmblooded 5. Have highly developed brains 6. Have differentiated teeth
Nonessential Attributes	1. Habitat 2. Height and weight 3. Color of their skin, hair, and eyes 4. What they eat
Examples	1. Apes 2. Dogs 3. Man 4. Whales
Nonexamples	1. Salamanders 2. Spiders 3. Sparrows 4. Frogs

animal to have to be classified as a mammal. By pointing out those attributes which occurred only in particular examples and could be varied without changing the example to a nonexample, the teacher was teaching nonessential characteristics. Knowing which characteristics are essential and nonessential is important if we want students to be able to generalize to new examples of the concept and distinguish from nonexamples.

Teaching students all of the examples of a concept does *not* insure that the students have learned that concept. The story of the student who knew all of the elements in the table of periodic elements is a case in point. The student could rattle off all of the elements but when asked, "What is an element?" the student responded, "We don't have to know that!"

There is some research (Peters, 1975-1976; Dunn, 1983) to suggest that both good and poor comprehenders are aided in understanding the written text when they are provided with the information in the Frayer model before they read.

udent Constructed Organizers

Experimentation by Barron and Stone (1973) led them to question the proper placement of structured overviews. They questioned the effect of student constructed overviews on the learning of vocabulary relationships from a passage of school science content. These structured overviews, called graphic post organizers, were constructed by students and preceeded the unit of content.

The day after students read the passage, they were placed in groups of two or three and provided with the learning passage and a set of 3 x 5 cards on which were typed the terms taken from the structured overview given to another experimental group. The students were then given twenty minutes to arrange the cards in a way that would depict relationships among the terms used in the learning passage. Research results indicated that the student constructed overviews were more effective than the structured overview.

More recently, Novak and others (1983) have developed strategies to help science students organize their knowledge hierarchically. The two strategies tested were the concept map and the Vee map.

The concept map is very similar in design to Pearson and Johnson's semantic map (1978). Concept maps can be constructed in several ways. Novak recommends the following:

> A simple method is to supply students with a list of related concepts and have them construct a map, placing the most inclusive, most general concept at the top and then showing successively less inclusive concepts at lower positions on a hierarchy. Students must decide how best to represent the concepts hierarchically and the words to use to link concepts together. Another method is to have students identify key concept words in text of some kind and then to use these concepts to form a hierarchical map. The greatest creativity may be required to construct a concept map without any supplied words or text, but drawing on an individual's fund of knowledge for some specific topic. (p. 626)

Vee maps are also developed by the students for a lab exercise, a textbook description of an experiment, or a research paper. Novak and his colleagues describe the procedure as follows:

> The procedure involves first identifying the "focus" question or questions and the events or objects observed to answer the question(s). These first steps can be surprisingly difficult and lead to much useful class discussion. Identifying the eight other elements on the Vee can also be challenging. Often published reports of investigations do not state key relevant concepts, principles, or theory, since "experts" in a field usually bring this knowledge to the interpretation of the study. When students perform a laboratory investigation and "place it on the Vee," they are often surprised to

learn that different principles or theories considered on the left side will lead to an expectation of different knowledge claims. Science students may be surprised to learn that every knowledge claim can also be the basis for a value claim. Vee mapping produces on paper the structure of the unit of knowledge being studied. (p. 629)

One limitation of using the Vee map, however, was the time it took for students to understand and apply it as a learning tool.

Shulman and Tamir (1973) state that the crucial question for science educators has been how to transmit a particular concept or structure of knowledge to students so that it becomes an enduring component of the learner's cognitive structure. The works of Ausubel, Barron, Frayer, and Novak are attempts to answer that question. If the learner's cognitive structure is not organized, new ideas are incorporated as isolated meanings which are quickly forgotten and do not become enduring components of that structure. It would appear that the teacher's first task is to discover what is in the learner's existing cognitive structure and to build upon that structure.

Not all new concepts need clarification. To avoid assumptive teaching, however, the teacher should make some attempt to discover how well the students' cognitive structures are organized. This could also be accomplished by presenting vocabulary words which students can be expected to know and directing students to label the category.

Vocabulary

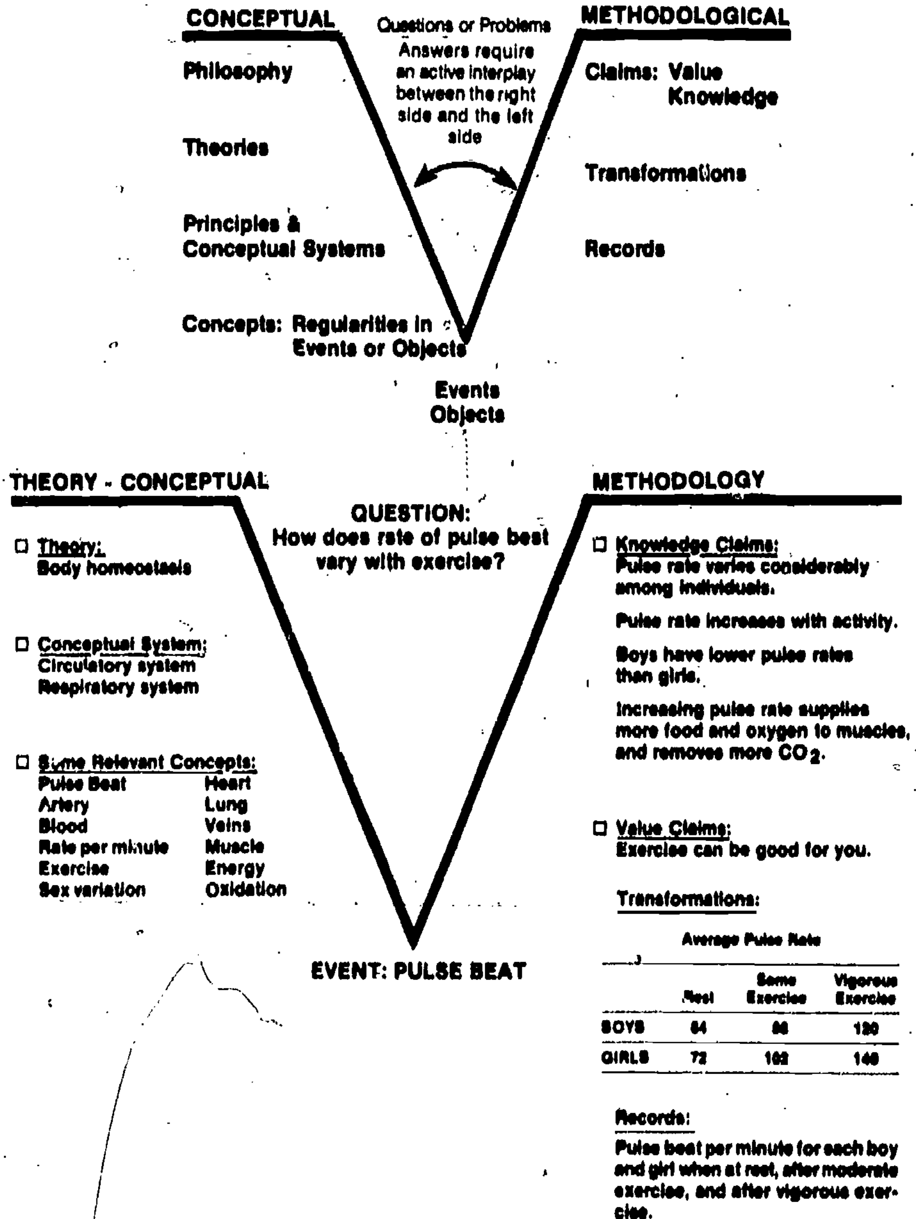
In order to function at the factual or literal level, students must be able to recognize and determine the meanings of words. Many science teachers believe they develop word recognition skills, or preteaching technical vocabulary, when they require students to look up new words in the dictionary and use each word in a sentence. This activity tends to be meaningless and often results in rote learning and rapid forgetting.

Science teachers need not preteach each new word. Vocabulary words which require preteaching are those the teacher believes students must learn in order to understand concepts previously selected by the teacher.

Teachers who select the most representative concepts to be taught and complete the first step in Barron's criteria for constructing structured overviews, probably have reduced the number of vocabulary words which need to be taught.

Teachers should look at the vocabulary they select as important for students to understand. Most of the words probably are already identified for the student in the context of the textbook; if so, a guide similar to the one shown in Figure 11 would most likely be used. The numbers in parentheses following each statement refer to the page, column, and paragraph where the word can be located in context. Students usually complete this kind of homework assignment before the actual reading of the text takes place and compare their responses with small student groups the following day. The lists are *not* collected and graded by the teacher.

Figure 11. Gowin's Vee Heuristic showing the 10 elements included in this representation for the structure of knowledge. Top figure shows the general form of the Vee and lower figure shows how a seventh grade laboratory activity was "mapped" onto the Vee in class discussion after the activity.*



*From Novak, Joseph D.; Gowin, D. Bob; and Johansen, Gerard T. "The Use of Concept Mapping and Knowledge Vee Mapping with Junior High School Science Students," *Science Education, 67*, p. 628.

What about words that cannot be defined in context? Bamman (1964) used the following list of words to illustrate that scientific classifications are based on similar structures: lepidoptera, hymenoptera, hemiptera, and homptera. These are used to describe the wing (pteron) structure of particular orders of insects: scale (lepido), membrane (hymen), half (hemi), and same texture throughout (homo). Students who are made aware of the structure of words are helped to acquire word meanings without yielding to the temptation to memorize terms and examples of each.

In a science lesson, the teacher probably would want the students to know more than the four words listed. Herber (1978) claims that the remaining words need only to be pronounced, as this clue alone may give students a basis of recognizing them later in print. Additional teaching strategies for vocabulary development can be found in Herber's book as well as Vacca (1981), Dishner et al. (1981), Johnson and Pearson (1978), and Moore et al. (1982).

Reading at the literal level would be greatly enhanced if the science teacher made an effort to preteach essential vocabulary. It may be helpful to put a structured overview on a transparency and refer to it each time a new term is introduced. However, students must go beyond the literal level for an understanding of scientific concepts. Chapter 4 attempts to illustrate ways to accomplish this goal.

Chapter 4

USE OF GUIDED MATERIAL IN TEACHING SCIENCE

Once students have sufficient prior knowledge about the new material to be learned, they should be ready to read the text. However, most students need guidance to comprehend the material. Guidance is the procedure of helping students through concept forming processes and can be accomplished by the use of reading guides. It's not enough to tell students what to look for when assigning reading from a textbook. If we do not provide some guidance for those students with low verbal ability and low motivation, they will learn by rote a few key terms without trying to understand what they mean. And if we require verbatim answers on our tests, we are forcing our students to rely on rote memorization.

Some faculty members feel that by providing guidance they are "spoonfeeding" their students. Spoonfeeding can only occur when a student has learned a process and is not allowed to practice it. We cannot assume that students know how to process information; therefore, we must provide guidance.

Guides are merely simulators of the process of thinking. The teacher must determine what the process is by rereading the portion of the text to be assigned to the students. During the rereading of the text, teachers must keep several questions in mind. What concept, inferences and/or applications do they want their students to understand once the students have read that section of the text? What thinking process is experienced in order to arrive at these concepts? Is it inductive? Will students be able to read the literal statements and make inferences expected? Is the text cluttered with unrelated factual statements? Does the author assume students can make the correct inferences and ultimately apply what they have learned in the lab?

Strategies that have been used to improve students' comprehension such as concept guides, three level guides, and simple guides will be discussed in this chapter.

• Concept Guides (Two-Level Guides)

Most instructors would agree that their responsibility is to help their students understand fully the concepts of their discipline. A concept guide is an exercise that aids students in identifying instances, or examples, of a concept and directs them to seek relationships in those examples and categorize them under more abstract concepts. It is an excellent companion to the preparation techniques suggested in the previous chapter. Sample concept guides are reproduced in Figures 12 and 13.

Figure 12. A Concept Guide Developed by Richard Barron.

Part I: Check the statement which represents what the author said, literally or in paraphrase.

_____ 1. Living things organize protoplasm.

_____ 2. When certain proteins, carbohydrates, fats, and other substances are organized into a system by an organism, a state of chemical activity termed "living" is established.

_____ 3. Life requires a constant source of energy.

_____ 4. The various substances associated with the living condition are organized in basic structural units called cells.

_____ 5. Cells are never organized in nonliving materials.

_____ 6. At least for a time, living things grow by enlarging.

_____ 7. Living things undergo growth and maintenance without enlarging.

_____ 8. You expect a plant or animal to resemble its parents at maturity.

_____ 9. Genes regulate the development of organisms.

_____ 10. Sooner or later, all living things die.

_____ 11. An organism's period of existence may be divided into five stages: origin, growth, maturity, decline, and death.

_____ 12. The substances comprising any organism have the capacity for indefinite activity.

_____ 13. Reproduction takes many forms, but it always involves the same principle—a mass is divided or a small portion of a mass is separated from a parent.

_____ 14. Reproduction is necessary to perpetuate life.

_____ 15. Protoplasm can respond to external conditions.

_____ 16. Light, moisture, oxygen supply, temperature, air currents, soil conditions, and variations in the earth's surface may have a direct influence upon organisms.

_____ 17. If an organism is unsuited to its environment and it cannot migrate or adapt, the species will disappear.

Part II-A: Listed below are ten terms or phrases. List the number of each statement from Part I next to the phrase to which it is most nearly related.

______ 1. Chemical organization

______ 2. Cellular organization

______ 3. Reproductive capacity

______ 4. Energy requirements

______ 5. Variation and adaptation

______ 6. Critical relationship with environment

______ 7. Life span

______ 8. Response capability

______ 9. Growth and maintenance

______ 10. Form and size range

Part II-B: Listed below are several statements about the phrases in Part II-A. Check the statements which you think are true. Be prepared to defend your choices.

______ 1. Each of the phrases in Part II-A is related to the condition known as "life."

______ 2. Each of the terms above is *necessary* for life.

______ 3. Each of the terms above is *sufficient* for life.

Figure 13. Concept Guide Developed by Sandra Schroeder.

Ecology

Part I-A

Directions: True/False. Read each of the following statements carefully and then place a T for each true statement and an F for each false statement in the blanks provided. Correct the false statements. (Hint: The number of true statements equals the number of false statements.)

______ 1. All organisms depend on their environment and surroundings for carrying on their activities of life.

______ 2. Ecosystems remain in a constant equilibrium and don't show any changes.

______ 3. The nitrogen cycle is primarily concerned with freeing nitrogen from the detergents and ammonia salts.

_____ 4. Humans exert very little influence on their environment.

_____ 5. Organisms that live together in an ecosystem form a biotic community.

_____ 6. In nature, natural enemies play an important role in maintaining the balance in populations.

_____ 7. In an ecosystem, interactions occur between the biotic community and the physical environment.

_____ 8. In the process of photosynthesis, oxygen is taken in and carbon dioxide is given off.

_____ 9. Sunlight, soild, temperature, and water are important, necessary factors of the physical environment important to the biotic community.

_____ 10. There is a tendency for overpopulation in nature that results in little competition for food and shelter.

Part I-B

Directions: Fill in the blanks. After you have read the statement, choose the correct word from the list that will fit into each blank. then put the circled letter of the word in the blank to the left of the question number. Upon completion, you should be able to read a word that is related to the main concept of ecology.

Possible Words

Evaporation	Biome	Carbon-Oxygen
Biosphere	Populations	Predator
Water	Precipitation	Ammonification

_____ 1. Water moving from the earth to the atmosphere is the process of

(_)_ _ _ _ _ _ _ _ _ _.

_____ 2. The process by which water moves from the atmosphere to earth is

_ _ _(_)_ _ _ _ _ _ _ _ _ _.

_____ 3. A geographical location called _ _(_)_ _.

_____ 4. _ _ _ _ _ _ _ _ _ _(_) are groups of organisms of the same kind within a community.

_____ 5. A cycle which involves the two basic life processes of respiration and photosynthesis is called _ _ _ _ _ _ _ _(_)_ _ _ cycle.

_____ 6. The _ _ _(_)_ _ _ _ _ is the thin layer where life exists.

_____ 7. The cycle by which water moves continuously from the atmosphere to the earth and back again is the _ _(_)_ _ cycle.

_____ 8. If an eagle preys on smaller animals, it can be classified as a

_ _(_)_ _ _ _ _.

_____ 9. The process (_)_ _ _ _ _ _ _ _ _ _ _ _ is the release of ammonia from decaying protein by means of bacterial action.

Part II

Directions: Below are four general categories related to the chapter on ecology. Take each question from Part I-A and place its number under the category that best applies. A question could possibly go under more than one category depending on your reasoning.

Physical Cycles ____________ Population Factors ______________ Processes ________

Environmental Relationships

____

Vacca (1981) claims that concept guides "extend and reinforce the notion that information is hierarchically ordered in factual material, that some ideas are subordinate to others" (p. 152), and his book contains some very good examples of concept guides. The best examples of concept guides can be found in the text by Estes and Vaughan (1978).

In 1969, Barron gave four steps in the use and construction of concept guides:

1. Analyze the reading passage to determine the major concepts you wish the students to acquire. List them in a word or a phrase. These words and phrases will comprise Part II of the guide.
2. Reread the passage and judiciously select statements which underlie the major concepts. These statements plus distractors will comprise Part I of the guide.
3. Have students respond to the guide by
   a. indicating whether the statements in Part I actually occurred in the passage; and
   b. categorizing the statements from Part I under the concept(s) to which they most nearly relate in Part II.
4. Provide students with feedback. This may be accomplished in teacher-led discussions with the entire class and/or in student-directed small group discussions. Guides are merely stimulators of the reading process. Once students have been given the opportunity to rehearse and learn that process they should be allowed to practice it.

• Three-Level Guides

Facts are needed as a foundation for concept development, but knowing them does not guarantee their proper use or their value. Mastery of a concept is indicated by the student's ability to generalize beyond specific stimuli to a variety of new situations. In 1970, Hurd assigned to the science teacher the task of finding ways to make the learning of science possible without drowning insight in details. He further charged the teacher to make knowledge meaningful, to release students from the confines of current knowledge, and to provide a means for acquiring new knowledge. Too often, science teaching has been confined to the findings of science or worse, to the memorization of facts (such as the parts of a leaf). In his discussion of the meaning of concept, Hurd denounced this meaningless knowledge and asked whether knowing the parts of a leaf is the same as understanding the complementarity of structure and function. The answer is that knowing the fact does not necessarily imply understanding the concept. We have a responsibility to help students learn how to use facts to form meaningful concepts; the three-level guide attempts to do this.

The purpose of these guides is to simulate the inductive process of thinking by asking students to make inferences about what they read, support those inferences from facts supplied in the text, then apply them to other situations. Herber (1978) has named the levels *literal comprehension, interpretive comprehension,* and applied comprehension.

It is not implied here that there are only three levels of understanding; the point is that we recognize that there *may* sometimes be a progressive level of abstraction.

Defining the three levels as reading the lines, reading between the lines, and reading beyond the lines has been attributed to Edgar Dale. A further definition may be appropriate at this time.

The literal level represents what the author said. At this level, students are pronouncing or decoding words and determining their meanings in context. Students may identify the literal level statements without understanding what they mean (as when they read *Jabberwocky*).

The interpretive level suggests reading between the lines and requires the skill necessary to answer the question, "What did the author mean?" The student must be able to see relationships among the literal statements and have had prior experiences with those details to be able to interpret the statements.

The third level of understanding, the applied level, carries the reader beyond the passage by taking the results of the literal and interpretive levels and applying them to other experiences in the reader's cognitive structure so that a new idea evolves.

Figure 14 illustrates the simulation of the three levels in a study guide for "reading" a ninth grade earth science film.

Figure 14. Three-Level Guide.

Erosion—Leveling the Land
Study Guide # 1

Concepts to Be Developed: Weathering, Erosion, Deposition, Effects of Erosion

Part I: Literal Understanding

Consider each of the statements below. Decide whether the message of the film you saw agrees with what each statement says. If you think so, place a check on the line before the statement. If not, leave the line blank.

_____ A. When rocks are wetted and dried repeatedly they begin to decompose.

_____ B. The best headstones are made from marble.

_____ C. As a rock weathers, some of the minerals in the rock decompose and cause slabs to come loose.

_____ D. Grooves in limestone prove that this hard rock can eventually be dissolved and washed away by rainwater.

_____ E. Over long periods of time, the alternate freezing and thawing of water pushes the rocks apart.

_____ F. Avalanches and landslides transport weathered material.

_____ G. As streams rush downhill toward the sea, they pick up weathered rock and other debris and carry them off.

______ H. Rock, sand, and mud that are washed into a landlocked valley have no way to get out.

______ I. Some turbulent streams carry sediments into calm waters of a lake and the sediments settle out on the lake bottom. Eventually, the lake will be filled with rocks and debris.

______ J. An oval pattern formed by exposed edges of tilted layers of hard rock was recreated in clay to show that at one time a dome-like structure had been there but was eroded.

Part II: Interpretive Understanding

Several statements are listed below. Some may represent the meaning of the movie or the "correct" interpretation of the movie. When we interpret what we see and hear, we try to combine parts of the movie to generate an idea. Each of us may do this in a different way.

Read the first statement below. Then read the statements from Part I as identified by the letters in parentheses. Decide if the information from the statements in Part I could be combined to develop an idea like the one expressed in the statement in Part II. If so, place a check on the line before the statement. Follow this same procedure for each of the remaining statements.

______ 1. Water in any of its three forms is the main agent in erosion. (A, C, D, E, G, H, I)

______ 2. Rocks weather faster in dryer climates than in wet and changeable ones. (A, D, E)

______ 3. Rocks subjected to wet and changeable climates will soften, crumble, decompose, and split. (A, C, D, E)

______ 4. Material that is weathered from high places is eventually deposited in low places.

______ 5. Accumulation of rock, sand, and mud eventually levels the floor of a landlocked valley and fills inland lakes, often obliterating them. (H, I)

______ 6. Rushing streams, landslides, and avalanches transport weathered rock and other debris. (F, G, I)

Part III: Applied Understanding

To apply what we read, we must combine what we read, hear, and see with ideas or experiences which are personal to us. That is why we have called "applied understanding" the "personal" meaning of a passage or movie.

In column I below, there are statements you might have checked in Part II. In column II there are other ideas you personally may have had about the same topic. In column III there are possible applied understandings, formed by combining statements in columns I and II. Above the list in column III you will find letters and numbers in parentheses. These suggest combinations of statements from columns I and II which might lead to the creation of ideas similar to those column III statements.

Read the first statement in column III. In the blank space write the letter and number combination which indicates which column I and II statements are represented in the first statement. Follow the procedure for the other statements in column III.

Column I

1. Water in any of its three forms is the main agent in erosion.
2. Material that is weathered from high places is eventually deposited in low places.
3. Accumulation of rock, sand, and mud eventually levels the floor of a land-locked valley and fills inland lakes, often obliterating them.
4. Rushing streams, landslides, and avalanches transport weathered rock and other debris.

Column II

a. Some of the material from cliffs along Erie Boulevard slid into the backs of stores after the heavy snowfalls.
b. The potential energy of material at a higher elevation is changed to kinetic energy as the object moves downhill.
c. A few years ago a dam broke in Italy, flooding and wiping out an entire village.
d. Gravity has the effect of pulling objects "down."

Column III

(1, a) (2, d) (3, c) (4, b)

______ A. Water is the greatest agent for change on earth.

______ B. Gravity is the force that drives water to move material.

______ C. Weathered material at a high elevation will erode faster than weathered material at a lower elevation.

______ D. Erosion and deposition could level the land eventually.

A three-level guide should reflect content and process. In the earth science guide, the process was inductive—going from concrete to more abstract information. (Many guides supply several factual statements and require students to check true statements that can be found in the text.) Teachers must now think about the content they want their students to learn. This task is not always easy because teachers have to make decisions about what to delete and what to emphasize.

The easiest way to construct a three-level guide like the earth science guide is to list the inferences the teacher thinks are important, and then list the facts from the text that support those inferences. Throw in some distractors—statements that are *not* true—and direct students to check true statements as they read. (The earth science guide does not do this because it is based on a film.) The final step is to formulate generalizations which go beyond the text.

In constructing the three-level guide, place literal level statements first, interpretive level statements second, and applied level statements last. Notice that the sample study guides contain *statements* not *questions*. There is a reason for that. Herber and Nelson (1975) suggested that by using statements initially, instead of questions, students would not be pressed into producing an answer but they would be able to react and respond to the text.

Figure 15. Three-Level Guide.

Study Guide—Insects

Level I

List the six major advantages insects have that will insure their survival. Also list the examples of these advantages on the lines below. There may be more or less than three examples. The first is done for you.

1. *WINGS* ____________________

a. flight-to-move ____________________

b. to search for mate ____________________

c. to escape ____________________

2. ____________________

a. ____________________

b. ____________________

c. ____________________

3. ____________________

a. ____________________

b. ____________________

c. ____________________

4. ____________________

a. ____________________

b. ____________________

c. ____________________

5. ____________________

a. ____________________

b. ____________________

c. ____________________

6. ____________________

a. ____________________

b. ____________________

c. ____________________

Level II

Support the following inferences with your statements from Level I.

Statements

1-a, b, c ____ The ability to move around insures the survival of insects.

____________ Insects eat a variety of things, but all insects do not eat the same food.

____________ If all insects ate the same food their chance for survival would be lessened.

____________ The external skeleton of the insect contributes to the success of the insect's survival.

____________ If both immature and adult insects ate the same food supply their chances of survival would be diminished.

____________ By providing the insect with a reproductive system so that fertilization is timed with favorable environmental conditions, nature has insured their chances of survival.

____________ Insects become pests because of their divergent appetites.

Level III

Check the ideas that seem to be most valuable as an extension of the inferences.

______ 1. Population control is necessary for survival of the species.

______ 2. Mobility is an aid for survival.

______ 3. Insects shall inherit the earth.

______ 4. Might makes right.

Guides do not have to assume the same form as the examples given, so long as they accomplish the same thing. Be creative. Try a few guides based on the samples and then experiment with your own. Three-level guides take time to create and construct, but are worth the effort.

• Simple Guide

Constructing a simple guide is easy and consumes little time. Students like the guide because it provides them with very personal attention and direction.

A professor in a college physical science class was experiencing one frustration after another with his nonscience majors. He and a reading education faculty member teamed their efforts to provide guidance for the equally frustrated students. Here is how it was done. About one week before a chapter was to be assigned in the text, the science professor advised the reading professor which concepts he thought the students should understand as a result of reading the text. The reading professor, who had a nonscience background, read the chapter and asked questions when the text was not clear. It was found that the author of the science text was very assumptive and frequently made highly generalized statements without showing the student *how* he arrived at the statements. Another shortcoming of the text was that it rarely provided the student with sufficient background knowledge. As the professor read, she jotted down her thoughts as if she were talking to the students. A sample guide is reproduced in Figure 16.

Figure 16. Simple Guide on a Physical Science Textbook.

Physical Science

Remember the example given to you on page 241 concerning trucks loaded with grapefruit and oranges? We knew that each truck had equal numbers of the fruit. Knowing this, we could find their relative weights.

The same line of reasoning can be applied to "Weighing and Counting Atoms and Molecules."

Instead of weighing oranges and using oranges to compare relative weights, the author uses the hydrogen atom (page 277, line 3, "for any given element. . . .").

As you read pages 276-282 keep in mind that the author is using the hydrogen atom as a basis for comparison only.

To do this, the author must establish a) which hydrogen compound contains the smallest amount of hydrogen and b) how much volume will hold this smallest amount.

1. What are the answers to: Which two hydrogen compounds contain the smallest amount of hydrogen (page 274, table 8-2)? Which hydrogen compound does the author select (page 277)?

2. Hydrogen chloride contains only _____ gram of hydrogen per _____ (page 277). Therefore, to find a volume that contains one whole gram (not a fraction) we have to divide _____ gram into one gram. This number will be _____ liters (page 277) and that is the volume that will hold 1 gram.

3. What weighs one (1) gram in 22.4 liters of hydrogen chloride? ____

4. The next logical question is, we know how much hydrogen atoms contained in 22.4 liters of hydrogen chloride weigh but how many hydrogen atoms are there in this volume? The number of hydrogen atoms in 1 gram of hydrogen is called ____ number. It is the number of ____ atoms in 1 gram of hydrogen; it is often referred to as the letter ____; and it is 6×10^{23} or 600,000,000,000,000,000,000,000. In other words, there are ____ hydrogen atoms in one gram of hydrogen.

5. How many hydrogen atoms are there per molecule in hydrogen chloride (page 278, lines 1, 2 and 3)? If there are N, or 6×10^{23} hydrogen atoms in 22.4 liters of hydrogen chloride, how many molecules are there ____ (page 278, "Theoretical Implications")?

6. Chloride weighs approximately ____ grams (page 344, table 10-5). Therefore, 22.4 liters of hydrogen chloride must weigh ____ grams (page 178).

Eventually, the physical science professor began writing his own guides, but it was not as easy for him as it was for the reading education professor. The latter's very slight background knowledge allowed her to look at the text through the eyes of the nonscience students. The physical science professor was unable to do this because of his extensive prior knowledge. Science teachers, therefore, are advised to assume the role of their most unenlightened students. It is often difficult to imagine that students have difficulty with concepts that come so easily to teachers.

Another function of this type of guide is to direct student attention to the often neglected external aids of the text (graphs, figures, tables, and diagrams) and actually guide the students in the use of these aids. The guide in Figure 17 was developed for a science text by Scott L. Shablak of Syracuse University. An interesting observation one teacher made when using the guides was that the most frequently read paragraphs were those the teacher had decided were unimportant, repetitive, or unrelated and had labeled "skip it."

Figure 17. Reading Guide.

Paragraph 10. (Yes, that's right, Paragraph 10.) Read paragraph 10 first and keep it in mind as you follow the exercises on this sheet. Now proceed to:

Paragraph 1. Draw a picture of a light spectrum.

a. Does it look like a rainbow?
b. Why do they call it a rainbow pattern?
c. If you take the orange out what color will replace it—black or white?

Paragraph 3.

a. Read sentence 1.
b. Look at Fig. 5.8 and read (a) sentence 1.
c. 1. Does it look like a rainbow?
   2. List 3 things that are the same or different between 6.8 and a rainbow.
      a. ____
      b. ____
      c. ____

Don't bother to read the rest of the paragraph.

Paragraph 3. Read the paragraph. Look at Figure 6.9 and read the caption. Draw a picture of what calcium and strontium look like when they are combined.

Paragraph 4. Skip it.

Paragraph 5.
1. Read the first two sentences.
2. Look at your diagram of calcium and strontium.
3. Can you separate ~~your lines for calcium~~ from the whole picture?

This is how scientists can figure out what elements are in a whole mixture of compounds. They are smart enough to remember where all of the lines go. Look at Paragraph 6 and write a ratio of the number of known lines to the total number of lines that have been observed.

Paragraph 7. Read it. Go back to p. 116 and read the last paragraph. Write two words that show me that you know how these two paragraphs are related.

____________________ ____________________

Paragraphs 8, 9. These paragraphs give you a science history lesson about how scientists
1. Discovered some new elements 93 million miles away.
2. Discovered 5 new elements that were really small. What else did Bobby Bunson do? When we look at elements produced in nuclear reactions why do we have to use spectral analysis?

Paragraph 10. Read it again. Doesn't it make more sense now?

• Utilization of Gui

Not all chapters, units, topics need instruction. Guidance is determined by the difficulty of the mate l and the competency of the students.

The guided materials sug sted here are used in the following manner. If at all possible, assign the guide as homework. During the following class period, have students divide into groups. Groups can be formed according to student strengths but should remain flexible enough so that students can shift from one group to another depending on their needs. Each group should include from three to five students. Every time the group meets, a secretary should be selected from its members to record the consensus of the group.

As soon as the groups are formed, students should begin to discuss the guide and to resolve any differences they may have on a particular question or item. Occasionally, a student will not have completed (or even attempted) the guide. It is recommended that the teacher not collect nor grade these guides because group discussion and eventual group consensus are more important. Collecting the guides could bring peer pressure on the negligent student and defeat the whole purpose of the discussion.

While students are discussing their responses, teachers should move about the room to encourage and assist. In the college physical science class discussed earlier, the professor walked among the groups so that a group having any particular difficulty could be spotted, and the professor could step in and answer questions. Often students are reluctant to ask questions of the instructor; small group discussions enable those students to gain answers from peers.

When it becomes apparent that nearly all groups have finished their tasks, it is time to discuss the guide among groups. This is done by having the teacher call on the group secretaries and responding to each item seriatim. One group should not be asked to respond to the whole guide; instead, each group should be given a chance to respond to the others' answers.

Meeting individual differences is not easy in science classes which may include 30 or more students. Grouping, as described, is one way to cope with the problem.

Chapter 5

REINFORCEMENT OF VOCABULARY IN TEACHING SCIENCE

One of the shortcomings of traditional teaching methods, according to Skinner (1968), is the relative infrequence of reinforcement. He admits that large class loads limit the amount of reinforcement teachers can offer to individual pupils. Contained in this chapter are some suggestions for the reinforcement of vocabulary that can be used in small groups and in teacher-led discussions.

The research of Barron and Melnick (1973) and Barron et al. (1973) indicates that using vocabulary reinforcement exercises as a vehicle for small group discussion enhances vocabulary learning. In both studies, students were provided with "expanded direction"—a set of procedures designed to enhance student understanding about the purposes and processes of engaging in the learning task prior to being given the exercises. These directions can be found in Appendix B. It was Barron's opinion that the expanded directions were a necessary part of reinforcing vocabulary. Students in the group that had the directions asked that the vocabulary activities be continued. Most of the students who were not given these directions asked that the vocabulary exercises be dropped.

• Categorizing

Activities that involve categorizing are excellent ways to have students relate newly learned verbal associations to familiar and emphasized relationships. It is a method of taking inventory of how the cognitive structure has incorporated the new material. Figures 18, 19, and 20 show examples developed through a United States Office of Education research grant.

Figure 18. Vocabulary Reinforcement—Cytoplasmic Inclusions.

______________________________ (NAME)

Jamesville-DeWitt High School
Biology Department

Directions. There are five words in each section below. Cross out the *two* words in each that *you feel* are *not* related to the others. Explain the relationship by titling each group.

1. ______________________

amino acids
energy
water
enzyme
protein

2. ______________________

endoplasmic reticulum
ribosomes
mitochondria
golgi bodies
vacuoles

3. ______________________

plastids
lyosomes
cytoplasm
cell wall
molecule

4. ______________________

cell membrane
diffusion
secretion
permeable
osmosis

5. ______________________

waste
storage
food
pocket
contractile

6. ______________________

fluid
reticulum
densities
centrifugation
nuclei

7. ______________________

protein
endoplasmic reticulum
ribosomes
RNA
energy

Figure 19. Vocabulary Reinforcement—Nucleus.

______________________ Jamesville-DeWitt High School
(NAME) Biology Department

Directions. In the list below, *some* of the terms are associated with the functioning of the cell nucleus. Underline those terms, and give a brief definition for each.

1. golgi bodies

2. deoxyribonucleoprotein (DNA)

3. jacuole

43

4. mitochondria

5. ribonucleoprotein (RNA)

6. chromosomes

7. daned

8. nucleoplasm

9. chromatin

10. pinocytosis

11. nucleoli

Figure 20. Categorization.

Directions. Cross out the word from each group that does not belong and then give a title.

1. ____________
plasma
platelets
red corpuscle
white corpuscle
saliva

2. ____________
gall bladder
capillaries
blood
arteries and veins
heart
William Harvey

3. ____________
platelets
fibrinogren
red and white cells
fibrin
blood types

4. ____________
A B
O
A
D
B

5. ____________
ventricle
pump
auricles
capillaries
valve

6. ____________
Rh positive
857 degrees
protein
Rh negative
coronary thrombosis

7. ____________
superior vena cava
capillaries
heart
blood without oxygen
inferior vena cava

8. ____________
O_2
fights disease
anemia
spleen
CO_2

9. ____________
superior vena cava
aorta
blood with oxygen
capillaries
thick walls

• Word Puzzles

Word puzzles are fun for students and are not difficult to create. If students have trouble making puzzles, give them a Scrabble set and tell them they may only use words that relate to the unit they are currently studying. This game will provide good reinforcement for students, and the teacher will discover that a Polaroid shot of their finished work can serve as a crossword puzzle for future exercises.

In Figure 21 you see another type of puzzle. Note that the main idea or topic of the unit is spelled out, "Sources of Energy."

Figure 21. Word Puzzle: Science (Biology).

Directions: Using the clues on the next page, complete the spelling of each word.

1. _ _ _ _ _ S
2. _ _ _ _ _ O _ _ _
3. _ _ _ U _ _ _ _ _
4. R _ _ _ _ _ _ _ _
5. _ _ _ _ C _ _ _ _ _ _ _
6. _ _ _ _ _ _ _ _ _ E _ _ _ _ _ _ _ _ _ _ _ _ _
7. _ _ _ _ _ S _ _ _

   _ _ _ _ _ _ _ _ _ _ _
8. _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ O _ _ _ _ _ _ _
9. F _ _ _
10. E _ _ _ _ _
11. _ N _ _ _ _ _ _ _
12. E _ _ _ _ _
13. _ R _ _ _ _ _
14. _ _ _ _ G _ _ _ _
15. _ _ Y _ _ _ _ _ _ _

1. Source of chemical energy in all animal cells
2. Plant energy source
3. Reaction involving gain of electrons
4. Conversion of organic acid
5. One place where reaction for liberation of energy takes place
6. Key substance which occurs in every living organism and cell
7. ADP
8. Technical name for a series of reactions that liberates the chemical energy necessary to make ADP and ATP
9. Source of energy
10. Necessary for synthesis of proteins
11. Term meaning the formation of a complex chemical compound by combing two or more simpler compounds
12. Released when glucose is oxidized
13. Living
14. Nonliving
15. Oxidation in the absence of oxygen

Science teachers report having success with another puzzle (sample shown in Figure 22) where students find and circle science words across, down, or diagonally.

• Matching

This is probably the easiest exercise for students to complete. Its purpose is also to review the new vocabulary terms and their definitions. Remember, these are not tests but merely aids to insure retention. A simple exercise would be to list the new and related terms in one column with their possible meanings in another column.

Most science teachers have used the suggested activities, but how often have they provided detailed preparation of the students? And how often do students, after individually completing such activities, get an opportunity to share their responses in small peer groups?

Many more examples of vocabulary reinforcement exercises can be found in work by Herber (1970, 1972).

• Magic Squares

Vacca (1975) suggests using Magic Squares for vocabulary reinforcement. They are very easy to construct. Figure 23 shows eight combinations, plus a magic square using the second combination. Many more combinations can be made from the original eight.

Figure 22. Word Puzzle.

A	R	A	N	D	N	V	O	S	Y	M	I	K	D	E	W	H	A	Y	N	E	R	I	A
R	T	L	I	T	H	O	S	P	H	E	R	E	E	B	O	Y	B	R	Y	D	O	U	G
H	I	M	A	S	S	T	E	P	H	E	N	H	C	H	A	D	L	E	R	B	I	L	L
Y	V	O	O	N	E	P	E	T	R	A	C	K	I	G	A	R	L	E	C	A	H	R	E
D	Y	O	N	S	G	S	V	O	N	Y	B	E	B	V	E	O	R	C	L	Y	K	A	T
R	R	V	E	E	P	N	D	O	N	O	A	G	E	A	I	G	R	L	B	E	V	E	R
O	L	A	Y	A	K	H	A	R	E	N	D	O	L	N	N	E	A	G	A	I	M	L	O
S	P	C	E	L	R	G	E	N	A	B	R	C	D	E	S	N	F	G	H	E	I	J	P
P	K	U	L	E	M	N	O	R	P	A	Q	R	S	T	U	V	W	X	R	Y	Z	A	O
H	B	U	C	V	D	E	F	G	E	H	I	J	K	L	M	N	O	C	P	Q	R	S	S
E	T	M	U	E	V	O	P	Q	R	S	T	A	B	C	D	E	U	M	N	O	R	J	H
R	W	P	X	L	V	A	L	T	I	M	E	T	E	R	B	R	L	D	E	F	G	H	E
E	Y	A	Z	J	K	L	E	M	N	O	P	Q	R	S	Y	T	U	V	W	X	Y	Z	R
A	I	C	W	A	B	B	Y	X	P	E	R	F	E	C	T	V	A	C	U	U	M	E	E
H	N	K	G	A	M	A	B	N	N	H	X	G	U	B	W	Y	N	R	D	X	W	R	A
E	J	E	N	O	O	C	D	O	E	K	G	P	B	E	A	A	D	F	E	Y	V	U	C
M	M	D	R	N	M	N	H	L	K	J	I	H	L	N	Y	I	M	I	F	Z	U	S	B
I	O	O	P	O	Q	P	E	R	S	T	U	V	W	O	N	K	E	H	G	E	T	S	E
S	R	M	D	Q	I	R	S	X	T	U	V	O	Y	I	D	K	J	H	I	D	S	E	D
P	L	U	O	S	B	D	A	Z	Y	X	W	H	Y	S	U	E	L	F	G	O	R	R	F
H	A	I	N	C	D	E	F	G	H	I	J	C	Z	E	V	M	N	E	D	L	Q	P	G
E	P	L	L	M	M	O	N	O	S	P	H	E	R	E	W	O	P	C	A	P	P	R	H
R	O	E	K	J	I	H	G	F	E	D	C	A	B	Z	X	Q	R	B	N	M	O	I	I
E	N	H	E	M	I	S	P	H	E	R	E	B	C	A	Y	S	T	M	L	I	K	A	J

*Developed by Larry Patterson, Bruce High School, Westernport, Maryland.

Figure 23. Adapted from Richard Vacca, "Reading Reinforcements through Magic Squares," *Journal of Reading,* May 1975, pp. 587-590.

MAGIC SQUARES

7	3	5
2	4	9
6	8	1

0* 15**

10	8	6
2	9	13
12	7	5

4* 24**

7	11	8
10	12	4
9	3	14

5* 26**

9	2	7
4	6	8
5	10	3

1* 18**

9	7	5
1	8	12
11	6	4

3* 21**

16	2	3	13
5	11	10	8
9	7	6	12
4	14	15	1

0* 34**

19	2	15	23	6
25	8	16	4	12
1	14	22	10	18
7	20	3	11	24
13	21	9	17	5

0* 65**

2	7	18	12
8	5	11	15
13	17	6	3
16	10	4	9

2* 39**

* foils needed in answer column
** magic number

Directions: This is a magic square! On the left side of the paper there are symbols for nine elements. On the right, thirteen elements are identified by name. Put the number of the element in the box that corresponds to the letter of each element's symbol. You'll know your answers are correct because if you add across each row and down each column the sum will be the same!

Element Symbol		Element Name
A	He	1. Chlorine
B	I	2. Tin
C	Pb	3. Sulfur
D	Sn	4. Strontium
E	Si	5. Carbon
F	Na	6. Lead
G	Li	7. Calcium
H	Ca	8. Iodine
I	C	9. Silicon
		10. Helium
		11. Potassium
		12. Lithium
		13. Sodium

A	B	C
D	E	F
G	H	I

The magic number is ________

Notice that in this Magic Square there were no answers for numbers 1, 3, 4, and 11. Those numbers are what Vacca calls foils.

Magic square on elements prepared by Betty Leonard, Kenai, Alaska.

Chapter 6

EVALUATION IN THE TEACHING OF SCIENCE

Evaluation of classroom learning/teaching is an unending process. Teachers must evaluate when they make judgments about the skills of their students; when they decide what should be taught and how it should be taught; when they determine the level of proficiency achieved by each student; and, finally, when they appraise the value of their own instruction.

In the preceding chapters, methods are suggested which are intended to help the teacher evaluate the reading skills students need to successfully use science texts. Chapter 6 presents some techniques intended to help the teacher in the evaluation of classroom learning, teaching, and materials.

• Every-Pupil Response

Every-pupil response was devised by Donald Durrell of Boston University. This method provides immediate feedback for the teacher and allows each tudent the opportunity to respond. So often, after a concept has been introduced, the teacher asks the students questions to see whether they have understood. Of course, only one student gets to answer a question and that really does not tell the teacher how all of the students are progressing. The following : a variation of Durrell's technique.

Students should paperclip six 3 x 5 cards to their notebooks. At the beginning of the term, students are instructed to write in large, readable letters one entry for each card. They then will have a set of six cards with the following entries (one entry per card): TRUE, FALSE, ?, 1, 2, 3. Variations can be added later. At the end of a difficult lesson, the teacher directs the students to take out either the TRUE/FALSE/?/ cards or the 1/2/3 cards.

For the TRUE/FALSE/? cards the teacher should develop meaningful questions that can be answered either "true" or "false." In response to the teacher's oral questions, students demonstrate their answers by holding the appropriate answer cards in front of them or by displaying the cards on their desks. The ? card is available so that students feel free to respond even if they do not know the answer.

Classroom learning of three concepts can be evaluated using the 1/2/3 cards. In this instance, the teacher selects three concepts. For example, assume the class has just studied the three kinds of equilibrium—*stable, unstable*, and *neutral*. The teacher wants feedback on whether the students understand the distinctions among these ideas. Therefore, the three terms are written on the board with one number placed under each:

stable	unstable	neutral
1	2	3

Students are instructed to take out their 1/2/3 cards. Students demonstrate the answer to oral questions requiring one of the three responses in the same manner they did for the true/false questions. For example, the teacher may ask, "What kind of equilibrium is demonstrated by a billard ball resting on a horizontal plane?" (applied level) or "What kind of equilibrium is demonstrated when a body returns to its original position after being slightly disturbed?" (literal level).

As students display their responses, the teacher quickly scans the room, makes mental notes, and gives the students immediate oral feedback. If too many students respond incorrectly, the concept should be retaught.

Multiple-response techniques conserve teaching and evaluating time and permit evaluation of many students on every item. To teachers who become concerned about students who do not know the answer, two responses may allay their uncertainies: 1) If students look at other students for the answer, they still receive correct feedback when the teacher orally gives the answer. 2) In the author's graduate classes, classroom teachers who evidenced signs of insecurity and hesitation in demonstrating their cards sometimes glanced at another teacher's card before responding. It became evident that the teachers were afraid of being wrong even though the professor was the only one who knew. This problem involves trust between the class and the teacher; however, the acceptance of a student's "?" response by the teacher often sets a positive atmosphere.

Figure 24. Graph for Estimating Readability—Extended.

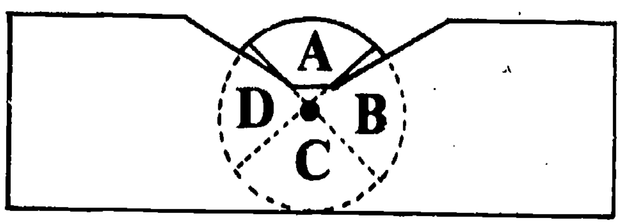


Figure 24 shows a variation of the every-pupil response. Students are given four choices: A, B, C, and D. Letters also can be designated as True (A), False (B), and Uncertain (C). To make it easier for the teacher to get immediate feedback, students should color letters uniformly. For example, A (red), B (blue), C (yellow), and D (green). The circles are attached with a brad. Only one color can be displayed at a time.

These devices were introduced to the Kenai, Alaska, Junior High staff by Dick Carignan and used in many of the content area classes.

• Teacher-Made Tests

Testing is necessary but time consuming. In order to save time, many science teachers resort to unscientific methods of testing pupil understanding of what has been taught.

Science is a discipline which demands mastery of a hierarchy of skills. Students must master one level before proceeding to the next. Many teacher-made tests fail to assess whether a student can use or apply the new knowledge and ask primarily literal level questions which often are not representative of what was covered in class. On the other hand, the reverse situation may occur when the test asks questions primarily at the applied level when prior instruction at that level has rarely occurred.

Criticisms of teacher-made tests are that they often lack validity. If a test is to be valid, it should measure a representative sample of the concepts which were taught. It should also include a representative sample of the levels of understanding that were utilized in the teaching. That is, if a teacher teaches only at the literal level, then a test of the topic should also be at the literal level. If, however, the teacher is interested in assessing students' abilities to apply what they have inferred from details, and if the teacher has taught on all three levels, then the tests should measure that type of learning.

An organized way to insure the validity of a test would be to use a table of specifications for each test. A table of specifications is a two-way grid (see Figure 25) that relates the concepts taught (effect of wind on waves, oscillitory movements of waves, refraction of waves, seismic sea waves) with the levels of comprehension.

Figure 25. Sample table of Specifications—Two-Way Grid.

Levels of Comprehension

Major Concepts	Literal	Interpretive	Applied	Content Total
Effects of wind movements	5/100 = 5%			30/100 = 30%
Oscillitory movements of waves				35/100 = 35%
Refraction of waves				15/100 = 15%
Seismic sea waves				20/100 = 20%
Total				100 pages

The teacher must decide how much emphasis was given to each of the major concepts. For example, for the test on waves, the teacher decided to test the knowledge learned from the textbook. The information on waves covered exactly 100 pages. To estimate how much emphasis was given to each concept, the teacher merely counted the number of pages given to each concept (for example, information on the effect of wind on waves covered 30 of the 100 pages or 30 percent of the unit; oscillitory movement of waves, 35 pages or 35 percent; refraction of waves, 15 pages or 15 percent; and seismic sea waves, 20 pages or 20 percent).

The third step is primarily subjective. The teacher must decide how much emphasis was given in the text and study guides to each of the three levels of understanding. For example, 30 out of 100 pages (30 percent) were devoted to the effect of the wind on waves. This science teacher used guided materials with

Figure 26. Completed Table of Specifications—Percentages of the 40 Questions to Be Written.

Levels of Comprehension

Major Concepts	Literal	Interpretive	Applied	Content Total
Effects of wind on waves	5% 2	20% 8	5% 2	30% 12
Oscillitory movement of waves	10% 4	20% 8	5% 2	35% 14
Refraction of waves	2½% 1	10% 4	2½% 1	15% 6
Seismic sea waves	5% 2	10% 4	5% 2	20% 8
Total	22½% 9	60% 24	17½% 7	100% 40 questions

heavy emphasis on interpretive understandings. In fact, about 2 percent of the time was spent on the interpretive level; 5 percent, on literal understanding; and 5 percent, on applied level understanding.

Figure 26 shows that most of the teacher's emphasis was at the interpretive level. Twenty percent of the time was spent on level two for the oscillitory movement of waves. Since only 35 percent of the total time was spent on that whole subject and 20 percent on level two, only 15 percent remained for levels one and three. The teacher felt that, of the 15 percent, 10 percent was spent on building a literal level understanding for level 2 and, therefore, a fair test must include that many questions. That left 5 percent or 2 questions at the applied level.

It was decided that 40 questions could be answered by most students in one class period. Since 30 percent was a good estimate of how much emphasis was given to the topic on the effect of wind on waves, the teacher knew that to make a fair test, 30 percent of those 40 questions (or 12 questions) had to be on that topic.

The final task was easiest; multiple-choice questions were decided upon and the 40 questions were written to fit each cell. For example, for the first concept, the following kinds of questions were written: 5 literal, 20 interpretive, and 5 applied. Constructing tests in this manner (rather than asking questions in a somewhat random, unscientific way) makes for better, fairer, and more valid evaluation techniques.

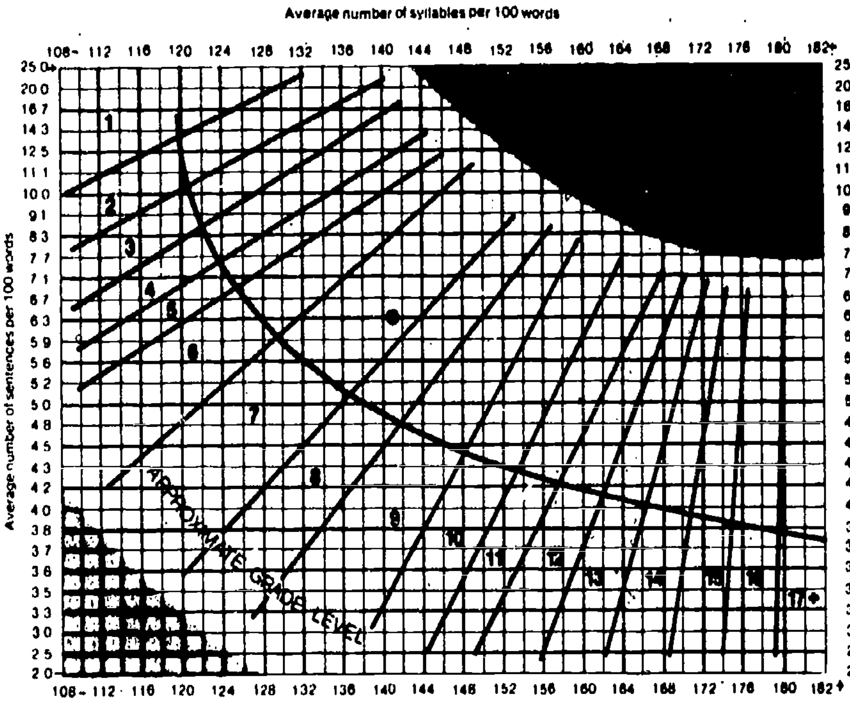
If distractors—those wrong alternatives on a multiple-choice test—prove too difficult to write, ask the students to write them. At the beginning of the term, hand out a dittoed sheet containing the major concepts to be taught, and ask the students to try defining them without reference aids. This provides an idea of what the students already possess in their cognitive structures. Incorrect definitions can become good distractors for future tests. If a majority of the students fail a test, one can assume that the teacher has not presented the material adequately. Unrealistically difficult tests or tests that ask ambiguous, literal level questions discourage students.

• Assessing Grade Levels of Textbooks

The tremendous interest in the readability levels of materials used in the classroom, makes it appropriate to include in this chapter, the extended directions for using the Fry graph for estimating readability. Original directions called for skipping all proper nouns. New directions count proper nouns but recommend skipping numbers. Directions are as shown with graph, Figure 27.

Figure 27. Graph for Estimating Readability—Extended

by Edward Fry, Rutgers University Reading Center, New Brunswick, N.J. 08904



Expanded Directions for Working Readability Graph

1. Randomly select three (3) sample passages and count out exactly 100 words each, beginning with the beginning of a sentence. Do count proper nouns, initializations, and numerals.
2. Count the number of sentences in the hundred words, estimating length of the fraction of the last sentence to the nearest one-tenth.
3. Count the total number of syllables in the 100-word passage. If you don't have a hand counter available, an easy way is to simply put a mark above every syllable over one in each word, then when you get to the end of the passage, count the number of marks and add 100. Small calculators also can be used as counters by pushing numeral 1, then push the + sign for each word or syllable when counting.
4. Enter graph with *average* sentence length and *average* number of syllables; plot dot where the two lines intersect. Area where dot is plotted will give you the approximate grade level.

5. If a great deal of variability is found in syllable count or sentence count, putting more samples into the average is desirable.
6. A word is defined as a group of symbols with a space on either side; thus, *Joe*, *IRA*, *1945*, and *&* are each one word.
7. A syllable is defined as a phonetic syllable. Generally, there are as many syllables as vowel sounds. For example, *stopped* is one syllable and *wanted* is two syllables. When counting syllables for numerals and initializations, count one syllable for each symbol. For example, *1945* is four syllables, *IRA* is three syllables, and *&* is one syllable.

Note: This "extended graph" does not outmode or render the earlier (1968) version inoperative or inaccurate; it is an extension (REPRODUCTION PERMITTED—NO COPYRIGHT).

FINAL STATEMENT

Concerned science teachers often say, "My students can't read!" What they usually mean is that students do not understand what they have decoded. Although as far back as 1920 research criticized the practice of having students read aloud from the textbook, the practice is still in great use today. What often happens is that students decode so well, the teacher is led to believe they understand the meanings of the words and can use those meanings in making inferences and applications. Secondary teachers have tended to teach "what" rather than the "how."

All too often, the science teacher has never been aware of how to teach content *and* process at the same time. This monograph was written to help this science teacher. Herber (1978) labels this teacher an "assumptive teacher," one who relies on the recitation method and who gives assignments expecting students to already have the skills and background knowledge needed to learn the assignments.

Reading teachers who lack expertise in science should not feel reluctant to work with science teachers. Remember, reading teachers have expertise in the reading/thinking process. As pointed out earlier, a certain naivete of content can become an advantage to the reading teacher in helping the science teacher overcome the tendency to teach assumptively.

Science is an exciting discipline; yet Hurd noted in 1970 that the average American was a scientific illiterate. One of the recommendations by the National Commission on Excellence in Education was to include as goals in Science education the teaching of concepts, laws, and processes of the physical and biological sciences. Yet science classes today are still overwhelmingly fact oriented.

Science educator Dorothy Gabel (1984, p. 585) believes that "...the reason why many students do not do well in science courses may be because science educators for too long have not taught students how to read science materials." The intent of this monograph was to present some strategies that the science educator can use to help students comprehend the text. Developing and using these strategies will take time, but as high school science teacher Dempster (1984) says, "Although presentation of reading, studying, and learning techniques initially takes some class time, I have found that in the long run, I save time. As students learn to apply reading strategies to scientific text, they are better able to read and understand assignments outside of class, and I have more time to focus on the problem solving and laboratory aspects of my courses" p. 583.

Helping science teachers to guide student understanding of today's world and prepare science students to meet unknown questions of tomorrow's world is difficult, but necessary.

Appendix A

Informal Study Skills Inventory on a Physical Science Textbook

(Developed by Scott L. Shablak, Syracuse University)

1. Take out your science book. Look at it while you count to five. Sit on it. Then answer the following upside down questions:

   a. What color is the book?

   b. Write as many words as you can remember from the cover (if possible).

   c. Draw the picture from the front cover.

   d. Draw the picture from the back cover.

   e. You and a partner check and discuss each other's answers.

Now take your book out again and answer the following questions:

2. Circle the date that is closest to the copyright date of your book.

   1958 1962 1966 1970

3. Check the statement below that expresses what the *author* feels is the *theme* of this course.

   ______a. The exploration of biological aspects of all life.

   ______b. The development of evidence for an atomic model of matter.

   ______c. The investigation of the elements essential to ecological balance.

   ______d. The extension of ideas dealt with in the AAAS Science Program.

4. Check below the section in the book where you found the answer to question #3.

   ______a. Introduction

   ______b. Table of Contents

   ______c. Index

   ______d. Preface

   ______e. Epilogue

5. Number the following topics in the order they are dealt with in your textbook.

   ______Molecular motion

   ______Quantity of matter: mass

   ______Solubility and solvents

   ______Sizes and masses of atoms and molecules

   ______Characteristic properties

6. The answers to question #5 were found (by me) in

   ______Index ______Introduction

   ______Contents ______Looking through the book

   ______Epilogue ______My head

7. Look at Figure 1.1 and Figure 4.8. State three things that are the same in both pictures and three things that are different.

Same	*Different*
a. ______	a. ______
b. ______	b. ______
c. ______	c. ______

8. What do you think *Fig.* mean in this book?

9. Take exactly 30 seconds and look at the pictures in the book.

10. Now, from your observation of the pictures, list or draw ten objects we will be using in science this year. (Don't look back!)

11. Put a circle around the number that best expresses how many experiments we can deal with in this book.

    19 29 39 49 59

12. On what page(s) can the following be found?

______Calibration	______Dalton, John
______Mass (unit of)	______Caloric (definition of)
______Radioactivity (discovery of)	______Precipitate
______Alcohol	______Geiger Counter
______Marsh Gas	______Oxymuriatic Acid

13. At the end of the book the authors state what they hope you have gained from the course. Which of the following is not stated?

    ______a. More expert experimenter

    ______b. More critical reader

    ______c. More careful observer

    ______d. Sharper thinker

14. Look at the pages listed below. Then answer question #15.

    p. 5 p. 9 p. 31 p. 32 p. 37 p. 41 p. 56

    p. 74 p. 84 p. 88

15. Write between 13 and 17 words describing the difference between what the authors label *Fig.* and what they label *Table*.

16. Why is the picture on page 35 labeled *Fig.* rather than *Table?* Give your most logical guess.

17. On page 19, do the best you can on question #1.

18. Without turning around, answer the following:

    a. Is the person seated behind you a boy or a girl? (If you're in the back seat, use the person in the front seat of your row. Do not peek!).

    b. What color eyes does he/she have?

    c. What color clothes is he/she wearing?

19. List the steps to follow in doing Experiment #1.1 on pages 4 and 5.

20. a. Write the topic of the last article or book you have read concerning anything scientific.

    b. Write the topic of the last TV show you saw concerning anything scientific.

    c. Write the one most interesting thing you remember from your science course last year.

    d. Write the one most boring thing you remember from last year's science course.

    e. Write the one most difficult thing you remember from last year's science course.

21. Look on page 19. Read the two paragraphs in Section 2.14. Then, in one sentence, state the main idea expressed in the two paragraphs.

22. List in order everything you did from the time you woke up yesterday until the time you woke up this morning.

23. Write a couple of your own words stating what you think each of the following terms means. Do not look them up. If you don't know, guess.

    a. Apparatus
    b. Mass
    c. Solubility
    d. Graph
    e. Properties
    f. Volume
    g. Cm
    h. Scientific method
    i. Conservation
    j. Hypothesis

24. Look at the lab setup your teacher has prepared. List below all the things you think are *wrong* with the setup. Use your past experience and your head.

25. a. Write 3-5 words describing your feelings about science courses in general.

    b. What have you heard about what to expect in this course?

    Note: When all of the above questions have been completed and checked, proceed to question 26.

26. All of the above questions have somehow attempted to do which of the following:

    a. Familiarize you with this year's program.

    b. Help you learn to fool around with science stuff.

    c Help you and your teacher learn your strengths and "not-so-strengths" in what you will be doing this year.

27. In the space below, attempt in some manner to chart the questions you have answered well and not so well. Put the questions in categories you think they best fit. You may work with someone else if you like. You may use some of the categories listed and or *make up some of your own.*

    Observation skills
    General information
    Compare and contrast
    Following directions
    Interpretation
    Location skills

Appendix B

Expanded Directions

Today we would like you to read about something that is very important. It is at the very heart of everything you will ever try to learn. We are talking about *thinking*.

Ever since you first came to school, your teachers have tried to encourage you to think. Too often, however teachers simply *tell* you to think. During the next few weeks we are going to try to *teach* you some ways of thinking.

First, it is important that you know something about thinking. What is it? How do people think? As you read on, we will discuss two kinds of thinking. Then we will try to show how words and thinking go together. Finally, we will relate what has been said to some activities we shall undertake for the remainder of the school year.

The people who study thinking tell us that it can be broken down into two broad types: analytic thinking and intuitive thinking.

Analytic thinking is a very careful kind of thought. It usually proceeds one step at a time. These steps usually are very clear and each step usually can be reported by the thinker.

Remember when your teachers tried to teach you how to solve word problems in arithmetic. They gave you a series of steps like these:

1. Find out what the problem is asking.
2. Determine what information you have been given.
3. Decide how you should solve the problem—will you add, subtract, multiply, divide, or use a combination of operations?
4. Solve the problem.
5. Check your answer.

When you figure out a problem by following steps like these, you are thinking analytically.

Intuitive thinking, on the other hand, does not proceed in careful, well-defined steps. Thinkers arrive at answers with little, if any, awareness of the processes by which they read them. They can rarely provide an explanation of how they get their answers.

Let us use mathematics again for an example. Did you ever look at a problem and, all of a sudden, seem to know the correct answer? Then, as you tried to tell someone how you got the answer, you found that you could not do so? If this has happened to you, then you have experienced intuitive thinking.

Both types of thinking are important. Intuitive thinking has led to some of the world's greatest discoveries. However, intuitive thinking becomes nothing more than guessing unless one is able to go back and verify what has been found. In other words, one should always attempt to confirm intuitive thinking by a more caref. !, analytic method.

Now let us consider some relationships between *words* and *thinking*.

What is a word? Whole books have been written about this question. However, for our purpose, let's define a word as a spoken, or written symbol that "stands for a thing, experience, or idea." When we say "apple," all we have done is made a series of noises or sounds (ap'l). Due to the fact that we have experience with apple, we *think* of something round, red, and edible. We all may not think the exact same thought. However, our thoughts usually are along similar lines if we have had similar experiences with the idea represented by the word.

At your present age and grade level, almost all the thinking you do is performed with words. *You think with words.* Would it be possible to think about and learn about any of school subjects without knowing the important words of those subjects? Possibly, but you certainly would have a very difficult time.

It is not enough to know or agree upon the meanings of words. We must also know how words (or rather, the ideas represented by words) are related. For example, how are the following words related: animal, vegetable, matter, mineral? Does one word seem to be more important than the others?

During the next few weeks we will provide you with different kinds of vocabulary activities which will

1. help you learn the meanings of important terms,
2. help you see relationships among these terms and discover which words are most important, and
3. provide opportunities for you to practice intuitive and analytic thinking.

We believe that these activities will cut down on some of your study time as well as help you discover more effective ways to go about learning in other subjects.

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