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ABSTRACT

The material in this monograph is based on the idea that science content and the reading and reasoning processes for learning may be taught simultaneously in the science classroom. Topics of the six chapters are: distinguishing between content and process, developmental and functional reading; diagnosis in teaching science; preparatory activities for teaching science; the use of guided material in teaching science; the reinforcement of vocabulary and comprehension in teaching science; and evaluation in the teaching of science. Two appendixes include an informal study skills inventory on a physical science textbook and an extensive statement to students about learning to think. (JM)

reading aids series

IMPROVING READING IN SCIENCE

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The International Reading Association attempts, through its publications, to provide a forum for a wide spectrum of opinion on reading. This policy permits divergent viewpoints without assuming the endorsement of the Association.

FOREWORD

In this monograph, 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 was prepared as a practical tool for teachers in the science classroom. This new title in IRA's Reading Aids Series is a welcome addition to the Association's growing list of publications.

Harold L. Herber
Syracuse University

Chapter 1

DISTINGUISHING BETWEEN CONTENT AND PROCESS: DEVELOPMENTAL AND FUNCTIONAL READING

"To teach *only* the findings of science is to teach an illusion of scientific knowledge" writes respected science educator Paul Hurd *(8)*. Hurd does not deny that knowledge of facts is necessary for learning, but the teaching of science content must go beyond that. The science teacher's responsibilities are to help students develop skills necessary to the learning and application of science concepts.

Olsen *(9)* suggests that many subject matter teachers believe that they do not have sufficient time for teaching content plus reading/thinking skills. Yet, of the 102 science teachers who responded to Olsen's survey, a little more than one-half felt that they *knew* the special reading skills needed to learn their subject. Braam and Walker's more recent survey *(4)* confirms this finding.

Otto *(10)* found that secondary teachers who responded to his survey felt that, without some special training, they were not competent to teach the reading skills needed for their subject. This result may explain why many teachers believe that they do not have time to teach reading skills. It seems reasonable to assume, further, that this is why 45 percent of the teachers in Otto's survey disagreed with the statement, "Every high school teacher should be a teacher of reading." Every secondary school teacher is *not* a teacher of reading. Every secondary school teacher is first a teacher of course content in this case, science. It is possible, however, to teach content and learning skills simultaneously; and the purpose of this monograph is to provide the science teacher with suggestions on how to combine these activities effectively.

Before embarking on such an assignment, it would be appropriate to distinguish between content and process and learning to read (developmental reading) and reading to learn (functional reading).

Content and process. Content can be defined simply as subject matter. More specifically, it is the accumulation of details, concepts, and generalizations of a particular curriculum.

Process consists of the reading and thinking skills necessary to acquire and apply content. Depending on the focus, deductive and inductive thinking can be thought of as equal parts of the cognitive process.

The science teacher has been trained in content and the reading teacher has been trained in process. Reading in the content area can be facilitated best when these two teachers combine their efforts.

Developmental and functional reading. In order to distinguish between learning to read and reading to learn, the terms developmental and functional reading will be used. By comparing the materials and methods utilized in each of the above systems, we can better understand the differences in focus.

• Developmental Reading Materials

The majority of school children today receive reading instruction in books called basal readers. These readers are part of a graded and coordinated series. The vocabulary and concept loads are limited and, often, the reading content of the stories is criticized by persons who fail to realize that the story is important only as a vehicle for developing and extending skills.

• Functional Reading Materials

Content, or subject matter, is very important in science textbooks where the vocabulary and concept loads are not controlled and often are highly technical. Because there are few restrictions, the process of reading to learn the *structure* of the content becomes a very difficult task. The reading level of the basal text is geared to the highest level at which the learner can read satisfactorily under teacher supervision (instructional level). The readability level of the content text often is above the level at which the learner can read with full understanding (independent reading level).

In science classes, the objectives should be to guide the reader to the point where he can assimilate those concepts which the teacher believes are important. The narration, in this case, is not a means to an end but rather an end in itself.

• Developmental Reading Methods

The directed reading activity (DRA) is probably the most common technique used in teaching a child to read, perhaps due to the fact that the process is incorporated in the basal readers. Generally speaking; there are four steps involved: 1) readiness period, 2) guided silent reading, 3) skills development, and 4) follow-up with supplemental activities for enrichment.

During the readiness stage, new vocabulary words and concepts necessary for comprehension of the story are introduced. In some cases, the teacher then sets purposes for reading the story by asking the children to read silently, the second step of DRA, and answer simple questions about the characters and/or the plot. During skill building, the third phase of the DRA, word recognition and comprehension techniques are developed further. Relevant phonics instruction also takes place at this time, and comprehension skills are refined. Workbooks which accompany the basal reader are often used so that students may practice skills taught in the day's lesson. During the final follow-up stage of the DRA, teachers bring in related supplemental materials such as tapes, records, films, and filmstrips to enrich student background. This activity generally occurs for each story.

In the past, some reading specialists have suggested that it is the science teacher's responsibility to adopt the DRA as a method of teaching content. This suggestion seems impractical and illogical because, in the DRA, narration serves as a means of teaching reading and in science texts the narration is the essence of the lesson.

• Functional Reading Methods

If current teaching methods are not meeting the needs of the student, what method or methods can be suggested to facilitate learning in science? It will be the purpose of this monograph to describe a method that has met with some success. Some readers may argue that the method described here is a modification of the DRA The proposed method includes five steps: 1) diagnosis, 2) preparatory activities, 3) use of guided materials, 4) reinforcement, and 5) evaluation.

Content further defined. In order to understand the reasoning behind the suggested activities, it is necessary to further define content and process.

Content is the accumulation of details, concepts, and generalizations. The content of most science curricula should be structured. Structure is defined by Barron *(3)* as the "hierarchical ordering of principles, concepts, and details." Bruner *(5)* believes that teaching students the underlying structure of a subject (that is, teaching them how things are related) is a minimum requirement for using knowledge. In the past, many science teachers were satisfied with literal level learning. Thus, there is no guarantee that students who learn many unrelated facts also learn major concepts. Hurd *(8)* suggests that to know the number of miles from the earth to each planet does not mean one comprehends distance. He further states that it is the responsibility of the science teacher to help young people learn how facts are known and how they can be built from fragments of information into structures having more meaning, how to develop a representative and significant reservoir of scientific concepts, and how to minimize the rote memorization of factual information.

Content determines how conditions of learning are implemented. Therefore, content selection is crucial to the teaching of structure or how things are related. Most science textbooks contain too many concepts to be taught in one semester. Thus, the delimiting criteria suggested by Earle *(6)* seem most appropriate. Earle believes that the selected content should be interesting to the student, significant to the discipline, broadly applicable outside the discipline, and important in terms of its potential for attacking the problems and issues of the present and the future. In other words, will it matter ten years from now?

Process further defined. Content analysis is the first step in determining which teaching methods to use. The next step is to focus on the process of learning. Process is defined here as the reading and thinking techniques that must be utilized to produce a clear understanding of new materials. After the science teacher reads the material and selects concepts to be taught, process identification is facilitated if he asks himself "What thought processes will my students have to go through to arrive at these generalizations?" This task is not simple and could be done incorrectly if the science teacher is not fully cognizant of the fact that his background of experience and familiarity with the material gives him an advantage over the students. It is essential for the teacher to be aware, to some extent, of student background and differences in cognitive structures. Without these precautions, the teacher may be guilty of what Herber *(7)* labels "assumptive teaching." Hurd *(8)* claims that one of the difficulties in learning new science curricula is that students are not guided through concept forming processes.

• Deductive and Inductive Thinking

Depending on focus, deductive and inductive thinking can be thought of as equal parts of the cognitive process. In teaching deductive thinking, the pupil is presented with generalizations and guided toward understanding the relationships present among the concepts and the details subsumed under the generalizations. Chapter 3 deals, in part, with deductive teaching concepts formulated by Ausubel *(1, 2)* and Barron *(3)*. These concepts have been found to be successful in preparing students for new material. In learning inductive thinking, pupils consider literal level data, discover relationships among the facts to make inferences, and ultimately form generalizations. A section of Chapter 4 illustrates a teaching method designed to accomplish these objectives.

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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. Lockwood *(4)* reports that several studies by Mallinson confirmed this belief. Lockwood also reports that studies dealing with teacher ability to estimate reading difficulty of science textbooks indicated inconsistency and suggested that teachers be provided with objective methods for evaluating materials. The cloze method developed by Taylor *(7)* can be used to accurately and quickly screen each student's ability to understand the text.

Cloze reliability and validity. Levels of individual learners have been classified by reading authorities [Betts *(1)* in particular] as independent, instructional, and frustration. For all practical purposes, the independent level is the highest level at which a learner can read on his own. The highest level at which the learner can read *with teacher guidance* has been labeled the instructional level. The frustration level is that plateau where the learner is frustrated in his attempts to comprehend and decode. Materials are considered suitable for use in the learner's independent study if he can correctly respond to 90 percent of the questions constructed on those materials, and suitable for guided instruction when he responds to only 75 percent of those questions.

Studies were conducted by Bormuth *(3)* and Rankin and Culhane *(6)* 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 determining comparable scores on cloze and multiple-choice tests. Rankin and Culhane's study was a replication of Bormuth's 1968 study *(2)*. Conclusions indicate that if a student receives a cloze score of 61 percent on a passage, he 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 $1\frac{1}{2}$ inches). The test should start and end with a complete sentence. An example of a cloze test can be seen in Figure 1.

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 that was deleted is supplied. Research by Taylor *(7)* and Bormuth *(3)* 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 percent and 60 percent usually means that 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 will probably not have much difficulty reading the book at the literal level. Scores below 40 percent do not necessarily mean that the student will have difficulty reading the material. On the contrary, the examiner may discover that 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. If the student has not written appropriate or relevant synonyms, the teacher can expect that the student will have difficulty 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

Once the teacher has determined that the text material is suitable for his students, it would be to his advantage to discover whether his students have

Figure 1. 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 into 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.

Figure 2. Study Skills Needed to Aid in the Understanding of Scientific Materials

Vocabulary Skills	Comprehension Skills
Using context	Following directions
Using prefixes, suffixes, and roots as aids to meaning	Locating main ideas, supporting details
	Following sequence
	Organizing
Locational Skills	Using problem solving techniques in
Using graphs, charts, tables, figures, scales, and diagrams	formulating hypothesis
Using a glossary	collecting data
Using table of contents and index	organizing data
Using appendixes	forming a conclusion
Using chapter headings and subtitles	testing a conclusion
	Others
	Observing
	Gaining knowledge of labs and apparatus

the necessary study skills for the successful use of that text; skills which are similar to those needed in most content areas. Some of the study skills useful in science are included in Figure 2. An informal study skills inventory is an instrument the classroom teacher 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 2 as a guide, the teacher 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 molecules

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 the Westhill, New York, Public School System) on a science textbook is provided in Appendix A.

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 3). Each chart is constructed by filling in those skills the inventory measures. Niles and Early *(5)* suggest that pupils' scores be recorded as follows:

a. leave the space blank if the student has demonstrated acceptable competence in a given skill

b. use a single check if he is having some difficulty

c. use a double check if he is 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.

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Figure 3. Class Analysis Chart*

Textbook ______ Subject ______ Grade ______

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

*Reprinted from Olive Niles and Margaret Early, "Adjusting to Individual Differences in English," *Journal of Education*, 138 (1955).

Chapter 3

PREPARATORY ACTIVITIES FOR TEACHING SCIENCE

In developing the concept of preparation, we have to assume two principles: the student's existing cognitive structure and the material he must learn.

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

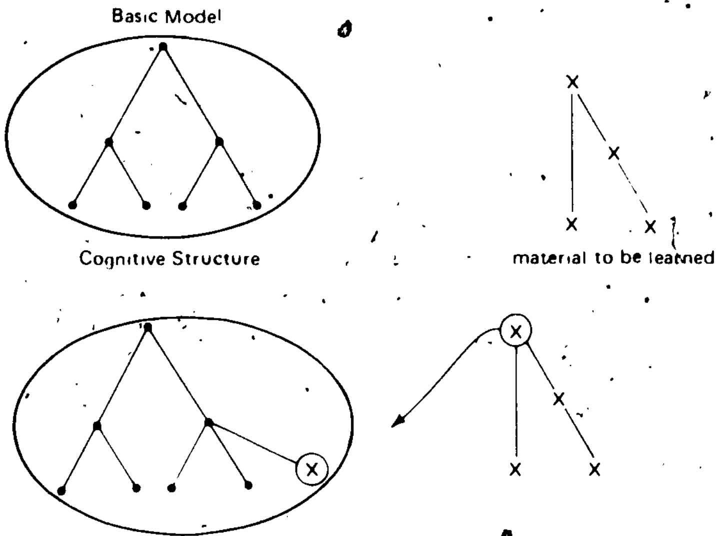
• Cognitive Structure

Cognitive structure may be defined as all of an individual's *existing* knowledge. It may be likened to an ideational filing system. Each individual has his own way of organizing existing knowledge hierarchically into his 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 a student's face when he discovers that *he* is an animal? This situation results when the cognitive structure does not have the necessary attributes for a particular concept to enable the learner to relate new material to that he already knows. This may not happen, for example, if his concept of animal includes small attributes such as living organism 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: the student's existing cognitive structure and the material to be learned.

Robinson *(11)* 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 4) 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 X's.

Figure 4. Schematic Representation of Cognitive Structure and Its Relationship to New Material 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 *(10)* contends that, if this theory describes the way a student learns new material, teachers must organize their teaching in a way so as 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 the student before he is confronted with a new learning task. Ausubel *(1)* labels these aids as advance organizers.

Advance Organizers

Ausubel suggested that students should be presented with passages containing an orderly arrangement of highly generalized concepts needed in their cognitive structure *before* they try to learn new concepts. Called *advance organizers*, Ausubel's passages were given in advance of the new material to be learned. The intent was to organize the student's cognitive structure and prepare him 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 the student's existing cognitive structure.

In 1960, Ausubel experimented with a passage on the properties of steel as an alloy and the relation of its internal structure to a) temperature, b) carbon content, and c) rate of cooling. In the experiment, one group of college students read a short introductory passage (advance organizer) on the more abstract material concerning how, because of its limited grain structure, pure metal should alloy with other metals or non metals to create a wider variety of metals and that to know the grain structure of an alloy one must know a) the temperature, b) its principal metal component, and c) 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 *(11)* 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.

Barron *(4)* recognized that the absence of directions for constructing advance organizers would pose a serious problem for the overburdened classroom teacher. Thus, in 1969, 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 et al. as "visual and verbal representation of the key vocabulary of a learning task in relation to more inclusive or subsuming vocabulary concepts that have previously been learned by the student" *(7)*. Estes explains the construction of a structured overview as a graphic arrangement of words relevant to the important concepts in the learning passage.

The creation of this visual representation depends on two things: how well the science teacher has internalized his 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 they are with teaching concepts. Hurd *(9)* 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 that teachers should select representative concepts, hopefully, 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 *(4)* 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.

Robinson *(11)* admits there is a major difficulty in constructing an organizer a teacher cannot assume that the cognitive structures of any two students will be identical with respect to relevant background knowledge. The interaction between learner 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 5 shows an example of a structured overview [by Estes, et al. *(7)*] used in a tenth grade biology class. Students using this overview scored significantly higher on a delayed test of learning and retention than students who received purpose questions or no guidance at all prior to the reading *(6)*.

The reading selection was an adaptation from *Modern Man* by Moon, Otto, and Towle. It contained information on the form and structure of fungi. As you can see, the structured overview consisted of a series of vocabulary terms organized to depict fungi within a broad taxonomy. In the teacher led discussion, comparisons were drawn between algae and fungi.

Figure 5. Biology Unit—Structured Overview

PROTISTS (PROTISTA)	ANIMALS (ANIMALIA)	PLANTS (PLANTAE)
VIRUS BACTERIA RICKETTSIAE SPIROCHAETES CYANOPHYTA MYXOMYCOPHYTA	PROTOZOA HIGHER, MULTICELLULAR PHYLA.	ALGAE FUNGI HIGHER, MULTICELLULAR PHYLA.

KINGDOM: PLANTAE

SUBKINGDOM: THALLOPHYTA—PRIMITIVE NONVASCULAR PLANTS

(EMBRYOPHYTA-HIGHER PLANTS)

DIVISION: ALGAE

CLASS OR PHYLUM:
- CYANOPHYTA—BLUE-GREEN
- CHLOROPHYTA—GREEN
- CHRYSOPHYTA—GOLDEN, DIATOMS
- PHAEOPHYTA—BROWN
- RHODOPHYTA—RED
- PYRROPHYTA—DINOFLAGELLATES
- EUGLENOPHYTA—EUGLENAS

DIVISION MYXOMYCOPHYTA: (SLIME MOLDS)

DIVISION EUMYCOPHYTA: (TRUE FUNGI)

CLASS OR PHYLUM
- PHYCOMYCETES—ALGAL FUNGI (MOLDS AND MILDEWS)
- ASCOMYCETES—ASCUS OR SAC FUNGI (YEAST, MOLDS)
- BASIDIOMYCETES—BASIDIUM OR CLUB FUNGI (MUSHROOM)
- FUNGI IMPERFECTAE—IMPERFECT, DO NOT FIT ELSEWHERE, NO SEX REP.

GENERAL DESCRIPTION—MYCOLOGY
- ACHLOROPHYLLOUS, HETEROTROPHIC PLANTS
- HAVE PLANT BODIES MADE FROM CELLS, EACH WITH NUCLEI
- NEED MOISTURE AND WARMTH, DARKNESS
- SOME SPECIES BENEFICIAL, SOME HARMFUL
- STRUCTURE—MULTICELLULAR HYPHAE WITHOUT SEPTATIONS IN SOME GENERA
- PIGMENTED, NO CHLOROPHYLL
- REPRODUCTION—ASEXUAL SPORES OR SEXUAL REPRODUCTION

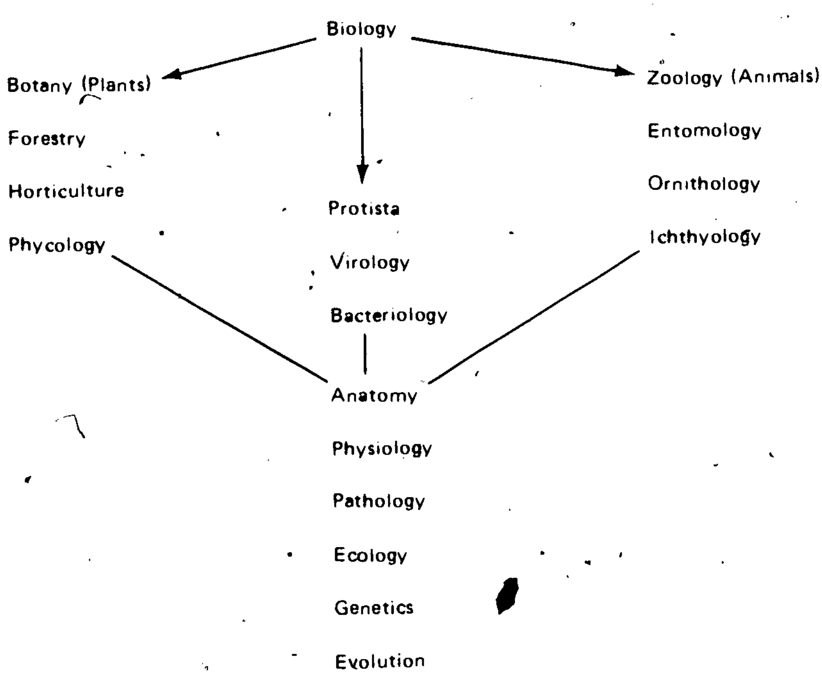
Figure 6 illustrates a less complicated overview [by Earle and Barron *(6)*] which was used successfully to introduce students to a course of study in biology. The directions given to the students were as follows:

> This course is a difficult one in the sense that there are a great number of new ideas and terms to learn. I'll be using diagrams similar to this one to help you see which ideas are most important and how these ideas fit together. Don't feel that you must memorize these diagrams. Rather, try to relate new and more specific information from our labs, large group lectures, and reading assignments to these diagrams. This course, as you can see, deals with biology — the study of life. What can you tell from this diagram?

Experimentation by Barron and Stone *(5)* led them to question the proper placement of structured overviews. They questioned the effect of student constructed structured overviews on the learning of vocabulary relationships from a passage of school science content. These structured overviews were called graphic post organizers, and they were constructed by the student and preceded 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 × 5 cards on which were typed the terms taken from the structured overview (or graphic

Figure 6. Structured Overview



advance organizer) 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 postgraphic overviews were more effective than the structured overview.

In Travers' *Second Handbook of Research in Teaching*, Shulman and Tamir *(12)* state that the crucial question for science educators has been how one transmits a particular concept or structure of knowledge to students so that it becomes an enduring component of the learner's cognitive structure. The work of Ausubel and Barron 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 before and after presenting new materials to build upon that structure so that it can be sensibly related. Using preparatory activities, such as structured overviews, and aiding students in receiving new material helps to guide students toward deductive thinking.

Not all new concepts need a structured overview. 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 words the teacher believes students must learn in order to understand concepts previously selected by the teacher.

If the teacher has selected the most representative concepts to be taught and has completed the first step in Earle and Barron's criteria for constructing structured overviews *(6)*, he has probably reduced the number of vocabulary words he needs to preteach.

Teachers should look at the vocabulary they select as important for the student to understand. Probably most of the words are already identified for the student in the context of the textbook; and, if so, then a guide similar to the one shown in Figure 7 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 nor graded by the teacher.

Figure 7. Vocabulary Development—Word Meaning

Today's Basic Science
pp. 90–100

Directions: Read each sentence below. Turn to the page number listed after the sentence and try to locate a word having the same number of letters as spaces provided. Write letters in the spaces to complete the word on the line. Complete the word for each sentence.

1. The name of the moon at the third quarter. (91, 2, 2)

   g _ _ _ _ _ _

2. Apparent changes in shape. (91, 2, 4)

   p _ _ _ _ _ _

3. Deep pits on the moon's surface. (94, 2, 1)

   c _ _ _ _ _ _ _

4. Steep cliffs on the moon. (94, 1, 2)

   s _ _ _ _ _ _

5. Space pilots. (95, 2, 2)

   a _ _ _ _ _ _ _ _ _

What about words that cannot be defined in context? Bamman *(2)* used the following list of words to illustrate that scientific classifications are based on similar structures: lepidoptera, hymenoptera, hemiptera, and homoptera. These are words used to describe the wing (pteron) structures 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 *(8)* claims that the remaining words need only to be pronounced, as this clue alone may give students a basis for recognizing them later in print.

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. The following chapter attempts to illustrate ways of accomplishing this goal.

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Chapter 4

USE OF GUIDED MATERIAL IN TEACHING SCIENCE

Once the student is sufficiently prepared through vocabulary and concept development, he is ready to read the text. Most students need guidance to comprehend the material. Guidance is a procedure of helping students through the concept forming processes and can be accomplished by the use of reading guides. Guides differ in format and construction and range from simple to complex, depending on the student's ability, level of difficulty of the text, and level of comprehension the student is expected to attain.

Guides are merely simulators of the process of thinking. The teacher must determine what that process is and does so by rereading the portion of the text to be assigned to the students. During the rereading of the text, the teacher must keep several questions in mind. What concepts, inferences, and/or applications does he want his students to understand once they 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 the inferences the teacher expects)? Is the text cluttered with unrelated factual statements? Does the author assume that the student can make the correct inferences and ultimately apply what he has learned in the lab?

In this chapter, the construction of simple and three-level guides will be discussed.

• 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 8.

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 because of his extreme familiarity with the subject matter. The reading professor possessed a naivete that enabled her to anticipate sections of the textbook which would present problems to the nonscience majors. Science teachers, therefore, should be forewarned to assume the role of the most naive student; it is often difficult to imagine that students have difficulty with concepts which come so easily to the teacher.

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 9 was developed for a science text by Scott L. Shablak of the Westhill, New York, School System. 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 labeled "skip it."

• Three-Level Guide

Facts are needed as a foundation for concept development, but knowing them does not assure their use or value. Mastery of a concept is indicated by the student's ability to generalize beyond specific stimuli to a variety of new situations. Hurd *(2)* assigns to the science teacher the task of finding ways to make the learning of science possible without drowning insight in details. He further charges 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 concepts, Hurd denounces this meaningless knowledge and asks whether knowing the parts of a leaf is the same as understanding the complementarity of structure and function? The answer is, "no." 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 *(1)* has named the levels *literal comprehension*, *interpretive comprehension*, and *applied comprehension*.

It is not inferred here that there are only three levels of understanding; the

Figure 8. 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 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, he 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. Chlorine weighs approximately ____ grams (page 344, table 10-5). Therefore; 22.4 liters of hydrogen chloride must weigh ____ grams (page 278).

Figure 9. 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 Fig. 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.

______________________ ______________________

Paragraph 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?

point is that we recognize a progressive level of abstraction from the literal level to the applied level.

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 decoding words and determining their meanings in context. Students may identify the literal level statements without understanding what they mean.

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 to interpret those 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 10 illustrates the simulation of the three levels in a study guide for "reading" a ninth grade earth science film.

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 the student to check true statements that can be found in the text.) The teacher now must think about the content he wants his students to learn. This task is not always easy because the teacher has 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 that are determined 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 statements that are true *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 questions first, interpretive level questions second, and applied level questions last. Directions should be helpful, not overbearing. Examples of different styles of three level guides are illustrated in Figure 11.

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 like the samples and then experiment with your own. Three-level guides take a good deal of time to create and construct, but they are worth the effort.

Figure 10. Three-Leval Guide

Erosion—Leveling the Land
Study Guide # 1

CONCEPTS TO BE DEVELOPED: WEATHERING, EROSION, DEPOSITION, EFFECTS OF EROSION

PART I: Literal Understandings

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 Understandings

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. (G, H, I)

_________ 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 in the 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 same 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 landlocked 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.

Figure 11. Three-Level Guide

STUDY GUIDE INSECTS

LEVEL I: Literal Level

List the six major advantages insects have that insure their survival. Also list examples of these advantages on the lines below. There may be more or less than three examples. The first one 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: Interpretive Level

Support the following inferences with your statements from Level I.

STATEMENTS	
1—a, b, c	Mobility is an aid for survival.
____________	Insects eat a variety of things, but all insects do not eat the same food.
____________	If all insects ate the same food, their chances for survival would be lessened.
____________	The external skeleton of the insect contributes to the success of the insects' survival.
____________	If both immature and adult insects ate the same food supply, their chances of survival would be diminished.
____________	By providing insects with reproductive systems 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: Applied Level

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

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

________ 2. External skeletons perform the same function as internal skeletons.

________ 3. Insects shall inherit the earth.

• Utilization of Guides

Not all chapters, units, or topics need instruction. Guidance is determined by the level of difficulty of the material and the level of competency of your students.

Both the simple guides and the three-level guides are used in the following manner. If at all possible, assign the guide as homework; and during the following class period, have students divide into groups. Groups can be formed according to student strengths while remaining 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 the group discussion and ultimate group consensus are more important. Collecting the guides could bring peer pressure to bear on the negligent student and defeat the whole purpose of the discussions.

While students are discussing their responses, the teacher should move about the room to encourage and assist. In the college physical science class discussed earlier, the professor walked between the groups so that if he spotted a group having any particular difficulty, he could step in and answer questions. Often students are reluctant to ask questions, and small group discussion enables 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 include 100 or more students. Grouping, as described, is one way to cope with the problem.

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Chapter 5

REINFORCEMENT OF VOCABULARY AND COMPREHENSION IN TEACHING SCIENCE

One of the shortcomings of traditional teaching methods, according to Skinner *(5)*, is the relative infrequency of reinforcement. He admits that large class loads limit the amount of reinforcement a teacher 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. Also included are suggestions for further application and reinforcement of comprehension skills.

• Reinforcement of Vocabulary and Comprehension Skills

Barron's most recent research *(1, 2)* indicates that using vocabulary reinforcement exercises as a vehicle for small group discussion enhances vocabulary learning outcomes. In both studies, students were provided with "expanded directions"—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 is Barron's opinion that the expanded directions are 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 12, 13, and 14 show examples developed through a United States Office of Education research grant.

• 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 can

Figure 12. 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

use only words that relate to the current unit they are 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 15 you see another type of puzzle. Note that the main idea or topic of the unit is spelled out, "Sources of Energy."

Science teachers report having success with another puzzle (sample shown in Figure 16) where students find and circle science words across, down, or diagonally.

Figure 13. Vocabulary Reinforcement Nucleus

______________________________ (NAME)

Jamesville-DeWitt High School
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
4. mitochondria
5. ribonucleoprotein (RNA)
6. chromosomes
7. daned
8. nucleoplasm
9. chromatin
10. pinocytosis
11. nucleoli

Figure 14. Categorization

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
   - fibrinogen
   - 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

• 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 works by Herber *(3, 4)*.

• Reinforcement of Comprehension Skills

Recently, the term *learning centers* has become very popular, especially at the elementary school level. Some middle and high school teachers do not seem to know much about these centers and cannot see any place for them in the curriculum. Recently, in an attempt to make reading functional, Waynant and Wilson *(6)* devised a very simple, economical, and time-saving method of reinforcing reading skills at the application level.

The teacher can make three to five learning centers in one evening; and, eventually, when the students get the hang of it, they can make additional ones. The only items needed are file folders, scissors, and paste—plus ideas. Figure 17 illustrates a sample learning center. The front of the sample folder is attractively illustrated with a picture of an indoor seed starting kit. On the inside, lefthand panel of the folder are directions on how to use the kit. On the inside, righthand panel are seed starting kit directions about *what* should be done and *when, why,* and *how.* Students usually learn the answers by reading the instructions on the inside panels of the folder; answers to the questions, however, are provided on the back panel of the folder. Thus, learning centers are self-directing and self-correcting. The language of the center should, of course, be geared to the students.

Teachers sometimes fear that students may "cheat" and copy the answers. Since no one grades nor collects the work, students realize that they cheat only themselves and that, in fact, they receive immediate feedback to the questions as in programed learning.

Learning centers, then, serve as practical ways to apply and reinforce reading skills taught in the classroom. Teachers can get ideas for building centers by asking themselves, "Why are the students learning this? Will they be able to apply it, in some small way, to everyday living?" Should a teacher be unable to satisfactorily answer these questions, then another question should be, "Why am I teaching this material?"

References

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2. Barron, Richard, et al. "The Effects of Expanded Directions and Interdependent Group Discussion Upon Learning of Vocabulary Relationships in Tenth Grade Biology," in Harold Herber and Richard Barron (Eds.), *Research in Reading in the Content Areas: Second Year Report.* Syracuse, New York: Syracuse University Press, 1973, 40–45.
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Figure 15. Word Puzzle: Science (Biology)

Directions. Using the clues at the bottom of the 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 combining two or more simpler compounds
12. Released when glucose is oxidized
13. Living
14. Nonliving
15. Oxidation in the absence of oxygen

Figure 16. 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	L	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 17. Sample Learning Center

Directions: Planting your own vegetables can be fun and save you money, but you must know how! On a separate piece of paper, see if you can write the answers to the questions below. Use the directions on the opposite page to answer the questions.

1. When do you add the seeds?
2. How should you prepare the soil?
3. When do you add fertilizer—before or after spading?
4. Should you transplant to a sunny or shady location?
5. Can you transplant around Christmas? Why?
6. How far apart should you put the plants?
7. If you want a sweet pepper, when should you pick it?

Check your work with the answers provided on the back cover.

Inside Pages

Figure 17. Sample Learning Center

1. After you add the water

2. Spade the ground, rake or hoe well to smooth the soil and level the surface layer

3. Before.

4. Sunny

5. Not in Maryland! Because, at that time, there is still danger of frost.

6. Eighteen inches.

7. When fully red.

Back Cover

Front Cover

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 student 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 is a variation of Durrell's technique.

Each student should paperclip six 3 x 5 cards to his notebook. At the beginning of the term, the student is instructed to write in large, readable letters one entry for each card. He then will have a set of six cards with the following entries (one entry per card): TRUE, FALSE, ?, 1, 2, and 3. Variations can be added later. At the end of a difficult lesson, the teacher directs the student 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, each student demonstrates his answer by holding the appropriate answer card in front of him or by displaying it on his desk. 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, un-*

stable, 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 billiard 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 uncertainties: 1) If a student looks at another student for the answer, he still receives 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 these 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.

• Teacher-Made Tests

Testing is necessary and it is 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 18) 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.

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 heavy emphasis on interpretive understandings. In fact, about 20 percent of the time was spent on the interpretive level; 5 percent, on literal understanding; and 5 percent, on applied level understanding.

Figure 19 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

Figure 18. 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

Figure 19. 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	7½% 7	100% 40 questions

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 two questions at the applied level.

It was decided that forty 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 forty questions were written to fit each cell (e.g., 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.

• Student Evaluation

Student participation in teacher appraisal is very limited at the high school level. However, a simple technique is suggested here for teacher self-evaluation with the aid of students.

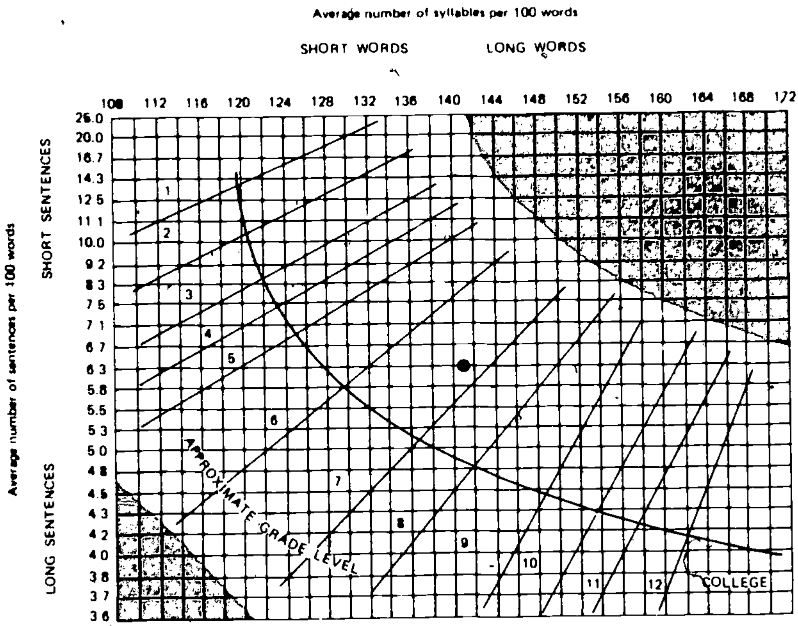
Trust plays an important part in the system. After each lesson, students hand in signed 3 x 5 cards with comments about that lesson. When they have difficulty understanding, students are encouraged to say so. By signing the cards, those students who express misunderstandings can be helped by the teacher on an individual basis and without embarrassment in front of the whole class. Student-teacher trust plays an important role in this technique.

• Assessing Grade Levels of Textbooks

The present tremendous, almost inordinate, interest in the readability levels of materials used in the classroom, makes it appropriate to include in this chapter the revised 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.

GRAPH FOR ESTIMATING READABILITY

by Edward Fry, Rutgers University Reading Center, New Jersey



Directions for Working Readability Graph

1. Randomly select three sample passages and count out exactly 100 words beginning with a beginning of a sentence. Don't count numbers. Do count proper nouns.
2. Count the number of sentences in the hundred words estimating length of the fraction of the last sentence to the nearest 1/10th.
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.
4. Enter graph with average sentence length and 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, putting more sample counts into the average is desirable.

For further information and validity data see the April, 1968 *Journal of Reading* and the March, 1969 *Reading Teacher*.

FINAL STATEMENT

Concerned science teachers often say, "My kids 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 that the students understand the meanings of the words and can use those meanings in making inferences and applications.

All too often, the science teacher has never been made aware of how to teach content *and* process at the same time. This monograph was written to help this science teacher. Herber *(1)* 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 *(2)* notes that the average American is a scientific illiterate. There has been a massive reform to improve science teaching in the past ten years, but science classes today are still overwhelmingly fact oriented.

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

The intent of this monograph can be summed up by the following adage—"Give me a fish and I eat for a day. Teach me to fish and I eat for a lifetime!"

References

1. Herber, Harold. *Teaching Reading in the Content Areas*. Englewood Cliffs, New Jersey: Prentice-Hall, 1970.
2. Hurd, Peter. *New Directions in Teaching Secondary School Science*. Chicago: Rand McNally, 1970.

Appendix A

Informal Study Skills Inventory on a Physical Science Textbook

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 below 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
______Contents
______Epilogue
______Introduction
______Looking through the book
______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.* means 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 below 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
______Mass (unit of)
______Radioactivity (discovery of)
______Alcohol
______Marsh Gas
______Dalton, John
______Calorie (definition of)
______Precipitate
______Geiger Counter
______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 that 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	Following directions
General information	Interpretation
Compare and contrast	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 that 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. The thinker arrives at an answer with little, if any, awareness of the processes by which he reaches it. He can rarely provide an explanation of how he gets his answer.

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 very important. Intuitive thinking has led to some of the world's great 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 careful, 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 purposes, 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 your 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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