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ABSTRACT

Several practical methods are presented in this handbook designed to aid the science teacher in the incorporation of reading strategies into the science curriculum. Included are suggestions for assessing the reading levels of science students and textbooks students will be using in the classrooms. Examples and illustrations are provided to clarify and reinforce the ideas presented. (CS)

reading in the science classroom

by
Judith Bechtel
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Science Consultant
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A National Education Association Publication

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Dr. Judith Bechtel
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FOREWORD

There is a growing understanding within the educational community that if the improvement of students' reading skills is to be realized, the problem must be addressed not only in reading classes but by all teachers in all content areas. Perhaps students' reading skills have become the accidental victim of curriculum departmentalization and specialization.

Science teachers, though not specially trained in the teaching of reading, should accept some of the responsibility for helping to improve the verbal skills of their students.

In this book Drs. Judith Bechtel and Bettie Franzblau present several practical methods by which the science teacher can easily incorporate reading instruction into the science curriculum without taking time away from teaching content. Included also are suggestions for assessing the reading levels of science students and of the textbooks they will be expected to use. There are many examples and illustrations to clarify and reinforce the ideas presented.

Reading in the Science Classroom can provide the science teacher with the tools needed to meet the obligation to improve the reading skills of students.

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PREFACE

Reading in the Science Classroom is one of a series of books published by the National Education Association to help content teachers use print materials in teaching the specific content areas.

Each book in the series will (a) provide a rationale for teaching reading in that discipline, (b) introduce assessment techniques for the purpose of organizing for instruction, (c) furnish specific classroom activities, and (d) list professional texts and journals in addition to sources for classroom aids.

Science teachers should find this book helpful for its suggested teaching methods, developed from the professional literature and through many hours of trial teaching in classrooms. Teachers in training will find this a valuable resource book, an integral part of their repertoire. In short, Drs. Bechtel and Franzblau have made a significant contribution to student understanding of the sciences by facilitating the often difficult task of teaching reading in the sciences.

Alfred J. Ciani
Series Editor

1. THE NEED FOR READING INSTRUCTION IN SCIENCE

"All subject matter learning depends in large measure on the student's competence in the language of the subject."

- David L. Shepherd (1)

There has been a great deal of discussion within the academic community about the need to teach language skills across the content curriculum. Reading skills are central to the acquisition of information in most content area courses (2) This is particularly true in science. It is variously estimated that from 50 to 80 percent of the learning that takes place in science classes comes from reading. when we define reading as thinking about as well as decoding and processing information.(3) Research suggests that language difficulty is the main reason for not succeeding in content areas.(4) Often students cannot comprehend lectures and labs until they have given close and careful attention to a science textbook. Competence in science assumes the ability to comprehend other types of reading material as well. handbooks. almanacs. encyclopedias. and current scientific publications.

Reading has become an especially important component of the science curriculum with the growing acceptance, since the 1950s, of the inquiry approach to learning. (For a full discussion of the implications of the inquiry approach to present methods of instruction in science, see Hurd and Longstreet.)(5) Because of the information explosion in science, facts learned today will soon be obsolete. Therefore, the thrust of today's science courses is to help students become lifetime learners. That is why the recent National Assessment of Science Teaching (reported by Sund and Picard)(6) evaluated not only information and concepts demonstrated by science students, but also such study skills as the ability to pick out the key words of a problem and use various techniques for obtaining relevant information. The assessment team also found evidence of serious deficiencies in the comprehension and vocabulary skills of science students.

True, most science teachers have neither the time nor the training to set up remedial reading programs. and that job is best left to the reading specialists. Yet no one is better trained to offer reading instruction in science than the science teacher who understands the specialized vocabulary and concepts of that discipline. According to David L. Shepherd, "Logical reasoning about reading instruction in the content subjects points to the fact that the teacher who has a background and expertise in a specific subject is the one best qualified to adapt the reading skills to it."(7)

IMPLICATIONS FOR SCIENCE TEACHERS

The present decline in verbal skills comes at a time when science education is a prerequisite for an increasingly large number of career options. This means that science teachers must be sensitive and responsive to the special reading problems of their students.

In any given science classroom the range of reading abilities is likely to be extremely wide- as many as eight to ten grade level differences within a heterogeneous grouping.(8) Yet standardized reading scores, usually reported as grade levels of reading ability, do not represent static attainments or even conditions of absolute mastery or absolute deficiency in any one reading skill. Average readers and even those better than average often need special guidance to develop the specific skills needed to comprehend and remember what they read in science.

How can science teachers, already busy with heavy teaching loads and extra responsibilities of maintaining laboratories, be expected to teach reading skills along with science content? The answer is by thinking of reading skills as inseparable from thinking and understanding skills, and by focusing on those aspects of reading that can maximize students' success in science. Some emphasis on reading skills does not necessarily mean that time is taken away from the study of science itself. It is important to remember that as students work with the language of science they are also working with the concepts of science.

THE VISIBLE SIGNS OF READING PROBLEMS

Science teachers have made three basic observations about the way students read science texts:

- Some students don't read their assignments.
- Other students don't read carefully enough to really understand.
- Most students can't remember or apply what they have read.

These points are often expanded to include more specific problems. For example, some students focus on unimportant details or skim over key points. As one teacher put it, "They get the feeling that they understand as they read, but this feeling is misleading simply because it is *only* a feeling; they may have mispronounced or misunderstood the special terms they read, and they don't think while they read."

SOME CONTRIBUTORS TO READING PROBLEMS

An analysis of the particular difficulties inherent in science texts helps us understand how to improve the reading skills important to the mastery of science.

Vocabulary

The vocabulary of science books often poses difficulties. It is not simply the high density of polysyllabic, technical words; there is also the problem of familiar words used in a new, specialized sense. Rote learning of definitions may foster a veneer of verbal competence without guaranteeing understanding.(9) Often students lack the background and experience to understand newly learned scientific terms.

Actually, every person has several layers of vocabulary proficiency: a large recognition vocabulary of words that look or sound familiar but which the person cannot define, a smaller range of words that are clearly understood but never actually used, and a still smaller list of working words. Science teachers should aim to expand each student's working vocabulary. This process involves more than mere memorization, since various restrictions and rules of appropriateness govern the usage of new words. These rules, taken for granted by those familiar with the words, must be acquired by the student gradually, through practice.

Interest

When students have difficulty understanding vocabulary, they lose interest in the content. This is especially true if most of their previous reading experience has been confined to news stories and fiction. Not only are science texts heavy with new vocabulary and complex information, the highly abstract explanations are difficult to follow because there is no way to picture them.(10) In addition, science material is often presented in very confusing ways: several new concepts might be introduced at once without an adequately established frame of reference, or concepts totally unrelated to one another are made to seem linked by proximity.

Syntax

Sentence structures that differ from normal spoken usage present yet another difficulty in science texts. Linguists are just now identifying some of the syntactic structures that characterize the language of certain disciplines. In scientific writing we often see these forms (adapted from a list in Karlin(11)):

1. *the passive voice*
   "A narrow beam of molecules *is formed* by letting molecules of a hot gas pass through a series of slits."(12)
2. *subordinate clauses and other words that limit the apparent meaning*
   "*Normally* a bleeder resistance valve is chosen so that the bleeder will draw *approximately* 10 percent of the full-load current *when no load is connected*."(13)
3. *separation of modifer from what is modified*

"At higher temperatures the *wave length* radiated most brightly is *shorter* and the color *yellow* to *blue*."(14)

4. *high proportions of verb forms (gerunds, participles, etc.)*

   "A molecule *possessing* the activation energy *associated* with a *given* reaction does not necessarily react when it undergoes a collision."(15)

5. *inverted word order*

   "Just inside the pellicle *are the trichocysts*, which appear as tiny lines through the microscope."(16)

HOW STUDENTS LEARN

Give all these difficulties, it is easy to understand that poorly prepared or inexperienced students can be intimidated by science texts. Naturally a classroom of students will function at different levels in relation to any given textbook. Some find the book easy enough to read independently (*independent level*). Others can read it with guidance and supervision (*instructional level*). Still others will be completely overwhelmed by the text, even with guidance and supervision (*frustration level*).(17) Additionally, there are various kinds of reading frustration: some students are reluctant, some disadvantaged, some retarded, some merely slow.(18)

Science teachers must strive to offer the kinds of help that will keep students at the instructional level from frustration and keep students at the frustration level provided with alternate materials or supplemental activities to compensate for what they miss. Teachers will find that even readers at the independent level will profit from exercises that lead them to interpret and apply what they read.

Indeed, all students benefit from activities that move them beyond literal comprehension (decoding of individual sentences) toward interpretation (recognizing themes, making inferences) and application (solving problems). Although common sense suggests that the higher order comprehension skills cannot be learned until literal level skills are mastered, research reveals that (at least for students of adolescent age or older) the development of the higher orders of comprehension promotes understanding and retention at the literal level.(19)

The organization of information into concepts is a long-term process, the result of numerous interactions of combinations of facts and experiences. Therefore, concepts cannot be taught directly, the way facts can.(20) Hurd defines concepts as "a synthesis of logical relationships given to relevant information" learned by discriminating, categorizing, and evaluating.(21) Concepts compress information into chunks and thus aid the memory in retaining facts. Concepts also transfer, enabling us to solve problems or make predictions. Furthermore, the recognition and utilization of concepts is an innately satisfying experience, perhaps the ultimate educational motivator.

It is important to remember, however, that scientific concepts or abstractions cannot be isolated from the vocabulary, the details, and the processes described in science books. The concepts cannot be separated from the way they are expressed. In other words the reading of science helps students develop cognitively, yet without adequate cognitive development, they cannot truly understand what they read.

The interaction between literal comprehension and abstract reasoning has been the special concern of numerous psychologists and educators, Piaget, Bruner, and Bloom among them. For example, Bloom's hierarchy of the various levels of comprehension is specified in the Taxonomy of the Cognitive Domain—from knowledge of terminology and facts, through application, analysis, and synthesis, to judgments based on internal evidence and external criteria.(22)

WHY READING PROBLEMS AREN'T SOLVED IN ENGLISH CLASSES

Reading is a complex activity, and slightly different reading skills are called forth in each discipline. Often students come to science textbooks with adequate reading skills, but somehow they fail to apply what they know to the new content. After all, as Sochor has noted: "Reading has no content of its own. It is a process used for acquiring information, for solving a problem, or for recreation and enjoyment. It is a means to an end."(23)

Science textbooks pose their own peculiar reading problems, necessitating new approaches. In some ways the content teacher has an advantage over the English teacher in that a reading lesson in science can be seen by students as fresh, immediately useful, and perhaps more "real" than a similar lesson in English.

Of course, some students will master new scientific material all by themselves, without special attention from their science teachers. Similarly, many children learn to read completely unassisted, even before they go to school. Still, just as the vast majority must be taught to read, this majority will also benefit from a deliberate and sequenced program of instruction in the specialized skills of science reading.

Good teachers will find that they have been teaching reading for years. In some cases it is not even necessary to prepare special reading exercises, activities, and worksheets, often all that is required is a different approach, a temporary focus on means rather than on ends. Reading must been seen as inseparable from the learning process. The long-term payoffs are great, because students proficient in reading have high morale, are eager to learn, and can move quickly past basic science content to experimentation, problem solving, and application of scientific principles.

SUMMARY AND OVERVIEW

Science students are having problems reading their science texts. Their reluctance to complete assignments and their inability to comprehend what they read is explained in part by the difficulties inherent in scientific writing its specialized vocabulary, terse style, and high concept load. Science teachers can help students understand the information in science texts on a literal level, and guide them beyond rote memorization toward interpretation and application of the concepts involved.

It is important to determine which students can handle the course textbook independently and which will function at the instructional or frustration levels. Several methods of assessment will be explained in Chapter 2 In general it helps to know more about students' reading skills than their standardized test scores reveal. A teacher-made Study Skills Inventory makes evaluation an easy task.

Once you have evaluated student performance in the specific reading skills needed for the mastery of science, various reading lessons can be incorporated into the normal coverage of course content. Chapter 3 offers specific lesson plans for helping students develop a scientific vocabulary, vary their reading rate, reorganize key concepts, and work in small groups. In addition, science teachers may wish to adapt one of the several models of structured overviews and study guides to their own purposes and course content.

Finally, Chapter 4 will suggest some ways to evaluate textbooks for readability. A textbook should be considered for adoption if it features content that meets department goals, a format congenial to the teaching methods of school staff, and a readability level commensurate with the ability of the students who will use it.

2. THE ASSESSMENT OF READING SKILLS

"Evaluation of classroom learning/teaching is an unending process"

—*Judith Thelen* (1)

Every science teacher is familiar with the unmistakable signs that certain students are experiencing difficulty reading their science texts. Confusion in class, lack of understanding, and mispronunciation are sure indicators of reading problems. Some students stumble over words when they read aloud in class, or reveal their difficulties at conferences or during tutoring sessions. Very often teachers can observe a blankness of expression, restlessness, or discipline problems—all indirect results of reading frustration. Many students do not even attempt to complete reading assignments because they have experienced so much failure in the past.

In order to tailor reading assignments to the particular needs of students, teachers must have accurate ways of measuring special reading skills. Assessment meets two needs:

1. to determine if the textbook is suitable for the students who will be using it
2. to determine which reading subskills need special attention throughout the course.

In general, the first point involves matching student and textbook as to grade-level proficiency. Most publishers indicate for which grade level their textbook is written. If not, teachers can make their own evaluation, using one of the formulas in Chapter 4. With this information teachers can judge which students can read independently, which students may need guidance and instruction, and which students will experience frustration with the text.

CLOZE TESTS

One way to determine the suitability of a textbook is to construct and administer a cloze test. Cloze tests measure a student's sense of closure (her/his language expectations) about the syntax and vocabulary of a book. Basically the test requires students to guess which words have been eliminated from a sample passage. Research shows there is a high correlation between the ability to perform this task and the ability to understand the text when it is whole.(2) A cloze test has the advantage of avoiding all the labeling inherent in grade-level placement. It is also a more direct measure of the match between student and book since the mutilated passage comes directly from the course textbook.

The teacher selects a representative passage of between 200 and 350 words. This passage is then retyped, the first and last sentences intact, but with a blank space replacing every fifth word. (A total of 50 blank spaces makes grading easier.) These spaces should be typed to uniform length so that the student cannot guess the missing word on the basis of the length of the space it should fill. The missing words will, of course, include most parts of speech since they are deleted randomly. A sample cloze test is shown in Text Reference 1 (Appendix A).

The student should score between 40 and 60 percent on a cloze test to succeed at the instructional level with that textbook. Students who score below 40 percent, however, are at the frustration level and will probably have a great deal of trouble reading the text. When more than one level of textbook is available for class use, the teacher should use the cloze procedure to assess the middle level book, then proceed to a lower level text for those who score below 40 percent on the original test and to a more difficult book for those scoring over 60 percent.

The cloze test makes a convenient pretest, and the cloze procedure is also adaptable as a teaching tool, especially for vocabulary. (See Chapter 3 for specific suggestions.)

INDIVIDUALIZED ASSESSMENT TEST

Still another way to determine the suitability of the text for the student is to construct an individualized assessment test. This procedure requires a little more work from the teacher than does the cloze test, but it has the advantage of being a more direct measure of the actual reading skills that will be used in the course. An individualized assessment test measures three distinct, yet interrelated skills: vocabulary, factual recall, and interpretation.

To construct an individualized assessment test, the science teacher should select a representative passage of about 350 words from the textbook. Care must be taken to select a passage that doesn't require extensive background information to be understood since the students will be taking this test early in the course. If necessary, such background information could be given in a brief introduction to the passage.

Next make up a multiple choice test of 30 questions—10 to measure vocabulary, 10 factual, and 10 inferential. An objective test makes grading easy. A sample individualized assessment test is included as Text Reference II (Appendix A).

Students who score higher than 90 percent on the individualized assessment test are reading at the independent level and could possibly work with a more difficult text. Those who score lower than 70 percent are at the frustration level and probably need a lower level, less difficult text. Those who score between 71 and 89 percent are reading at instructional level. They can probably handle the textbook at hand, but they will require some guidance in order to do so effectively.

INFORMAL STUDY SKILL INVENTORIES

Grade level assessment of reading skills or assignment to independent, instructional, or frustration categories provide only a rough approximation of a student's ability to comprehend the textbook. Although a grade-level placement test can indicate that work is needed on reading skills, the test does not specify which skills most need improvement. For this diagnostic purpose science teachers can construct an informal study skills inventory based on their own determination of the reading and study skills required in the course.

An informal study skills inventory is a checklist of those skills important for achievement in a given subject. These inventories are always preliminary and need to be confirmed by further observations and followed by directed instruction and retesting. The measure can be absolute (students are judged competent in a given skill or below criterion level) or relative (students are judged as good, fair, or poor in a given skill).

To construct an informal study skills inventory, make a list of those reading and study skills that your students must master if they are to succeed with their textbook reading. Give some thought to those problems that have given former students some difficulty. Text Reference III (Appendix A) represents one teacher's list of the skills needed for a biology course. Obviously some of these skills can be measured on the basis of test answers and other classwork; the others can only be measured indirectly, by observation.

KEEPING RECORDS

Once individual diagnostic assessments are made, it is important that classroom teachers make use of these evaluations. To do so, the teacher needs some method of keeping records that is easy to use and readily available. Note cards or file folders are popular, but class charts are more efficient since the needs of the whole class can be seen at once. Text Reference IV (Appendix A) represents a simplified way of keeping track of assessments for an entire class.

SPECIFIC ASSESSMENT MEASURES

Obviously some reading skills are more important than others in the study of science. Furthermore, any good teacher knows there are many other factors that contribute to academic success. Therefore, science teachers might like to supplement their assessment of general reading ability with a more focused measure of some special contributor to academic success, especially if it is an area of concern to be worked on throughout the course.

Vocabulary

Since scientific vocabulary poses special problems for students, it is sometimes a good idea to give a diagnostic test to determine competence in vocabulary. This can be done in various ways. A first step is to determine which words students understand. This can be accomplished by using word lists (such as those published in Panes and in Aukerman).(3) Another approach is to test how well a student can learn what a word means from its context. Robinson and Thomas offer the following list of types of context clues which students should be able to use in interpreting new words:(4)

1. *direct explanation*
   "The solid outer shell of the earth, the crust, is called the *lithosphere*."(5)
2. *examples*
   "In each area a different *gene pool* came to be established. Thus, Eskimos came to have certain traits unlike those of Plains Indians."(6)
3. *familiar expression, language clues*
   "Second, the *bleeder furnishes a path* so that the capacitors can discharge when the power supply is turned off."(7)
4. *summary*
   "Thus, mercuric oxide is not a mixture of mercury and oxygen in the same way that air is a mixture of nitrogen and oxygen. Mercuric oxide is a pure substance that cannot be separated into simpler substances by most of the methods we use to separate mixtures: but when it is separated by heating, it cannot be put back together simply by mixing. We call such substances '*compounds*' . . . ."(8)
5. *comparison/contrast*
   "Thus, *fraternal twins* are two completely different people. That is, their genes are no more alike than those of normal brothers or sisters . . . . *Identical twins*, on the other hand, are nearly the same person in duplicate."(9)

Students need also to process transition words. These are common but important words that indicate relationships between clauses and sentences. When students are inattentive to the distinctions between transition words, they often make faulty assumptions about the material they are reading, even when they understand the scientific terms within it. Some examples of transition words include:(10)

1. words that show a continuation of the same idea:

moreover	*for example*
likewise	*to illustrate*
too	*not only . . . but also*
furthermore	*in addition*

2. words that show a reversal of thought:

but	*however*
on the other hand	*on the contrary*

3. words that limit or qualify statements:

if	*when*
although	*approximately*
normally	*occasionally*
sometimes	*often*

4. words that warn of a surprise or apparent contradiction:

yet	*nevertheless*
in spite of	*not, no*
apparent	*paradoxically*

There are various ways to construct vocabulary tests. One format lists the words to be defined at the top of the page, with explanatory sentences below. Another format, suitable for a pretest of each chapter, lists difficult words along with the pages on which they are found. During a silent reading period students are instructed to define these terms *as they are used in the textbook*.(11). These tests can be given as part of a study guide if class time is limited.

Attitude Inventories

Whereas academic skills can be directly measured, attitude, background experiences, and study skills are usually assessed on the basis of what students report about themselves. As such, the reliability of these measures is dependent on the students' insight and honesty. Still, many teachers judge these factors as crucial to successful learning and wish to measure them as part of any assessment of student skills. A sample attitude inventory is given in Text Reference V (Appendix A).

In constructing an inventory of attitudes or behaviors, there are several principles to keep in mind (adapted from Estes and Vaughan).(12).

1. Offer the students five categories of response so that they will not feel they are making arbitrary responses.
2. Put statements in the present tense.
3. Avoid double negatives and difficult words.
4. Avoid the use of extreme statements such as "always," "never," "all," "forever," etc.
5. Offer some undesirable statements so that students will have to adjust to either end of the scale in order to answer consistently, rather than repeating a single response set.

THE NECESSITY OF ON-GOING ASSESSMENT

Although science teachers will want to assess their students' reading and study skills early in the year, particularly if there is a choice of textbooks available for class use, these early assessments are merely preliminary. Some form of assessment could precede each new unit, for students will be differently motivated and experienced in relation to different topics. End-of-term tests should also be designed to give some feedback on changes in reading and study skills. Both teachers and students will be encouraged to know that in-class work on reading and study skills has engendered improvements. Perhaps the activities suggested in Chapter 3 will inspire additional methods of assessing skills and integrating these assessments into the regular science classwork.

3. CLASSROOM STRATEGIES

"Ability to manage the language of a subject area can be developed, and that development is a function of teaching."

—*Dorothy Piercy* (1)

If teachers are to help students develop reading skills in science class, they must first realize that some strategies do not work. For example, some science teachers spend a great deal of class time reading aloud to their students from the textbook. This causes the students who have already read and understood the text to become restless, while poor readers get lost and become even more discouraged about their ability to learn. Sometimes students are asked to take turns reading sections of the textbook aloud. This strategy is even less effectual because poor readers are embarrassed and their stumbling bores the entire class. (Whenever students are asked to read aloud what they have not read silently, they are in an automatic "test of reading power" situation. Good readers perform well in this situation, poor readers flounder.)

Before asking students to read in class, spend some time pronouncing key words and establishing a purpose for the reading. One strategy is to ask a question that students will answer later, defending their answer by reading relevant parts of the text. If students falter while reading, offer pronunciation help immediately.

Many teachers use class time to provide students with background experiences that contribute to an understanding of the vocabulary and concepts of the course. Filmstrips, films, demonstrations, and field trips all encourage firsthand involvement with the course content. These activities can be planned to include opportunities for repetition of special vocabulary and syntax. Repetition is important because students need to overlearn new words before these words can become part of their working vocabularies, part of their cognitive framework.

The specific lessons in this chapter present science teachers with additional suggestions for developing reading skills. Each teacher must decide which skills to stress, based on an assessment of student ability and an understanding of the problems inherent in the course content. It helps to think of reading development as a continuous spiral; there is a need to return to work on certain problems, but each return is marked by more mature understanding.(2)

The most effective lessons emphasize one thing at a time and work from the known to the unknown, from the concrete to the abstract. Lessons should be selected only when they are germane to the unit being studied.(3) Some chapters introduce a great deal of new vocabulary; other chapters call for work in recategorizing information in charts or graphs. It is important to pick activities that help students learn the material at hand.

LOCATING INFORMATION

Early in the course the science teacher should devote class time to an introduction of the textbook. Questions, either oral or written, should direct student attention to the following features:

1. *the table of contents*
   How have the authors organized the material you are going to study? Approximately how many pages are in each unit?
2. *the index*
   On what page(s) will you find information about *circuits*? How many different key words can you think of that might help you find pages where *pollution* would be discussed?
3. *glossary*
   What is the difference between the index and the glossary? How is the definition of "primary" different from the definition you might find in the dictionary?
4. *vocabulary lists*
   How do the authors make these words stand out when they are introduced in the chapter? What is the quickest way of

looking up these words for your study lists?

5. *questions at the end of each chapter*
Can you see any advantage to looking at these questions and at the "summary section" before you read the chapter? How can you use the chapter headings to help you find an answer to question 5?

The teacher can decide whether this introduction to the textbook should serve as a review or as a reading lesson in itself. It is especially crucial that students have practice in using the index.

FLEXIBLE READING RATE

One of the most important principles of content reading is that students must vary their reading rates. They must be taught when to speed up and when to slow down. Skimming and scanning are appropriate for overviews, for locating specific points of information or special words. Whole chapters need not be scrutinized with the same care one gives to crucial explanations. Historical background, lengthy analogies, and extended examples usually call for speedier reading. Narration, news stories, and simple exposition do not require the same degree of conscious concentration that scientific material requires. Students need help in determining if passages require slow or fast reading. They also need to learn how to scan books and chapters before a more careful reading in order to determine the levels of information covered.

According to Walter Pauk, students can overcome inertia by doing a swift survey of assigned textbook readings. Once they have started to read, it becomes easier to shift into the study mode. Too frequently, however, teachers ask students to slow down, without realizing they may be encouraging inflexible reading patterns, making every assignment tedious and boring.(4).

An assignment that requires students to convert diagrams and text into procedures is one means of teaching students to slow down their reading rate at critical places. This is especially important in science classes when students are asked to perform experiments on the basis of information given in the textbook. Another way to get students to read slower is to ask them to find answers to specific questions or complete study guides. The point, of course, is to teach students to pay close attention to what they read so that they truly process it.

Although science teachers complain of it less often, there is also the problem of the student who reads material too slowly. Usually this student is trying to remember too many details rather than concentrating on the key ideas. This may result from excessive conscientiousness, from reading without a specific purpose, or from an inability to distinguish main points from details. (See later exercises on identifying main points.) No matter what the reason, plodders need to become more efficient.

SQ3R

To promote flexibility in reading rates and a means of locating material in the science textbook, science teachers should spend some class time presenting and practicing Robinson's SQ3R techniques.(5) At first teachers can lead students through the whole process:

- *Survey*
  Look at the length of the chapter, the headings, the list of vocabulary, the charts and diagrams to get a feel for the kinds of information covered in that section and the depth of treatment.
- *Question*
  Turn these observations into questions (especially how and why questions) that will give purpose to your reading. For graphs and charts, ask what point is being made. These questions can be asked aloud, written down, or merely thought about, but it takes discipline to do the latter.
- *Read*
  Now the reading has a purpose—to answer the questions posed on the basis of the survey. Since headings always indicate key ideas, questions based on headings help students discriminate between details and main points. Illustrations, on the other hand, may depict details and should be viewed as reinforcements of the text.
- *Review*
  Once a section has been read purposefully,

it can be reviewed more effectively just before the next class or before test time. The review should focus on the questions raised, key words, and the relation of each section to the others. Only key passages need be reread entirely, depending on the nature of the assignment. This review process may involve notetaking.

- *Recite*

  Preparing for a class discussion or test requires a high degree of comprehension. Even if students have already taken notes, they must be able to produce information on the slightest stimulus. As a last step in studying, the student should write down from memory:

  a. definitions of key words, or supply words to match key definitions.
  b. main ideas with explanation and illustrations.
  c. key measurements, formulas, relationships, etc.

ADDITIONAL LOCATING ACTIVITIES

Until the SQ3R technique has been practiced extensively, students will need additional help in locating important textbook material. The following activities familiarize students with new ways of locating information and also provide practice in comprehending the difficult syntactic patterns of science. These two goals can be met by asking individual students or small groups to answer questions or solve problems that require processing the difficult sentences. (Small groups are better because peers will be able to correct each other.)

Here are three activities that give students practice in locating specific information:

1. The teacher supplies a sentence (usually about a main point) and the students locate a sentence from the text that says virtually the same thing. This activity has the additional advantage of forcing the student to understand the material as well as find it, especially if the teacher's sentence is a difficult one.
2. The teacher asks students to find the answers to questions about new vocabulary or information. At first the teacher can give the page number and even the column in which the answer is found, later progressing to a more open format.
3. Vocabulary can be reinforced in an interesting way. With stopwatch in hand, the teacher writes a word and the page on which it can be found. Students keep their books closed, sometimes with the appropriate section marked, until they hear the word "go." The teacher keeps a record of time elapsed as students search for the word. Students can keep track of time elapsed to monitor subsequent improvement throughout the year.

VOCABULARY DEVELOPMENT

Vocabulary development is a constant, underlying goal of all science lessons. Vocabulary is being taught even when it is not directly stressed. However, it is better taught consciously. Here are a few general principles to think about as you direct your attention toward other concerns (adapted from Shepherd):(6)

1. Say new words frequently.
2. Display new words on boards or posters.
3. Take time to work on pronunciation.
4. Call attention to differences between scientific usage and general usage of problem words.
5. Constantly elicit context clues.
6. Be conscious of the occasional inapplicability of rules, such as those that apply to root words, prefixes, and suffixes.
7. Select vocabulary building techniques that mesh with your teaching style. If you proceed inductively, choose methods that lead into generalizations containing key words. If your approach is deductive, use techniques that introduce problem words first.
8. Study vocabulary in phrases whenever possible so that rules governing word usage are at least implicitly suggested.
9. Develop the index habit; have students

look up words whenever problems arise.

10. Keep a good general dictionary handy (preferably the one used in English classrooms at your school) for looking up both scientific and common words. Be sure that the "science" label is understood and identified from alternate definitions whenever the context requires it. In addition, keep a science dictionary and an encyclopedia of scientific terms on hand in the science classroom.

Vocabulary development is part of every science lesson. Periodically, special attention should be directed to problem words. Most commonly this is accomplished by assigning a vocabulary list of words to be defined from the text or glossary, but other procedures might also be tried:

- *Vocabulary recognition practice*—Practice sheets help students learn to pay close attention to the shape and structure of scientific words. Students choose a match from among three or four look-alikes. They are instructed to examine the word at the left and underline as quickly as possible the word at the right which matches it. This exercise may be timed.

oscilloscope	oscillotope	oscarscope	organically	oscilloscope
rotor	radar	rotor	roto-rooter	roter
hertz	hurtz	hertz	herz	ersatz
impedance	impotence	empidence	imPedence	impedance

Three of these exercises back to back generally help reinforce perceptual patterning. After more than three timed exercises, efficiency seems to diminish.(7)

- *Graphic syllables*—Long words can be broken into graphic syllables (adapted from Kennedy):(8)

Acetylcholine	Alveolus
A	Al
ce	ve
tyl	o
cho	lus
line	Alveolus
Acetylcholine	

- *Prefixes, suffixes, root words*—Lists of prefixes, suffixes, and root words might be used to help define unknown words or make up original words (such as imaginary names for animals in biology class). Good lists of suffixes and roots can be found in Pauk, Piercy, and Burmeister.(9)

- *Puzzles*—Occasionally crossword puzzles and hidden word puzzles can be devised using key words of a chapter or topic. To devise a crossword puzzle, use the two longest words in a lesson as the vertical and horizontal. Use a Scrabble board to work out how the other words might fit in. Then record the configuration on graph paper, numbering the top and left-most spaces at the beginnings of words. Next draw the puzzle so that you have the correct number of blank spaces, with the top and left spaces numbered. The last step is to write definitions or clues for the "down" and "across" columns. The finished puzzles can be duplicated and used year after year.(10)

- *Cloze tests*—The cloze test (fully described in Chapter 2) promotes discussion of context clues and can be constructed for vocabulary study. Depending on the lesson, specialized terms can be deleted from a passage. If all verbs are deleted, students are called on to distinguish between active and passive verbs.

- *Analogies*—Analogy tests and games help develop vocabulary and clarify relationships among concepts. This can be an especially useful technique if the correct answers are discussed by the students.

- *Interpreting chemical symbols*—Chemistry students can make up lists of regular, common words using chemical symbols and the rules for formula writing (suggested by Gage)(11). For example, *success* is spelled suc_2es_2. The winner is the person with the most words. A more elaborate game requires some special equipment. Six small cubes are imprinted on each side with the letter symbols of the chemical elements. Students take turns rolling the cubes, all players listing as many chemicals as they can from the top sides of the cubes. They may consult the Periodic Table, or make the game harder by working from memory. The winner is the person with the longest correct list after all players have rolled.(12)

This list of activities may suggest still other ways to reinforce the specialized vocabulary of science courses. When new words are pronounced, written, interpreted, or used they become part of the student's working vocabulary. That such activities can also be fun is an added bonus.

FINDING THE MAIN IDEA

Probably the central sign of reading comprehension is the ability to find and understand the main idea of a passage. That was the goal of Robinson's SQ3R technique, and that is what students do when they list procedures and when they locate information. Putnam suggests that teachers begin this work in class and then ask students to complete the search for main ideas as a homework assignment.(13) The results can be checked in small groups so students can learn from one another methods of identifying main ideas.

Here is a sequence for developing the ability to identify and restate main ideas:(14)

1. Begin by presenting three statements and ask students to choose the statement that contains the main idea. One statement should be irrelevant and one should be related but only a detail.
2. Furnish a partial outline with some headings and some subpoints, the others to be filled in by the students.
3. Furnish lists of details from the text with no headings. In supplying the headings, the students will be generating main ideas.

Another technique involves cutting down important sentences from the text so that all articles and extraneous words are eliminated, leaving only the key words or main idea. Make this a fun activity by having a contest to see who can come up with the shortest meaningful sentence. Or pretend that cablegrams cost $100 a word and students must send the least expensive, understandable telegram they can (adapted from Robinson).(15) This is another activity that works well with small groups and is good preparation for outlining and notetaking.

Science teachers will also want to point out to students that there are several strategies that authors use to emphasize their main points (adapted from Shepherd and Strang):(16)

1. devoting a large amount of text to the main idea and smaller amounts to less important ideas
2. asking a rhetorical question that the main idea answers
3. illustrating the main idea with a picture, chart, or graph
4. using the main idea as a heading for a section of the text.

STRUCTURED OVERVIEWS (ADVANCE ORGANIZERS)

Another way to help students find main ideas and understand relationships inherent in the material is to introduce a structured study guide before beginning the reading assignment.(17) These structured overviews are conceived at a more abstract level than the text on which they are based. Teachers explain them to students, at the same time previewing the assigned material on which the overview is based.

To develop a structured overview, the science teacher should jot down as many ideas as can be recalled after reading a passage. These ideas should then be grouped into a visual pattern that shows how the main ideas are related to each other or to subordinate details. Text Reference VI (Appendix A) shows a few of the shapes that might be adapted for structured overviews. Teachers can furnish students with all or part of the overview before students do the requisite reading. Once introduced, that visual pattern should be displayed and referred to frequently during subsequent lessons on that topic.

DECISION MAKING—INQUIRY STYLE

Text Reference VII (Appendix A) shows a

structured overview adaptation of a very intricate set of written directions. Students are asked to identify species of fish by referring to a list of 34 traits. Each decision about a single trait leads to a decision about another trait, until finally the range of possibilities is narrowed and a species identification is inevitable. In other words, the fish traits are presented as a hierarchy, yet the original list of 34 traits does not look like a hierarchy.

In the sample exercise students begin at the left and choose between two traits—either the fish has scales or it does not. The choice of scales leads to another choice further to the right, and that choice leads to yet another choice, until the student has finally worked across the list to identify the fish.

Students finish the exericse and correctly identify the species without comprehending the *concept* of a hierarchy of traits. This concept can be clarified by showing students at every step that they are choosing between two traits, finally narrowing down to a specific species identification.

STUDY GUIDES

When the material to be covered does not lend itself to graphic portrayal, science teachers might prefer to give students some purpose to their reading by using other kinds of study guides. The most common form of study guide is a list of questions. Questions should progress from the literal (about the facts and vocabulary), to the interpretive, to the applied (questions or problems to solve). Text Reference II (the individualized assessment test) contains such questions. Here are samples of each type of question, all based on the same passage:(18)

- *Literal*
  1. What does the term "structure" mean to the biologists of today and to the author of your textbook?
  2. What kinds of "structure" did the traditional biologist find long ago?
  3. When were the cell and the structures within it discovered?
- *Interpretive*
  1. Do the authors of your textbook believe in just one theory of structure? Explain.
  2. Why do we study biology?
- *Applied*
  1. Using a microscope, draw a diagram of the tissue slide given to you and label the parts as described in the text.
  2. Organize the life forms mentioned, from the largest groupings which include more than one organism down to the smallest grouping within a single organism.

It may be necessary to begin with highly structured questions and later progress to a more openended type of question. You could begin with multiple choice or true-false questions where all the options are furnished. (These questions can contain difficult syntax because in this context they will receive the careful scrutiny they require.) As the students become familiar with this study technique, give questions that require completion answers. On the interpretive level, offer problems that suggest cause/effect relationships.

SUMMARIES

Whenever students convert what they read into their own words, they are learning. A chapter or section summary may be done in several ways:

1. Students can list all the new ideas in the chapter in the order that each was introduced. Then they use this list to write a paragraph, adding transition words as needed.
2. Offer a set format, such as this one suggested by Adams:(19)

   What was the problem?
   What observations were made?
   How was it solved?
3. Students can summarize what they read in a specified number of words, condensing the material so that the depth of coverage is proportional to the original and no new information is offered. Any copied phrases should, of course, be enclosed within quotation marks.
4. Ask each student or small group of students to summarize a different section. Then compose a joint summary of all parts for distribution to the entire class.

In evaluating summaries, teachers should look for clear statements of the main idea and some detailed support of it. In stating the main idea, students should do more than announce the topic of the text or make a vague generalization about it. No extraneous information should be added to that given in the text, and, of course, any conclusions drawn from the text should be appropriate.(20)

SOLVING PROBLEMS AND MAKING PREDICTIONS

Study guides and summarizing activities are designed to help students clarify ideas and ultimately enable them to apply the principles and information they have learned. The best study guide is an unstructured, openended assignment—the solving of a related problem. To help students prepare for this kind of assignment, include some problem-solving questions among those that measure literal comprehension. Conscious attention to problem-solving strategies will enhance a student's ability to apply new knowledge to related situations.

Pauk suggests the following strategies for problem solving:(21)

1. List all the relevant known information.
2. Think through the gap between what is known and what is not known, working from the middle out or from the solution backwards.
3. Restate the problem in a different way, perhaps making a negative statement positive or stating the problem from an entirely different perspective.
4. State any equations or formulas that might be helpful. Supply known quantities and rearrange the formula to solve for unknowns.
5. Use common sense, based on what is known, in making guesses and judging the probabilities.

INTERPRETING ILLUSTRATIONS

Careful attention to illustrations should be a regular part of all reading lessons, because illustrations offer valuable visual interpretations of the material covered in the reading. Since illustrations contain relatively few words, poor readers have a better chance of understanding them than they do the text itself. Indeed, all students benefit from the additional sensory stimulation illustrations provide. In general, the more ways a concept is interpreted, the more memorable it becomes.

In thinking about illustrations, it helps to remember the following:

1. Illustrations always reduce potential data in the process of clarifying it. Compare photographs with diagrams. Compare different diagrams for different emphases.
2. Illustrations should be read from top to bottom, left to right (and constructed so that they can be).
3. In class questions, homework questions, and graphic overviews attention should be directed to the illustrations. These activities should progress from the literal, through interpretive, to applied questions.
4. Students themselves should construct illustrations, particularly graphs and charts, as this is a good way of recategorizing direct observations and information gleaned from reading. Furthermore, this kind of activity is a good first step toward generating inferences, thus replicating the experimental method scientists use. Text Reference VIII (Appendix A) shows a student-constructed chart. The categories "fraternal" and "identical" and the points of comparison were supplied by the teacher, and the student filled in the information.

Visualization, described below, is a good practice activity that develops students' abilities to interpret illustrations.

VISUALIZATION

Visualization is a teaching tool appropriate for both able and less able learners. The teacher should guide students through a chapter, paying careful attention to all illustrations that reinforce information given in the written text. Next the teacher should choose a passage students can read themselves and ask them to draw their own sketches to show how well they understand the data given in the text.

Earth science texts are particularly appropriate for this activity since they usually contain information that students find easy to depict visually. Here are some ways to encourage visualization:

1. Ask students to read a section of the textbook on the movements and effects of glaciers, then make a sketch of this phenomenon. Students can then exchange papers and explain what they learned from each other's sketches.
2. Ask students to make a drawing of layers of rock in a way that symbolizes the probable origins and processes that contributed to the formation of the layers. Students can compare the sketches and discuss the differences. One of the more artistic students might make a poster for classroom display.

CATEGORIZING

Categorizing key words in a textbook assignment gives students an opportunity to practice vocabulary and use organizational skills. See Text Reference IX (Appendix A) for an exercise on categorizing.

NOTETAKING

Research shows that the act of writing enhances concentration and forces students to select main ideas and categorize information, thus aiding retention. Yet students often claim that they are "too busy" listening or reading to take notes, or else they maintain that so long as they understand what they read or hear, they will remember it well enough without taking notes. The truth is that they usually need help in learning effective notetaking techniques appropriate to the content and testing procedures of the course.

It makes sense to discuss notetaking at the beginning of the science course, incorporating the following suggestions plus others appropriate to grade level and content emphasis.

1. Encourage students to date the page and either write the announced topic or draw a line at the top of the page (to be filled in with a topic heading later).
2. Suggest students incorporate diagrams from the board that restructure the information given in the lecture.
3. Suggest a notetaking format that would be appropriate throughout the course, such as an outline form or dividing a page in half so that notes from the book can be added later.
4. Offer continuous guidance in notetaking techniques. Check as you walk around the class that labels are accurate. Pay close attention to the questions being asked in order to restate confusing aspects of the lesson. Write your own set of notes on an overhead transparency during the lecture so you can point out the relation between oral and written content. Emphasize the need to write only key words and only sentence fragments, since there is not enough time and no need to transcribe every word. Organize your lectures to make notetaking easy. Filter out extraneous material and select only highlights and vivid illustrations, being careful to indicate how these bits of information are interrelated.

In addition to offering guidance in notetaking, science teachers should encourage dynamic (active) listening throughout the course. Take a few minutes at the beginning of each class to pose provocative questions that preview the material to be covered. Questions concerning processes set students' minds to the questioning mode and prime them for careful listening. Try to make connections between the new material and material already covered. Elicit responses from many students, and encourage students to verbalize their reactions to statements. If students have difficulty making a generalization and begin to wander from the point, state the generalization in the form of a question and ask them if this is what they mean.

Taking notes in class prepares students for taking notes from the textbook and from supplementary readings. Since most high school textbooks cannot be written in, this set of notes can be written beside lecture notes or on separate labeled pages. The first reading should be preceded by a preview that poses and answers the questions that students probably have about the new material. These questions, plus those posed in the text or study guides, should serve as a guide to notetaking on the second reading.

Text Reference X (Appendix A) illustrates a notetaking system that incorporates lecture notes and reading notes on a single page. Lecture notes are written on the right-most two-thirds of the page. Main ideas are restated in shortened form and subpoints are indented slightly to show that they are subordinate to the main ideas. Detail statements are further indented from the subpoints. On the lefthand side of the page the student can list key words that summarize information taken from the text.

FOLLOWING DIRECTIONS

The ability to follow directions is crucial in the study of science and is especially important in lab courses. This skill draws on many subskills that not all students share. Students with limited backgrounds may even need practice in sequencing before they can attempt lab work. The assignments below can help train students to follow directions and are arranged from the most basic to the more complex:

1. *Sequencing*—Begin by providing students with a list of sentences that describe a procedure. These sentences should be in random order. Ask students to arrange them chronologically. Students can work individually or in small groups.
2. *Transcribing*—Perform a simple task in front of the class. Ask them to state orally and then write down each step as you proceed. Then ask students to read back what they have written while you follow their directions exactly. This may result in some humor as they may have left things out or may state directions in misleading ways.
3. *Following directions*—A variation on this procedure is to have students follow each other's directions. Progress from simple tasks to an entire experiment, and have students first repeat directions orally and then write up the procedure after it is done. Again be sure some of the written directions are read aloud as someone actually performs the experiment.
4. *Refining the style*—At first allow almost any kind of sentence that can be understood, but gradually specify how procedures should be written—as directions (in the second person) or as statements (usually in the passive voice). The lab manual and sets of directions prepared by you can serve as models.
5. *Converting reading materials into procedures*—After students have mastered the concept of sequence, they need practice in converting visual and written explanations into a set of procedures appropriate for the laboratory. Making this translation is one way of giving purpose to a reading assignment. The job of making the conversion forces students to slow down and analyze what they see and read rather than just skim over the material and assume they understand it. Again it is helpful to have students draw diagrams or perform experiments on the basis of each other's oral, then written, directions. For this purpose students can be divided into two groups, each working from a different diagram or section of the text. Filmstrips, board drawings, and posters can also serve as stimuli for this exercise. The groups can exchange papers and attempt to draw the original diagram or perform the experiment using instructions written up by members of the other group. (Of course, to ensure everyone's safety, it is important that all students have access to a complete and accurate set of instructions.)
6. *Completing lab reports*—Most lab teachers require students to come to lab with a list of procedures written in their own words, but based on a diagram or description given in the text. To make sure students have learned to follow directions, make a periodic check of these reports before students

are allowed to begin lab work. Many lab teachers use a standard lab sheet that requires students to supply additional information. A typical lab sheet is shown in Text Reference XI (Appendix A).

RESEARCH METHODS

Frequent reference to supplementary sources (current articles and news stories, encyclopedia articles and almanac references, relevant biographies and other books) encourages a healthy attitude toward reading and toward science. The more often these sources are incorporated into regular classroom assignments, the easier it becomes to promote good research habits.

The first step in achieving competence in researching a topic is to learn how to locate relevant material and isolate it from irrelevant material. Activities that stress this skill have already been discussed as aspects of locating information, finding main ideas, and completing graphic overviews and study guides.

An actual report or term paper, however, should never be assigned without first assessing the group's ability to locate and interpret library materials. Mature scientific research entails notetaking, outlining, and adequate documentation, and requires that students follow standard footnote and bibliographic form. Students should have access to a handbook on research methods or teacher-made directions that specify procedures to follow and the format expected for any research project. If science teachers are not sure they can supervise and evaluate research reports, they should make less demanding assignments, such as those suggested below:

1. *Resource treasure hunt* (adapted from Piercy)(22)—The teacher or advanced students may make the preparations, which include reproducing a map of the school library and locating several articles on science in different kinds of reference books. Small groups of students are then given a numbered list of articles and clues such as the date the article appeared, the height of the shelf on which it can be found, etc. A map of the library is marked with corresponding numbers to show the locations of these articles. Titles of books or magazines are not given, so students must use indexes and the card catalog to find some of the resources. Points can be given to students who find the materials and correctly record all relevant bibliographic information (for a book: author, title underlined, place of publication, publisher, date of publication, and page numbers; for a periodical: volume number, date, page numbers).(23)
2. *Proofs of solutions*—Students can be assigned a problem and encouraged to copy (in quotation marks, of course) various authors' solutions to the problem.
3. *Contrasts in coverage*—Students can contrast the coverage of the same topic in two sources in order to solve a specified problem or answer some question.
4. *Assimilating information from various sources* (adapted from McAllister)(23)—Students can write a creative piece, applying information they have assimilated from a package of sources the teacher has gathered together for this purpose. These sources can include textbook readings plus articles from encyclopedias and magazines on the subject. For example, students might be asked to read about the water cycle, then write the life story of a drop of water, from the time it evaporates from the ocean until it reappears in the ocean again.
5. *Oral reports*—Students could go through the actual research for a term paper, but report their information orally rather than write it—or tell it before writing it. Students who make oral reports should be encouraged to use their notecards to be sure they offer specific information in an organized way.
6. *Term papers and reports*—After students have demonstrated their ability to locate materials, take notes, and assimilate materials from various sources, a term paper or report can be assigned. To make the project more interesting and discourage copying, the term paper or report should culminate

in some problem solving or value judgment by the student (adapted from Romey).(24)

INDIVIDUALIZING READING ACTIVITIES

In all of the foregoing it is evident that students work at many levels, are differently motivated, and respond in individual cognitive styles. Therefore they will not benefit equally from whatever classroom strategies you use to teach reading development. Certainly the average classroom teacher is too busy to manage each learner's progress individually. Yet there are ways to individualize each student's development and make the classroom teacher's job easier. Here are a few:

1. *Study groups*—Establish small study groups at the beginning of each course, mixing able and less able students. All small group activities can be done within these groups. Some teachers even make group members responsible for each other's grades on specified assignments by assigning grades to the whole group on the basis of problems solved by one member. This has the effect of encouraging the better students to tutor the less able ones. The good students, of course, reinforce what they already know by explaining material to the slower learners.
2. *Multileveled teaching*—Teach topics using more than one level of text. This can be accomplished by giving pretests and posttests and establishing a criterion level grade that would excuse better students from the normal reading assignments if they score well on the pretest (adapted from Daugs)(25). Other students could be graded on the basis of improvement.
3. *Learning centers*—Set up learning centers with projects and supplementary books. Judith Thelen suggests a format for creating learning centers using manilla folders. The front of a manilla folder is decorated. The left inside cover contains directions for using the kit, and the right inside cover explains the activity and poses questions. Answers are printed on the back cover.(26)

THE PAYOFFS

Sensitivity to the special problems inherent in science reading can result in better coverage of content, not time taken away from content. Lessons in vocabulary, comprehension, and motivation are, after all, lessons in science. The greatest deterrent to success in science is the defeatist attitude that many students develop when they face reading assignments they cannot understand. After repeated failures students give up on reading altogether. The good science teacher must mediate between students and content. In many cases, working out reading strategies that suit your style and the subject matter can be no more time-consuming than preparing any other lesson plans. Yet the dividends can be much more rewarding.

4. EVALUATION OF CLASSROOM MATERIALS

"A considerable portion of the difficulties of reading science is due to the inherent difficulty of the material."

—Bond and Tinker (1)

Because science teachers are already familiar with the concepts presented in science textbooks, it is sometimes difficult for them to anticipate the problems their students may encounter in reading. Often it is not just a matter of difficult material, but how the material is organized and presented. Science texts often feature a high density of new vocabulary words or familiar words used in a new, restricted sense. The sometimes convoluted syntax of scientific writing, with its heavy dependence on subordinate clauses and modifiers, is also likely to cause problems.

Even more troublesome is the tendency in much scientific writing to make assumptions about the reader's interests and background. For example, research has shown that many scientific texts offer historical information as a way of introducing an important new concept.(2) But since the historical information is also new material, the confused student is left with no means of relating the new information to past experience. A better introduction might relate the new concept to experiences that most students are likely to recall. Another pitfall is the inadvertent linking of two concepts in the same paragraph or chapter, leading students to incorrectly assume a relationship where none exists.

Such problems may not concern experienced readers who have a better background for the content or whose good study habits and perseverance enable them to make headway through even the most confusing material. But if an assessment of reading skills reveals deficiencies in your science students, you will have to guide their reading carefully or, perhaps, select materials that are more accessible to them. If students have difficulty finding main ideas, they may need a book with clear and numerous headings. If students read slowly, they may need a text with shorter chapters. If students are unskilled in determining meaning from context clues, they may need a text with vocabulary words in boldface or listed at the end of each chapter. Even though a science textbook must be used in class before it can be judged definitively, there are some relatively simple ways to determine potential difficulties.

THE INADEQUACY OF GRADE LEVEL DESIGNATIONS

Many publishers now label science textbooks with a grade level designation that suggests relative reading difficulty. To approximate the suitability of such texts for your class, compare the publisher's designation with the standardized test scores of your students. However, there are several reasons why this procedure alone is inadequate for the purpose of textbook selection. First, the standards for determining grade level might not be the same for the textbook publisher and the test publisher. Second, the results of a single test may not accurately indicate student competence, especially since many such tests do not compute scores for individual reading skills and often do not even focus on the kinds of reading skills required of science students. Finally, when choosing a textbook there are many other factors to consider besides grade level difficulty.

THE NECESSITY OF ESTABLISHING DEPARTMENT-WIDE GOALS

Paul Hurd clarifies the kinds of goals that science departments might consider—goals that would determine the sort of content they would require in a textbook.(3) Humanistic concerns might be reflected in the selection of a textbook that is clearly related to the needs or interests of students, that is related to everyday activities, that speaks to widely held scientific superstitions, or that explains issues covered in the popular press.(4) On the other hand, intellectual concerns might guide the selection of a textbook that prepares students for standardized tests, that stresses cognitive skills and builds concepts that provide connections with other disciplines, and that conveys the role of science in history.(5) For a totally coordinated program, it is important to consider the sequence of the whole science curriculum to make sure that each textbook reinforces the others in the sequence and offers the requisite background and process skills.

Of paramount importance is the philosophy of the textbook writer. Most science books are still set up as lessons that convey information deductively rather than leading students to make discoveries inductively. Care should be taken to select a textbook whose pattern of organization meets course goals.

OTHER FACTORS TO CONSIDER

Attractiveness

Some thought should also be given to the attractiveness and durability of the text. There are vast differences in the clarity and completeness of textbook illustrations. Graphs and charts should be labeled clearly and consistently and positioned close to the related section of text. Type size, type design, and margins can also contribute to legibility. In general, poor readers are overwhelmed by pages with too much print on them. Even the weight and color of the paper can affect a book's effectiveness.

Study Aids

If exercises from the book are going to be used for class activities, give careful consideration to their clarity and aims. Do the questions go beyond the literal level? Do they encourage careful reading skills? Are some answers provided so that students can check themselves? Do some of the questions lend themselves to group problem-solving sessions? One study based on a comparison of widely used biology texts revealed vast differences in the kind and quality of questions posed.(6)

Readability

Perhaps the most important traits concern organization and syntax. Since matters of organization take considerable time to analyze and are often open to multiple interpretations, most readability formulas focus on syntax. The more complicated formulas are concerned with those aspects of syntax likely to confuse the inexperienced reader. These aspects, some of which were illustrated in Chapter 1, include the following (adapted from Aukerman):(7)

1. number of subordinate clauses
2. amount of embeddedness or deletions in these clauses
3. the order of the clauses—whether they are direct or inverted
4. the frequent use of such verb forms as gerunds, participles, and infinitives
5. sentences that violate normal (spoken) expectations, that violate chronological order (with prior events or old information in the first clause of the sentence)
6. sentences where what is modified is widely separated from the modifying phrase.

All of these matters increase reading complexity even if the vocabulary and content are not in themselves difficult. Fortunately, however, these factors need not be individually computed in order to measure potential reading difficulties in a given textbook. Most readability formulas reduce these considerations to their simplest terms: sentence length and frequency of polysyllabic words.

READABILITY FORMULAS

The Fry Readability Formula

This is probably the most commonly used shortcut to measuring readability. The Fry formula is based on the premise that sentence length and the number of syllables in words are accurate ways of measuring the difficulties inherent in complicated syntax and specialized vocabulary. It is implied that these traits coexist with difficult content; therefore it is not necessary to evaluate the content *per se.* (8)

To use the Fry formula, collect data as outlined in the steps below and record your findings on a sheet similar to the form given in Appendix B.

1. Select three different passages of exactly 100 words each, excluding proper nouns.
2. Count the total number of sentences represented in all three passages to the nearest tenth of a sentence.
3. Then count the total number of syllables in each of the three 100-word passages, again excluding proper nouns.
4. Divide the total number of sentences by three to determine the average number of sentences per 100 words.
5. Divide the total number of syllables by three to determine the average number of syllables per 100 words.
6. Plot the figure for average number of sentences and the figure for average number of syllables per 100 words on the graph in Appendix B to determine the grade level of the reading material.
7. Repeat this procedure if there is a great deal of variation among the three passages selected.

Other Formulas

Most other readability formulas work on the same principle. The Dale-Chall formula, commonly used on elementary reading material, takes into account a list of difficult words compiled by Dale. The Flesch formula counts syllables and sentence length, but involves a longer sample and more mathematical operations than the Fry formula.

McLaughlin's Smog Grading procedure(9) is based on the probability that polysyllabic words and long sentences occur together. To compute readability according to this formula, use the following procedure:

1. Select ten consecutive sentences near the beginning, middle, and end of the reading material.
2. Count every word of three or more syllables. Recount polysyllabic words if they are repeated.
3. Estimate the square root of the total number of polysyllabic words by taking the square root of the nearest perfect square. If the total falls exactly between two perfect squares, use the lowest of the two.
4. Add 3 to the estimated square root to determine the reading level.

Example:

	Number of polysyllabic words
10-sentence sample 1	8
10-sentence sample 2	7
10-sentence sample 3	9
Total	24

The nearest perfect square to 24 is 25 (5x5). Add 3 to 5 and the reading level by the SMOG formula is 8, or eighth grade.

Other less well known formulas take more factors into consideration but are also more difficult to use (for example, see Aukerman and Robinson).(10) In general the readability formulas give only a rough approximation of reading difficulty. Content and format should also be considered when evaluating and selecting textbooks. The evaluation form given in Appendix C may be of some help in organizing a department-wide review of science textbooks.

FLEXIBILITY IN COURSE MANAGEMENT

Rewriting Materials

Some teachers have found it necessary or desirable to rewrite materials for poor readers. In doing so, they should offer more repetition and more details than the original, but check readability using one of the formulas offered here. Use no more than one difficult word per 200.(11)

Organizing by Topics

In selecting new textbooks, consider the many ways they can be used in setting up a course sequence. Donald Daugs suggests organizing a science course by topic, with students in the same class utilizing three levels of textbooks. He claims that this is no more expensive and only slightly more difficult than working with a single textbook. The plan, has the obvious advantage of meeting individual reading needs, and it provides a good basis for exchanges of information in small groups and class discussion.(12)

Encouraging a Variety of Reading Experiences

Although the textbook is central to classroom teaching, the concept of organizing by topic opens up the idea of incorporating a variety, even a choice of reading materials into regular class assignments. The possibilities include articles in *Readers' Digest, Scientific American,* and the popular media. See Appendix E for a list of supplementary classroom reading resources.

By encouraging a wider range of reading experiences than the textbook offers, we broaden the cognitive base upon which the textbook builds and promote an interest in science. Interest in science would at least keep people from being "foreigners in their own culture," an expression used by Hurd(13) to suggest that ignorance and apathy toward all branches of science are widespread among high school graduates. In speaking of the challenge to devise more efficient methods of teaching science, B. F. Skinner explains why science teachers can and should rise to the occasion:(14)

> It is the sort of challenge that scientists are accustomed to accept. . . . They should be best able to gauge the importance of science in the immediate and distant future and therefore the extent of the disaster which will follow if we fail to recruit for science large numbers of our most intelligent and dedicated men and women. It is no time for half-hearted measures. The improvement of teaching calls for the most powerful methods which science has to offer.

APPENDIX A

TEXT REFERENCE I: SAMPLE CLOZE TEST*

Figure 2-2 shows the relationship between the three principal genetic classes of rocks: igneous, sedimentary, and metamorphic rocks. This relationship is known ______ the rock cycle. Igneous ______ form by the cooling ______ hardening of melted materials. (______ Figure 2-3.) The word "igneous" ______ from the Latin word ______ fire. Igneous rocks and ______ kinds of rocks exposed ______ the surface of the ______ are subject to weathering. ______ involves both the chemical ______ physical breakdown of ______ exposed to the atmosphere ______ hydrosphere at the earth's ______.

The weathered rock that ______ on the earth's surface ______ continually moved by water, ______, and ice. This process ______ moving materials is known ______ erosion. Erosion eventually carries ______ of the broken-down ______ material to the oceans ______ it is spread in ______ of sediments as shown ______ Figure 2-4.

The sands and ______ sediments that make up ______ beaches extend out along ______ bottom of the sea. ______ time they are covered ______ other sediments and may ______ pressed together to form ______. Such rocks are called ______ rocks. Sedimentary rocks can ______ from any type of ______ that happens to be ______ at the earth's surface. (______ Figure 2-2.)

Metamorphic rocks are ______ from rocks that are ______ or pressed together under ______ pressure for long periods ______ time. They form deep ______ the surface of the ______. Bricks are made by ______ and heating blocks of ______ clay. In somewhat the ______ way metamorphic

*Reprinted with permission from Earth Science Curriculum Project, *Investigating the Earth* (Boston: Houghton Mifflin Co., 1967), p. 38.

rocks form ________ sedimentary rocks. They may ________ form from igneous rocks. ________ type of metamorphic rock ________ depends on the amount ________ heat and pressure and the composition of the rock being changed. *Metamorphic* comes from Greek words for change and form.

TEXT REFERENCE II: INDIVIDUALIZED ASSESSMENT TEST*

Directions Read the passage about heredity and then answer the questions given below. For multiple choice questions, write the letter of the most accurate answer in the space provided. For true-false questions, write T for true and F for false in the space provided. For completion questions, write the missing word(s) in the space provided.

I. Vocabulary

___ 1. "Lower" organisms than ourselves means

- a. less complicated forms of life.
- b. existing underground.
- c. pets and farm animals.
- d. musical instruments.

___ 2. Drosophila are

- a. inherited traits.
- b. a type of "lower" organism.
- c. the last name of an old family.
- d. biologists who study genetics.

___ 3. "A single cross" in the second line of the second paragraph means

- a. a traffic signal for pedestrians.
- b. mating of two organisms.
- c. a lie involving only one person.
- d. an unmarried person.

___ 4. "Marks on human faces" in the middle of the third paragraph means

- a. lines and wrinkles.
- b. bruises and cuts.
- c. tattoos.
- d. pencil marks.

___ 5. (true or false) "Passing on" in the third line refers to dying.

*Based on James H. Otto and Albert Towle, *Modern Biology* (New York: Holt, Rinehart & Winston, 1977), pp. 127-128.

___ 6. (true or false) "Sample" in the middle of the second paragraph refers to the number studied.

___ 7. (true or false) The word "Further" in the third paragraph refers to the distance between home towns of the two parents.

___ 8. The word which names something that comes in pairs (besides twins) is ______.

___ 9. The word which means children is ______.

___ 10. The phrase which states the exception to the possibility that no one is your genetic double begins with what word?

II. Factual Information

___ 11. (true or false) Laws of heredity are different for different organisms.

___ 12. (true or false) The environment is most helpful in studying human genetic background.

___ 13. The drosophila has

a. 46 pairs of chromosomes.
b. more inherited traits than humans.
c. 4 pairs of chromosomes.
d. none of these.

___ 14. The only way you can see someone who looks just like you is to have a ______.

___ 15. The name of the scientist who studied heredity in plants was

a. Mandel.
b. Drosophila.
c. Mendel.
d. Pasteur.

___ 16. (true or false) Aunts, uncles, and other close relatives cannot be included in tracing traits of human beings.

Name some details given in the reading to complete these lists below. Write an appropriate word in the numbered space to the left of the incomplete list.

___ 17. *Human traits:*

17. ______

eye color

___ 18. *Environmental factors which influence human traits:*

18. ________

experience
diet
general health

____19. 19. ________

gland activity

____20. Height and body build are influenced by ________ and ________.

III. Inferences

____21. We often hear about experiments performed on rats to determine whether different things cause cancer in humans. Which of the reasons given for studying heredity in drosophila seem to be a good reason for studying cancer in rats?

a. Drosophila have fewer chromosome pairs.
b. Lower animals live out their lives in a shorter time.
c. No one feels sorry for rats.
d. Biologists know more about drosophila than about humans.

____22. (true or false) Since human beings have 46 pairs of chromosomes, it can be assumed that they have 46 inherited traits.

____23. Pick the most likely range of years considered to represent a human generation.

a. 40-50 years
b. 5-7 years
c. 10-20 years
d. 100-200 years

____24. Pick the letter of the column in which animals are listed in the order that they might be useful for heredity studies (from the most useful at the top of the list to the least useful at the bottom of the list).

A	B	C
mosquitoes	sponges	elephants
sponges	mosquitoes	sponges
elephants	elephants	mosquitoes

____25. (true or false) The influence of environment is less of a problem in studying drosophila genetics than in studying human genetics.

____26. (true or false) A good way to study the influence of environment on human genetics is to study identical twins.

____27. The picture at the top of the page is supposed to show

a. that sunlight causes people to squint.

b. that people can't communicate very well.
c. that hairstyles change.
d. that members of the same family look alike.

____28. The main idea of this passage is that

a. environment influences heredity.
b. some plants and animals may produce thousands of offspring from a single cross.
c. athletes are the preferred subjects of genetic study since they have well-trained bodies.
d. since the laws of heredity apply to all organisms, we can learn about human inheritance by studying the lower forms of life.

____29. (true or false) It is preferable in studying genetics to study organisms that produce a large number of offspring.

____30. On the basis of the information given in the passage, which would you guess to be possible:

a. Two brown-eyed parents could produce a blue-eyed baby.
b. You could find another person who had exactly your same genetic makeup if you had the time to check out every single living person on earth.
c. You could change your genes by changing your diet.
d. Human beings in the future will be producing more offspring than at present.

TEXT REFERENCE III: STUDY SKILLS CHECKLIST*

E = Excellent VG = Very Good G = Good F = Fair P = Poor

	E	VG	G	F	P
Locating skills					
Uses index					
Finds relevant facts, words					
Determines kind of information to be covered (Table of Contents)					
Vocabulary skills					
Uses context clues					

*Adapted from Doris Johnson, Lecture/Workshop at Kanawha County Diagnostic Center, Charleston, West Virginia, March 25, 1969; see also David L. Shepherd, *Comprehensive High School Reading Methods* (Columbus, Ohio: Charles E. Merrill Publishing Co., 1973), p. 30.

	E	VG	G	F	P
Identifies common words with specialized meanings					
Learns definitions of boldface terms					
Selects correct dictionary definition					
Analyzes structure of words					
Literal interpretation					
Identifies main ideas					
Identifies details					
Inferential interpretation					
Draws conclusions					
Relates new concepts to old learning					
Critical interpretation					
Reorganizes data into new schemes					
Applies concepts to new situations					
Assimilation of materials					
Takes notes, outlines					
Summarizes					
Follows directions					
Generates procedures from text					
Research skills					
Uses *Reader's Guide to Periodical Literature*					
Records bibliographic data					
Finds relevant sources (almanacs, handbooks, etc.)					
Integrates materials from various sources					

Graphics interpretation	E	VG	G	F	P
Understands and uses symbolic and graphic symbols					
Handles quantitative concepts in graphs, charts					
Restates information conveyed in tables, diagrams, pictures					
Constructs graphics appropriate for content in text					
Attitude					
Develops purposes for reading					
Completes assignments					
Participates in discussion					

TEXT REFERENCE IV: CLASS LIST OF STUDY SKILLS (Compiled from Individual Study Skills Inventories)*

Checkmarks indicate problem areas where work is needed.

	SKILLS							
NAMES OF STUDENTS	Locating skills	Vocabulary skills	Literal interpretation	Inferential interpretation	Critical interpretation	Research skills	Graphics interpretation	Attitude
Adams, Jenny								
Blackburn, Ralph								
Borrock, Sandy								
etc.								

*Adapted from David L. Shepherd, *Comprehensive High School Reading Methods* (Columbus, Ohio: Charles E. Merrill Publishing Co., 1973), p. 156.

TEXT REFERENCE V: SAMPLE ATTITUDE INVENTORY

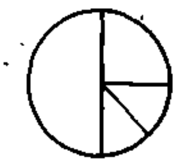
The following statements depict habits or feelings that may or may not describe you. Put a checkmark in the column that best describes how often you do or feel what the statement says. Answer honestly. This questionnaire is intended to help you understand yourself and set your goals for this school year.

	Always	Most of the time	Some-times	Rarely	Never
1. I do my assignments at the earliest opportunity.					
2. I participate in class discussions.					
3. My reading rate is slow.					
4. I read for pleasure.					
5. I understand graphs and charts.					
6. I have trouble learning math.					
7. I am dissatisfied with my grades in school.					
8. I get along well with people.					
9. I worry about my future.					
10. I think most courses are a waste of time.					
11. I understand the main point of what I read.					
12. I prefer to work alone rather than in small groups.					
13. I feel the need to improve my personality.					
14. I feel the need to improve my study habits.					
15. I daydream during class.					

TEXT REFERENCE VI: SHAPES THAT COULD BE ADAPTED FOR STRUCTURED OVERVIEWS

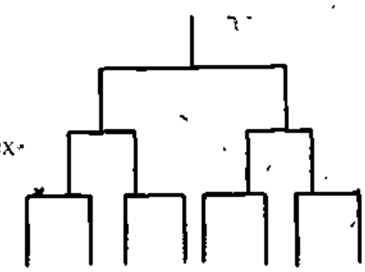
Pies

The whole and its parts show proportions.



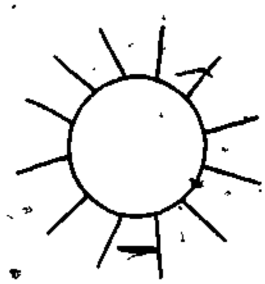
Hierarchies

The branches show subcategories and examples (see Text Reference VII).



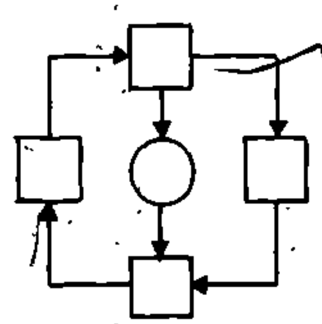
Spokes

The hub depicts a main idea and the spokes represent details when all details are of equal importance.

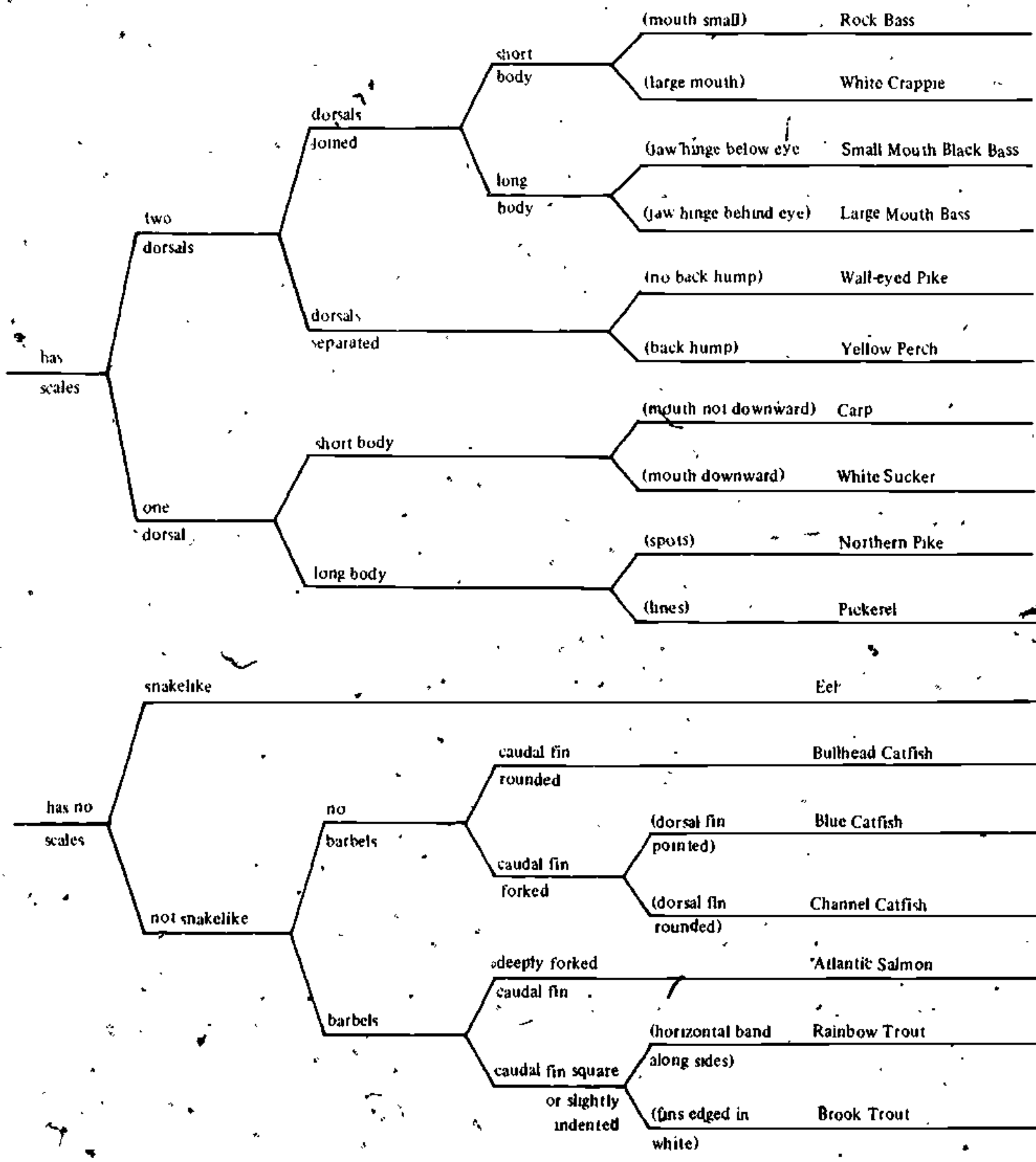


Flow charts

The geometric shapes represent stages and the arrows indicate the direction taken by the main idea, subordinate idea, and details.



TEXT REFERENCE VII: STRUCTURED OVERVIEW FOR IDENTIFICATION OF FISH SPECIES*



*Based on information in Otto, and others. *Biology Investigations* (New York: Holt, Rinehart and Winston, 1977), pp. 85-88.

TEXT REFERENCE VIII: CHART SHOWING DIFFERENCES BETWEEN FRATERNAL AND IDENTICAL TWINS*

TYPES	INITIAL DEVELOPMENT	PHYSICAL CHARACTERISTICS	PERSONALITY CHARACTERISTICS	MENTALITY
Fraternal	two different eggs	can be completely different	different	different
Identical	single fertilized egg	exactly alike	similar, but influenced by environment	similar, but influenced by environment

*Based on Otto and Towle, *Modern Biology* (New York: Holt, Rinehart and Winston, 1977), pp. 126-27.

TEXT REFERENCE IX: CATEGORIES

Word List: alcohol, asphalt, copper, lithium, cesium, calcium, petroleum, lead, phosphorus, titanium, methane, helium, pitchblende, potash, lime, sodium chloride, polonium, radium, ink, copper oxide

Directions: Make two different charts.

Chart 1: Decide which of the above are elements, which are compounds, and which are mixtures.

Chart 2: Decide which three topic headings would cover all of the words listed above

Example

Chart 1

Element	Compound	Mixture
copper radium lead	alcohol sodium chloride methane	asphalt ink pitchblende

Example

Chart 2

Liquid	Solid	Gas
alcohol	lead	methane

TEXT REFERENCE X: A SAMPLE PAGE OF NOTES*

The Cornell format for notetaking is: *record, reduce, recite, reflect, review.*** This page shows some sample textbook notes using the Cornell method. It is important that the notetaker write the content material to the right of the margin of the "law-ruled" paper, while key terms for recitation, reflection, and review are to the left of the margin.

	How Animals Receive Information, Chapter 26 1/8/79
Key Terms Main Ideas + Points	
two basic aspects of communication	1 reception of info. 2 transmission " "
difference between info. exchange of animals and plants	animals - number and variety receptors greater. plants - have no elaborate responses to environmental stimuli.
	Classification of Receptors (according to type of stimuli reception)
*Definition Mechanoreceptors	= change due to mechanical pressure; sensory nerve endings bent or stretch - main response to stimuli; steady or intermittent pressure; i.e. object grasped; i.e. sound waves to ear

*Based on Smallwood and Green, *Biology: Teacher's Edition* (Morristown, N.J.: Silver Burdett Co., 1968), pp. 601-602.

**Described by Pauk, *How to Study In College* (Boston: Houghton Mifflin Co., 1974), pp. 128-133.

TEXT REFERENCE XI: LAB SHEET

NAME ________________ NAME OF EXPERIMENT ________________

LAB PARTNER ____________________________ DATE ____________

Purpose:

Equipment:

Steps:

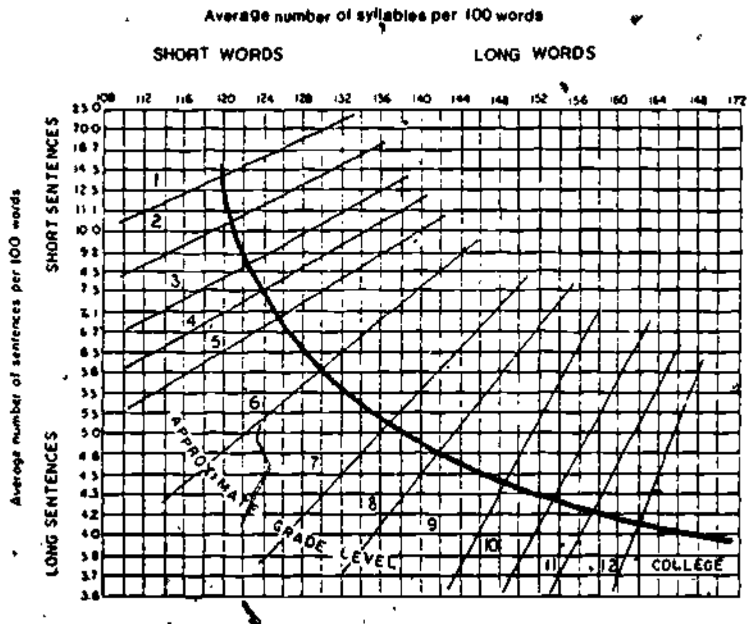
Observations:

Results:
(data sheets, graphs, and charts attached as appropriate)

APPENDIX B

GRAPH FOR ESTIMATING READABILITY

By Edward Fry, Rutgers University Reading Center,
New Brunswick, New Jersey



DIRECTIONS: Randomly select 3 one-hundred word passages from a book or an article. Plot average number of syllables and average number of sentences per 100 words on graph to determine the grade level of the material. Choose more passages per book if great variability is observed and conclude that the book has uneven readability. Few books will fall in gray area but when they do grade level scores are invalid.

RECORD SHEET: SUMMARY OF READABILITY DATA

Textbook title ______________________________

	Number of Syllables	Number of Sentences
Sample I, p. ______	____________	____________
Sample II, p. ______	____________	____________
Sample III, p. ______	____________	____________

Average number of syllables 3 samples ______________

Average number of sentences 3 samples ______________

Approximate grade level __________

APPENDIX C

EVALUATION OF TEXTBOOKS FOR SCIENCE*

Title ____

Author(s) ____

Publisher ____

Date ______________ Edition ______________________________

Subject ______________________________ Grade level __________

Check which materials are included:

___ Student book(s)
___ Teacher guide
___ Correlated lab manual
___ Visuals bound within books (photos, illustrations, diagrams)
___ Supplementary visuals (films, filmstrips, posters, etc.)
___ Supplementary equipment (learning centers, experiment packages, etc.)
___ Other (described below)

Instructions: Evaluate each item listed below by placing a check in the appropriate section of the graded scale. The low numbers at the left side of the scale denote unacceptable to less desirable performance, and the high numbers at the right side of the scale denote desirable to most desirable performance. All of the forms completed by the selection committee or science department can be tallied, and averages filled in on a master sheet for each textbook. Then set priorities for determining which characteristics are most important in making the decision about textbook adoption.

	1	2	3	4	5	6	7	8	9	10
Format of student book										
General appeal to students										
Visuals: clear, meaningful										
Study aids: vocabulary, headings, summary section										
Size (easy or difficult to handle)										
Binding										

*Adapted from Daniel M. Franzblau, "Evaluation of Course Materials for Foreign Language Teaching" (Oxford, Ohio: Miami University, March 1969).

	1	2	3	4	5	6	7	8	9	10
Paper										
Type, spacing, and page arrangements										
Format of teacher guide										
General appeal: uncluttered, easy to use										
Size										
Binding										
Paper										
Type, spacing, titles, page arrangement										
Content										
Fits in with course goals, school goals										
Adequately reviewed and tested										
Desirable depth of detail										
New concepts introduced carefully										
Includes questions and exercises at the interpretive and applied levels										
Readability										
Appropriate grade level according to ________ formula										
Syntax natural										
Vocabulary introduced clearly										
Sequence and organization of information										
Concepts related to past experiences, to graphics										
Adequate use of transitions										
Supplementary materials										
Lab manual experiments appropriate										
Lab manual format clear, consistent										
Supplementary visuals professional, stimulating										
Supplementary equipment worth price (which is ________) compared to school-generated materials										

Recommendations (Check A, B, or C)

___ Department/system should adopt the text reviewed.

List advantages:

a. Objectives are compatible with those of the science department.
b. Visuals are clear and interesting.
c. Others.

___ Department/system should conditionally accept the text reviewed.

List the conditions:

a. Text is acceptable if the materials are used at the junior high school level in the basic program.
b. Text is acceptable if supplementary visuals and equipment are purchased at the same time.
c. Others.

___ Department/system should reject the text reviewed.

List reasons:

a. Objectives are incompatible with those of the science department.
b. There are insufficient questions on the interpretive level.
c. Others.

APPENDIX D

SCIENCE TEXTBOOKS FROM WHICH EXERCISES WERE DEVELOPED FOR THIS BOOK

Earth Science Curriculum Project. *Investigating the Earth* Boston: Houghton Mifflin Co., 1967.

Haber-Schaim, Uri, and others. *Introductory Physical Science*. 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, 1972.

Kaufman, Milton, and others. *Understanding Radio Electronics*. 4th ed New York: McGraw-Hill Book Co., 1972.

Namowitz, Samuel M., and Stone, Donald B. *Earth Science, The World We Live In*. 2nd ed. Princeton, N.J.: D. Van Nostrand Co., 1960.

Otto, James H., and others. *Biology Investigations*. New York: Holt, Rinehart and Winston, 1977.

Otto, James H., and Towle, Albert. *Modern Biology*. New York: Holt, Rinehart and Winston, 1977.

Rutherford, F. James; Holton, Gerald; and Watson, Fletcher G., directors. *Project Physics* New York: Holt, Rinehart and Winston, 1975.

Smallwood, William L., and Green, Edna R. *Biology*, teacher's ed. Morristown, N.J.: Silver Burdett Co., 1968.

Toon, Ernest R. *Foundations of Chemistry*. New York: Holt, Rinehart and Winston, 1973.

APPENDIX E

SUPPLEMENTARY SOURCES FOR THE SCIENCE CLASSROOM

Nonprint Materials

Educator's Guide to Free Audio and Video Materials
Educator's Guide to Free Films
Educator's Guide to Free Filmstrips
Educator's Guide to Free Tapes, Scripts, and Transcriptions

Educator's Progress Service, Inc.
Randolph, Wisconsin 53956

NICEM–Index to Free Educational Material–Multimedia

National Information Center for Educational Media (NICEM)
University of Southern California
University Park
Los Angeles, California 90007

Print Sources

Scientific magazines, such as:

American Forests
Audubon Magazine
Chemistry
Current Science and Aviation
Mechanics Illustrated
Natural History
Popular Mechanics
Scientific American
Today's Health

Reprints of individual articles from *Scientific American*

W. H. Freeman and Company
660 Market Street
San Francisco, California 94101

Books with science content, such as:

Adamson, Joy. *Born Free.* New York: Random House, 1974.
Asimov, Isaac. *Of Matters Great and Small.* New York: Ace Books, 1976.
Carson, Rachel. *The Sea Around Us.* New York: New American Library, 1954.
———. *The Silent Spring.* New York: Fawcett, 1977.
Cousteau, Jacques-Yves and Dumas, Frederic. *The Silent World.* New York: Harper and Row, Publishers, 1965.

Herriot, James. *All Things Bright and Beautiful.* New York: Bantam Books, 1975.

Heyerdahl, Thor. *Kon Tiki.* New York: Ballantine Books, 1973.

Moore, Patrick and Jackson, Francis. *Life on Mars.* New York: W. W. Norton and Co., 1965.

Van Lawick-Goodall, Jane, and Van Lawick-Goodall, Hugo. *In the Shadow of Man.* New York: Dell Publishers, 1974.

Science fiction selections

Biographies of famous scientists

Reference books, such as:

Asimov, Isaac. *Words of Science* New York: Mentor Books, 1969.

Life Series on *The Sea. The Desert. The Forest.* and *The Mind.* Morristown, N.J.: Silver Burdett Co.

Mandell, Alan. *The Language of Science.* Washington, D.C.: National Science Teachers Association, 1974.

The World Almanac. New York: Newspaper Enterprise Association, published annually.

Specialized handbooks, such as:

Condon, E. U. and Odishaw, Hugh, eds. *Handbook of Physics.* New York: McGraw-Hill Book Co., 1967.

Weast, Robert C., ed. *Handbook of Chemistry.* West Palm Beach, Fla.: CRC Press, published annually.

Specialized encyclopedias, such as:

The McGraw-Hill Encyclopedia of Science and Technology New York: McGraw-Hill Book Co., 1963.

The Larousse Encyclopedia of Animal Life. New York: McGraw-Hill Book Co., 1961.

Encyclopedia of Chemistry. New York: Reinhold, 1966.

Encyclopedia of Physics. New York: Reinhold, 1966.

Research aids, such as:

The handbook used for research papers by the English department of your school.

Theriault, Albert A., Jr. *Guide to Writing Term Papers.* New York: AMSCO School Publications, 1971.

Warren, James. *How to Write a Research Paper.* Boston: Branden Press, 1972.

Indexes:

Readers' Guide to Periodical Literature
Biological and Agricultural Index

Applied Science and Technology Index
Environment Index

Dictionaries, such as:

Webster's International. Unabridged edition.
The American Heritage Dictionary

Free and inexpensive topical literature from:

The American Association for the Advancement of Science
1015 Massachusetts Avenue, N.W.
Washington, D.C. 10005

(for readable tradebooks)

Senior Scholastic Magazine Book Services
Science World Book Club
50 West 44th Street
New York, N.Y. 10036

(for inexpensive paperbacks)

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

(for a list of low-cost pamphlets)

REFERENCES

CHAPTER 1: THE NEED FOR READING INSTRUCTION IN SCIENCE

1. David L. Shepherd, *Comprehensive High School Reading Methods* (Columbus, Ohio: Charles E. Merrill Publishing Co., 1973), p. 1.

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3. *Ibid.*, pp. 2-6.

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