The Integration of Reading and Science to Aid Problem Readers

Genevieve J. Minge

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THE INTEGRATION OF READING AND SCIENCE TO AID PROBLEM READERS

by

Genevieve J. Minge

A THESIS

Presented to the Faculty of
The Graduate College in the University of North Florida
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For the Degree of Masters in Education
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Under the Supervision of Professor
Royal W. Van Horn

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G.J.M.
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This project was motivated by the needs of the science students at Orange Park IX. It is the hope of this writer that the strategies outlined here will aid problem readers in science classes by providing concrete strategies to integrate reading and science. The nature of this task involves the use of four information-processing models--Ausubel, Concept Attainment, Suchman, and Taba--in conjunction with the development of reading skills using science experience stories. The science stories are oral reports about activities within the science classroom. These reports are transcribed to written form and used as the basis for reading in the classroom. Although a sample story has been included in Chapter III, the developmental aspects of the process has not been tested. The story included here represents a first try by students who read at the second grade level. When the program is piloted, it is the hope of this writer to include a series of stories that illustrate the progress of the students. After much frustration in dealing with problem readers in science, this writer believes that these strategies will prove effective.
CHAPTER I

INTRODUCTION, THEORETICAL DIMENSIONS AND RATIONALE

PROBLEM STATEMENT

The purpose of this paper is to explain a curriculum package which was designed for science students at Orange Park IX, ninth grade center, Clay County, Florida. The target population consists of those students who read below the sixth-grade level according to the Stanford Achievement Test (SAT) scores and who are enrolled in a general science class. These students are also enrolled in a Reading Skills class and some are in the SLD and ED programs as well. Although there will be interaction with the reading, SLD, and ED teachers, the classes will not be team taught. Therefore, the science curriculum is intended to be contained within the fifty-minute sessions allowed for science classes. The curriculum will accomplish the following goals within twenty class sessions:

1. Science goals: For the student to understand and apply knowledge of the processes and products of scientific methods including experimentation, theorizing, technology, scientific law and cause and effect relationships.

2. Reading goals: For the student to understand and apply knowledge of word attack skills, main ideas, concept attainment, following directions, and organizing ideas.

The specific objections to be met are as follows:

1. The student will understand the following concepts so that
he/she can correctly identify critical attributes, definitions, superordinate, coordinate, and subordinate concepts, examples and nonexamples, and/or relationships with the other concepts listed below:

a. science
b. product of science
c. process of science
d. problem solving
e. hypothesis
f. problem
g. experiment
h. observation
i. inference
j. experimental group
k. control group
l. theory
m. law
n. technology
o. scientist
p. cause
q. effect
r. superstition

2. The student will understand and apply the methods used to discover scientific knowledge (stating problems, collecting data, forming hypotheses, testing hypotheses, accepting or rejecting hypotheses, drawing conclusions, communicating results) so the he/she can
correctly identify examples of each of these processes as well as use these processes in individual and group projects.

3. The student will gain knowledge of scientific discoveries and inventions so that he/she can correctly identify the sequence of events leading to the discovery or invention and state the impact on existing and future societies.

4. The student will understand and apply knowledge of main ideas so that he/she can correctly identify the main idea of a written passage and identify the statements that support the main idea.

5. The student will understand and apply knowledge of following directions so that he/she can correctly follow one-, two-, or three-step directions accurately and in sequence as well as read and follow directions for laboratory experiments so that each step is done accurately and in sequence.

6. The student will understand and apply knowledge of how ideas can be organized so that he/she can correctly identify the sequence of events within a passage, prepare a diagram or chart showing relationships among concepts, and identify the relationships shown in a diagram or chart.
DEFINITIONS OF TERMS

1. **Advance organizer**--a general, introductory statement that encompasses information to be taught and links that information to existing information.

2. **Cognitive structure**--the total amount of organized knowledge that an individual possesses at a given time.

3. **Communication**--the interchange of thoughts or opinion.

4. **Concept**--a form of content that results from the categorization of observations.

5. **Concept Attainment**--the process of forming categories of observations by identifying similarities and differences among things.

6. **Content**--knowledge that is stored in the brain and can be used in the future.

7. **Curriculum**--what is taught and how it is taught.

8. **Deductive reasoning**--a thinking process that moves from the general to the specific.

9. **Exemplars**--examples chosen by the teacher to illustrate the critical attributes of a concept.

10. **Generalization**--an inferential statement that expresses the relationships of concepts, applies to more than one event and has predictive value.

11. **Hierarchy**--relationships of concepts expressed in terms of superordinate,
coordinate and subordinate concepts.

12. **Hypothesis**--a possible explanation or solution to a problem.

13. **Inductive reasoning**--a thinking process that moves from the specific to the general.

14. **Information-Processing**--"the ways in which people handle stimuli from the environment, organize data, sense problems, generate concepts and solutions to problems and employ verbal and nonverbal symbols." (Joyce and Weil, 1972, p.9)

15. **Inquiry**--a process that uses both inductive and deductive reasoning to solve a problem.

16. **Integrative Reconciliation**--the process of relating major concepts to each other and resolving differences.

17. **Language Facility**--the ability of a person to deal with varieties of words, word patterns, and sentence structures.

18. **Problem reader**--a student who reads considerable (three or more levels) below his/her grade level.

19. **Process**--intellectual capabilities required to analyze information.

20. **Progressive Differentiation**--the process of breaking down broad ideas into narrower and less inclusive ones.

21. **Readability formula**--a system to determine the ease with which a student can read written material.

22. **Reading**--the ability to translate written words into thought or spoken
words and to comprehend and assimilate the information.

23. **Reading Level**--the ease with which an individual reads written material.

24. **Science Experience Story**--an oral, tape-recorded account of science phenomena prepared by students and transcribed into written form.
THEORETICAL DIMENSIONS AND RATIONALE

Introduction

The student who reaches ninth grade with his/her reading ability retarded by three or four grade levels is not likely to succeed in traditional classes that ignore the fundamental problem. These students tend to turn-off to science as they become frustrated by science vocabulary and the difficulty of the textbooks. The purpose of this curriculum is not to work around the reading problem but to tackle it head-on. Problem readers require specialized techniques that will provide successful experiences in dealing with scientific materials while upgrading their reading levels and establishing thinking skills that transcend the subject matter. Teaching strategies for problem readers should be specifically designed to reach the students via their existing communication skills and at their existing cognitive level. A curriculum designed to extend the student's cognitive structure should also create new needs for communications. As these needs are developed, new strategies should be implemented to alleviate the gap between existing communication skills and the new needs to express ideas.

Curricula designed to meet the specific needs of problem readers in science should be consistent with the philosophy engendered by three primary principles:

1. The processes of science, reading and thinking are essentially the same.
2. Information-processing models provide effective strategies for teaching these processes so that they become meaningful and stable additions to the student's cognitive structure.

3. Developmental interaction between thought-processing and communication skills serves as the basis for the simultaneous upgrading of these skills.

There are also several secondary factors that should contribute to the development and implementation of this type of curricula:

1. Science, reading, and thinking processes are dependent on science content which provides the medium for the application of the processes.

2. Appropriate intellectual, social and physical learning environments should be created in order for learning to occur.

3. The degree of structure in the learning environment can be adapted to individual needs via the implementation of thought-processing techniques.

4. The social environment is shaped by the personalities within the class, the personality of the class, and the role of the teacher in handling content, skills, and activities.

5. An appropriate physical environment is supportive of the
learning activities and serves as a resource for the student and the teacher.

These secondary factors are tangential to the primary principles and will not be dealt with directly or in depth. Nevertheless, the secondary factors require the teacher's consideration and cannot be completely ignored.

Relationship of Science, Reading, and Thinking

The strategies proposed by this paper stem first from the premise that the study of science is intricately linked and inseparable from the processes of reading and thinking. The simultaneous learning of these processes will lead to a complex pattern of interaction whereby one area strengthens each of the others and as a result further strengthens itself. It is impossible to separate the three types of activities (scientific investigation, reading and thinking) so they should be approached as a trilogy. All the members of this trilogy require the student to identify problems, propose hypotheses, devise methods to test hypotheses, distinguish between relevant and irrelevant data, utilize data to accept or reject hypotheses, reach generalizations, transfer generalizations to new situation, and communicate ideas effectively. As these processes are incorporated into the student's cognitive structure, he/she will acquire greater capacities for scientific investigation, reading, and thinking.

Information-Processing Models

The second contention of this writer is that the information-processing
models developed by Ausubel, Bruner, Suchman, and Taba possess orientations that are consistent with the goals of this curriculum and, therefore, provide strategies that are especially appropriate for the integration of reading and science. These models focus on processes by dealing specifically with "the ways in which people handle stimuli from the environment, organize data, sense problems, generate concepts and solutions to problems and employ verbal and nonverbal symbols." (Joyce and Weil, p. 105) Each model requires students to analyze their processing techniques so that these techniques can be assimilated into their cognitive structure in a meaningful and stable way. The information-processing system of the student is developed as processes are conceptualized and then used as a means for further learning. The interaction of the new cognitive system with the environment and the subsequent analysis of the processes used creates a cycle by which students acquire organized bodies of knowledge and increase their power to learn.

According to Taba (1966) "mental operations cannot be taught directly in the sense of being 'given by a teacher' or being acquired by absorbing someone else's thought products. The teacher can, however, assist the processes of internalization and conceptualization by stimulating the students to perform complex mental processes and offer progressively less and less direct support." (p. 34) Care must be taken to ensure that the invisible activity of thinking actually does occur and that the student does not passively receive information by memorizing procedures rather than developing an information-processing system that has been assimilated into his/her cognitive structure. Each of the information-processing
models is designed to elicit the learner's active participation in specific thinking processes so that those processes actually do become a part of his/her working cognitive structure.

The strategies of these models are especially suited to this curriculum because they focus on the processes required for concept development as well as the nature of concepts and the learning of specific concepts. Bruner recommends engaging the student in concept attainment games that require the identification of attributes and relationships of concepts which lead to the establishment of defined categories of concepts at various hierarchical levels. The underlying purpose of this approach is to "render discriminately different things equivalent...respond to them in terms of their class membership rather than their uniqueness" so that he/she can better cope with the overwhelming complexity of the environment. (Bruner, 1967, P.1) While Taba also focuses on categorizing information, she extends the degree of complexity of the thinking processes to include various forms of interpretation and application of the new concepts. Taba (1966) believed that there is a lawful sequence to the complexity of thought processes and that "in order to master certain thinking skills, you had to master certain other earlier ones and that this sequence could not be reversed. Therefore, this concept of lawful sequence requires teaching strategies that observe these sequences." (p. 35) Each stage of the model requires progressively greater complexities of thinking and is designed to expand the student's capacities for handling information.

Suchman had a similar purpose in designing his general inquiry model.
His goals were:

to develop the cognitive skills of searching and data-processing, and the concepts of logic and causality that would enable the individual child to inquire autonomously and productively; to give the children a new approach to learning by which they could build concepts through the analysis of concrete episodes and the discovery of relationships between variables; and to capitalize on two intrinsic sources of motivation, the rewarding experience of discovery and the excitement inherent in autonomous searching and data processing. [Suchman, 1962, p. 28]

Although Bruner, Taba, Suchman all employ inductive techniques that parallel scientific investigation, Suchman's strategies are designed to focus the student's attention on the inquiry processes which he views as natural or innate aspects of each individual: "left to his own devices, man feeds his expanding intellect through the process of inquiry. These processes are carried on through three interacting and complementary functions: (1) encountering the environment, (2) processing the data obtained, (3) reorganizing one's own knowledge." (Suchman, 1967, p. 1)

Thus, students who understand their own methods of inquiry can use this knowledge to increase the effectiveness with which they inquire and, as a result, increase their intellectual development. This can only be accomplished if the new knowledge is assimilated or accommodated by a rearrangement of the existing cognitive structure.

Ausubel's "advance organizer" model is based on many of the same underlying ideas as the other three models but the approach is considerably different. Ausubel emphasizes the goal of concept attainment via the development of hierarchically organized conceptual schemes and the assimilation of new knowledge within the existing cognitive structure. However, the teacher organizes the concepts and develops their attributes
and relationships by beginning with the very broad concepts and working towards more specific levels of concepts. The student is then lead through the thinking patterns of the teacher rather than discovering his own thinking patterns. Analysis of the thought-processes as the lesson evolves helps the student to conceptualize the processes being used. As new concepts are developed they are firmly anchored to the existing conceptual system via the use of the "advance organizer" and the ensuing processes of progressive differentiation and integrative reconciliation. The basis for this strategy is Ausubel's belief that "new ideas and information can be usefully learned and retained only to the extent that they are relatable to already available concepts or propositions which provide ideational anchors." (Ausubel, 1967, p. 10) Thus, the strategy of the "advance organizer" was conceived to provide these "ideational anchors" and to serve as the basis for a highly efficient learning model. Because the teacher's role is to lead the students along the correct thought paths to develop conceptual systems, the developmental process is not hampered by tedious wrong steps such as those involved in inductive strategies, such as the other models employ.

In order to integrate the information-processing models of Ausubel, Bruner, Suchman, and Taba, transition should be provided to guide students through the changes in environmental structure while clarifying the inter-relationships of the different approaches to thought processing. The integration of these four models is linked to the adaptability of the Ausubel model and the power of the organizer to enable students to visualize conceptual systems. The organizer can be
adapted for use with inductive models and is applicable not only as a means of presenting new ideas but also as a technique for closure and review. In addition, the organizer may be used as a transitional technique providing the means to aid students in moving from highly-structured environments to less-structured environments and back with a minimum of difficulty. Joyce and Weil (1972) support this view of the adaptive nature of Ausubel's original model and suggest the possibility of intermixing inductive and expository learning so that they may reinforce each other. In this way the teacher will be able to "provide the student with a structure of ideas representing the discipliness in such a way that these ideas and information are meaningfully related to the student's cognitive structure and implanted in the learner's information-processing system in a stable way. (p. 168)

Information-Processing and Communication

If the cognitive structure of the problem reader represents the cornerstone for building communication skills, the developmental interaction between thought-processing and communication skills can serve as the basis for the simultaneous upgrading of these skills. This involves the development of oral and written communication as the students are required to conceptualize experiences and knowledge of language and to process this information within their existing cognitive structures. Oral communication will enable the teacher to identify the ability of students to deal with varieties of words, word patterns, and sentence structures and to implement strategies to increase the ability of students to facilitate language. Written material based on the student's oral
language will encourage the identification of the similarities of these two forms of communication and thus facilitate the transfer of thought-processing skills to printed material. The teacher should strive to decrease the gap between the student's spoken language and his/her reading ability while upgrading the capacity of both by developing thought-processing skills and expanding the cognitive structure. The exploitation of newly acquired communication needs and skills can provide the teacher with the means to establish a developmental spiral of interacting processing skills. This can be affected by requiring students to tape accounts of experiments, demonstrations, field trips, and observations which can later be transcribed and used as a source of student reading material. These "science experience stories" should be used to promote the propagation of the spiral as the relationships of thought processing, oral communication, and written communication are clarified.

Secondary Factors: Content

Processing skills do not exist in a vacuum but derive their importance from their relationship to subject content. The content of science is generated by the application of these processes in an effort to investigate and understand the natural world. The complexity of the natural environment necessitates the processing of information to achieve meaning and to avoid inundating the learner with great quantities of isolated data. As the learner encounters the environment and processes the information obtained, he/she establishes categories of concepts and reorganizes his/her existing knowledge to assimilate the new material. The resulting cognitive structure developed by the student consists of concepts that are
hierarchically organized with the most abstract concepts at the top and the specific data at the bottom.

Joyce and Weil (1972) point out that "the structural concepts of each discipline can be identified and taught to the students and they then become an information-processing system for him: An intellectual map which can be used to analyze particular domains and to solve problems within those domains of activities." (p. 166) As processes interact to build a hierarchy of knowledge, that knowledge becomes the foundation for further building giving the student increased capacities to continue learning.

Learning Environment

The establishment of an appropriate learning environment (encompassing intellectual, social, and physical aspects) is a prerequisite for meaningful learning. Joyce and Weil (1972) uphold a view of learning that emphasizes the importance of the learning environment:

Teaching should be conceived as the creation of an environment composed of interdependent parts. Content, skills, instructional roles, social relationships, types of activities, physical facilities, and their use all add up to an environmental system whose parts interact with each other to constrain the behavior of all participants, teachers as well as students. Different combinations of these elements create different environments eliciting different educational outcomes. [p. 25]

Degree of Structure in the Learning Environment

The degree of structure in the learning environment can be adapted to individual needs via the implementation of thought-processing techniques.
Joyce and Weil (1972) describe a model for matching learning environments to people based on a correlation of the degree of structure required by the learning models with the complexity with which individuals are able to integrate new materials into their cognitive structure. Joyce and Weil maintain that some students learn best with techniques involving little structure (maximum student freedom) while other students do better with higher degrees of structure (greater teacher control). They also point out that this is an inverse relationship: students with low complexity levels require highly structured learning activities while students with high complexity levels require less structure. This writer believes that problem readers initially require more structured methods of learning such as those provided by information-processing models. These models are moderate to highly structured but they allow the teacher to practice a fairly wide range of structural flexibility so that the actual degree of structure may be adapted to individual differences within the same class and even within the same lesson.

Social Aspects of The Learning Environment

The social environment is shaped by the personalities within the class, the personality of the class, and the role of the teacher in handling content, skills, and activities. The personalities of individuals within the class constitute a controlling factor in determining how each individual assimilates or accommodates new information. Chess, Thomas, and Birch (1965) identify nine classifications of behavioral characteristics that they attribute to the personality of the child and which will influence the way a child learns. These include the child's
activity level, regularity, characteristic response to a new situation (approach or withdrawal), adaptability to change in routine, positive or negative mood, distractibility, persistence or attention span, and intensity of response. Awareness of how these traits manifest themselves within each student can ease the task of the teacher in handling specific problems. Teacher behavior consciously fashioned to contend with each child's personality can facilitate success in learning by removing superficial obstacles to learning. This is especially applicable to problem readers who might have experienced past failure as a result of the congruity between their personality traits and the methods used by their teachers.

It is not intended that teachers formally evaluate all the personality traits of each student but rather that teachers mentally consider these traits and develop a constant awareness of the role personality plays in the learning process. Perception and observation skills should be cultivated so that adequate data will be available to the teacher during problem-solving or decision-making related to individual learning. Thus, as difficulties with individuals arise, the teacher should be able to consider the relationship of teaching methods to the individual's personality as a possible contributing factor.

A class personality develops as a result of the interactions among personalities as students deal with the learning materials and the teacher. A teacher does not need to be an expert in group dynamics to identify positive and negative traits within the class personality.
Early recognition of the development of these traits can allow the teacher to encourage those traits that are conducive to learning while minimizing the effects of negative traits. The positive traits that should be cultivated include the group's acceptance of the value of learning, respect for the responses of others, encouragement of cooperative relationships, willingness to help each member develop to full potential, stimulation of members to achieve without creating anxieties or fear of failure, adjustments of expectations to the abilities of the members, support of creativity, pressure for "constructive" conformity to facilitate the group's activities, and willingness to be influenced by members while providing general stability and a sense of security for the members.

The negative traits that can be destructive to the learning process are primarily the antitheses of the positive traits but several warrant special consideration by teachers. Ego forces should be carefully guided into constructive channels and care should be taken not to allow these forces to disrupt class. Group values that promote blind conformity or destructive competition should also be curtailed early to prevent the undermining of the supportive and open atmosphere needed for information-processing. Finally, a group value that views the teacher as the enemy and the classroom as a battleground can present a barrier to learning. The teacher can effectively prevent the development of this type of value by projecting status and importance to the students and allowing students to assume leadership roles.

This reader believes that the teacher should consciously guide the development of the class personality so that students can be afforded
an atmosphere for learning that includes peer acceptance and encouragement. For problem readers this is of special importance due to low self-esteem and past experiences of failure which may have created barriers to learning. Some of these barriers can be eliminated by the early development of a class personality that promotes learning while alleviating personal anxieties arising from the types of peer-pressure that discourage learning.

The final aspect of the social environment is the integration of the teacher's role in handling content, skills, and activities. Teachers should understand and agree with the basic philosophy of each strategy to be used in the classroom so that their reactions to student responses are consistent with the intent of the teaching strategy. Generally, these responses should provide an atmosphere of acceptance and success. The information-processing models establish a framework that structures each lesson and guides the questioning techniques of the teacher. Incorrect, incomplete, or inappropriate responses should be guided to correctness by skillful questioning. Questions should be specific enough for the student to successfully respond but not so specific as to elicit a single desired response when a variety of responses should be considered correct. The teacher should ensure that his/her reactions facilitate thought-processing and that he/she does not provide pat answers by processing the information for the students. This can be done by organizing materials carefully, establishing a supportive atmosphere, and implementing procedures creatively within the dictates of the model but also in accordance to the needs of the individuals within the class.
Physical Aspects of the Learning Environment

An appropriate physical environment is supportive of the learning activities and serves as a resource for the student and the teacher. Although many aspects of the physical environment are beyond the control of the teacher, it is essential that a concerted effort be made to establish conditions that will contribute to learning. This writer believes that the students should play a major role in the creation and upkeep of the physical environment so that they will acquire a sense of pride in the room and a feeling that the room is in fact their room. The actual arrangement of the room should be contingent on the activities --changing as the activities direct. Arrangements appropriate for small groups may not be appropriate for lessons involving the entire class. Care should be taken to provide for intellectual stimulation in the form of bulletin boards, displays, plants, pictures, learning centers, reading nooks, etc. Basically, the teacher should ensure that the physical environment is not a deterrent to learning and endeavor to make it a resource that will enhance learning.

Summary

The theoretical dimensions outlined in this chapter form the basis for the development of a curriculum package designed to meet the needs of problem readers in science. The processes of science, reading, and thinking are viewed as inseparable and, therefore, should be taught simultaneously. The information-processing models proposed by Ausubel, Bruner, Suchman, and Taba provide the basic strategies for teaching
these processes so that the cognitive structure of the student may be developed in a stable and meaningful way. As the cognitive structure of the student is developed, oral communication skills should be developed to meet the greater demand for expression of ideas. These new oral skills should then be transferred to written form so that the student may learn to read ideas that have become part of his/her cognitive structure. The implementation of this type of curriculum in the classroom must also rely on consideration of the content of science and the establishment of appropriate intellectual, social, and physical learning environments.
CHAPTER II

REVIEW OF THE LITERATURE

Introduction

In order to understand the integration of reading into science curricula and its special application to problem readers, some background must be established regarding the processes of reading and the processes of science as viewed by educators in the respective fields. Analysis of the theory reveals several trends of thought: reading is similar to thinking and should be learned as a cognitive process; science students need to study the investigative processes used by scientists; and the role of the teacher is a major factor in establishing the learning processes that actually occur in the classroom. This reviewer will present the theory pertaining to these processes followed by a synopsis of three studies that evaluate the effects of the interaction of reading and science within selected science curriculum projects. These projects indicate that thought-processing skills learned in science can and often are transformed to other academic areas and that the reading of science poses special problems requiring special teaching strategies. The theory related to the teaching of reading within the science content area and to the teaching of the problem reader will be surveyed to provide a basis for a discussion of a curriculum which involves the integration of reading and science to aid the problem reader. The final consensus is that the unique needs of problem readers can be identified and coped with
in the science classroom by utilizing the interaction of thought-processing and communication skills to aid problem readers.

Reading Process: Theory

The process of reading has been described by many scholars through the years. As early as 1917, Thorndike described reading as reasoning: "understanding a paragraph is like solving a problem in mathematics. It consists in selecting the right elements of the situation and putting them together in the right relations, and also with the right amount of weight or influence or force for each." (p.135) Reading is not merely the ability to translate written words to thought or spoken words but also the ability to comprehend and assimilate the meaning of those words into the reader's cognitive thought patterns. [Kress, 1970] Stauffer (1970) surveyed the works of noted reading educators and found that they agreed that "reading is an intellectual process akin to thinking." (p.124) Among the scholars reviewed by Stauffer were Piaget, Sinclair-de-Zwart, Kress, Thorndike, Ennis, Russell, Taba, and Suchman. It would be repetitious and unnecessary for the purposes of this paper to discuss each of these works separately. The common threads running through these works include the notions that reading does not necessarily lead to thinking and that reading should be taught by first teaching thinking and then applying the thinking processes to reading. Piaget (1965) espouses this point of view in describing the relationship between intellectual processes and language: "thought precedes language and that language confines itself to profoundly transforming thought by helping it attain its forms of equilibrium by means of a more advanced schemati-
zation and a more mobile abstraction." (p. 18) Stauffer (1970) places strong emphasis on the relationships among reading, concept attainment and problem-solving pointing out that "all three are active cognitive processes of seeking relationships to, differentiating from, and reconciling with existing ideas and the processes therefore overlap in many ways. Some of the principal ways are hypothesis-generating and testing, abstracting and generalizing." (p. 134) Although the various scholars propose divergent approaches for the teaching of reading, they do agree on one aspect -- the need for thought-processing. Kress (1970) puts it aptly when he states that "the child's ability to deal cognitively with reading materials will be determined by the degree to which he has learned reading as a cognitive process." (p. 146)

Scientific Process: Theory

The advent of the "new" science in the late 1950s and early 1960s brought about the realization that the processes of science are as important as the content material to be learned. Many efforts were made to incorporate inquiry into science curricula and extensive curriculum projects were developed for this purpose. According to Joyce and Weil (1972), nearly all of these projects assumed that the disciplines in science were based on hierarchically organized levels of concepts that could be identified and used in sequencing inquiry activities. (p. 166) Hurd (1970) conducted a comprehensive analysis of the effectiveness of the curriculum projects that had been developed for national distribution. The ninth-grade projects included in this analysis were the Earth Science Curriculum Project (ESCP, Time, Matter, Space (TMS, also
known as the Princeton Project), and Introductory Physical Science (IPS).

Hurd discussed these projects at length evaluating each in light of content, processes, and actual application by teachers in the classroom. His conclusions resulted from extensive observations of the programs in action as well as interviews with teachers in the field. In these conclusions, he identified fourteen strengths and thirteen weaknesses or omissions in the new curricula. There is no need for exhaustive coverage of these findings but it would be pertinent to focus on a few aspects that are relevant to this paper.

Among the strengths, Hurd brought up the new emphasis on inquiry, discovery and the need for students to know and understand the thought processes used by scientists. He felt that a primary strength in the new curricula was the design of activities that called for students to develop and practice problem-solving skills which include hypothesis-generating, testing hypotheses, accepting or rejecting hypotheses, and generalizing. Hurd also felt that the agreement among scientific scholars and educators that the American citizen must be able to understand and use scientific thought processes to cope with the science-oriented society of the modern world was the most significant innovation of the new curricula. (p. 94-96)

The inability of the new curricula to deal effectively with the problem of skilled teachers was identified by Hurd to be the major source of weakness in the programs. Of the thirteen weaknesses discussed by Hurd, seven dealt with different aspects of the application of the program by teachers in the classroom. Hurd found that "a
large fraction of the teachers...are not certain as to what one does to effect an inquiry, discovery, inductive process, or investigative teaching style." (p. 117) As a result, "perhaps as many as two-thirds of the teachers using the new curricula are not teaching the course in mode envisaged by the authors." (p.117) Hurd blamed this condition on several elements: vagueness of the role of the teacher, the lack of teaching strategies within the Teacher's Guides and Handbooks, the inadequacies of in-service programs, the lack of incorporation of the new philosophies, goals, etc. into the educational programs of the universities, failure to include supervisors and administrators in the diffusion process, the lack of hard data in the evaluation of teacher effectiveness within the programs, and the general haphazard manner in which the curricula have been incorporated into the schools. Hurd basically found that the new curricula in themselves were not enough. Although some of the materials were designed to be "teacher-proof", Hurd felt that it was evident that the conceptual schemes, attitudes, and practices of the teacher determined the true learning environment in the classroom.

**Interaction of Reading and Science: Three Studies**

Three case studies involving the relation of science and reading skills within specific science curriculum projects indicate that students can and do transfer the thought-processing skills of science to reading. Kellogg (1971), working with first-graders in the Science Curriculum Improvement Study (SCIS), found that the SCIS program provided better reading readiness than the traditional reading readiness program. After
a teacher training program that involved forty-five teachers and was
designed to minimize teacher variability, the Materials Objects unit
was administered to selected first graders and the results compared with
those of first graders who did not receive the inquiry unit. The
experimental group scored 16.53 points in total reading readiness
while the control group averaged only 12.81 points per student. Further
analysis of the results showed that the experimental group outgained the
control group in word meaning, listening, matching, alphabet, and numbers
while the control group excelled only in copying. The testing was based
on the Metropolitan Reading Readiness Test.

Coffia (1970) corroborated Kellogg's findings in a separate study
in the same school district (Ada, Oklahoma) and dealing with fifth-graders
who had received four years of SCIS. Coffia set out to "determine if an
inquiry-oriented curriculum in science (SCIS) transfers to other academic
areas thereby resulting in more effective learning." (p. 2398 A) He used
an experimental group of forty-six students with four years of inquiry
experience and a control group of ninety-six students with no inquiry
experience. Using the raw scores from the Stanford Achievement Test, he
analyzed improvement in Math skills, concepts, and application, Social
Studies skills and concepts, and Reading paragraph meaning. He found
significant improvement for the experimental group in the areas of math
application, social studies skills and reading paragraph meaning while
there were no significant differences in the other areas. Based on these
findings, he concluded that "children who have had an inquiry experience
tend to utilize levels of thought that transcend mere recognition and
recall. They apparently are better able to use the higher powers of
thinking more effectively than those who have not experienced inquiry." (p. 2398 A)

Riley and Westmeyer (1972) studied the interaction of reading and science among seventh-graders in an Intermediate Science Curriculum Study (ISCS) program at Pennsville Junior High School and found that the students showed greater improvement in reading comprehension skills than seventh-graders who did not participate in the program. The study consisted of a fairly small sample (26 in each group) but the academic differences between the groups were minimal and the same texts were used by both groups with the exception of the science text. The Iowa Skills Test was used to compare the reading improvement of the two groups. The results of the study showed greater growth in reading comprehension in the group that used the ISCS program (.1.06 average growth as opposed to .80 for the control group. In their conclusions Riley and Westmeyer point out the dependence of the ISCS program on reading as a possible reason for the accelerated growth in comprehension. They emphasize that one of the basic assumptions of the course was that the students were able to read and comprehend the materials in order to obtain the desired results. Because the students in the school were homogeneously grouped and the students in both study groups were chosen from among the top levels in academic ability, no frustration problems arose as a result of the dependence of the curriculum on reading. Primarily due to the limited size of their sample, Riley and Westmeyer consider their finds to be merely an indication of a relationship that warrants further study.
Integration of Reading and Science: Theory

Reading experts have provided the content teacher with a variety of comprehensive works designed to aid in teaching reading in content areas. (Aukerman, 1972), (Burmeister, 1974), (Dechant, 1973), (Robinson, 1975), and (Shepherd, 1973). These authors provide information useful in evaluating reading materials and the ability of students to deal with those materials. They also discuss general strategies for use in all classes as well as specific subject areas. Each author includes a section on science which identifies the skills common to both reading and science, the problems unique to the reading of science and possible strategies for handling these problems. The skills commonly mentioned include word attack, concept attainment, the identification and support of main ideas, organization of ideas, following directions, making inferences and generalizations, fluctuating the speed of reading, dealing with charts and diagrams, and the reading of laboratory experiments. A summary of the problems would include the following:

1. The enormous number of new scientific terms that are difficult to pronounce and comprehend.

2. The need to shift the eyes back and forth from the text to diagrams and illustrations.

3. The orientation of science towards problem-solving tasks which tend to frustrate students who have not mastered the needed skills.

4. The broad scope of many scientific topics that students
fail to delimit to a workable scope when doing library work.

5. Directions in science usually have many steps that must be followed exactly and in sequence to avoid safety hazards or wasting of time and materials.

6. Reading laboratory procedures requires students to visualize themselves doing a procedure before actually doing it and then to go ahead and follow the steps exactly.

7. The science text contains mathematical problems that must be worked out with paper and pencil in order to follow the reasoning.

8. There are many symbols and formulas that must be translated and interpreted as the student reads.

The activities supplied by these authors are primarily short, success-oriented reading exercises utilizing science content. The teaching strategies recommended in these works obtain their validity from the experience and credentials of their authors. Very little quantitative work has been presented to verify the effectiveness of individual strategies. This is not to say that the strategies are ineffective but rather that there is little concrete data presented in any of the works to support the claims that the strategies the authors recommend are effective. Instead each author presents a wide variety of strategies and leaves the evaluation to the individual teacher.
The Georgia State Department of Education (1976) sponsored an analysis of the relationship of science and reading. The Georgia staff analyzed the role of science as an incentive for reading, identified teaching practices that interfere with student conceptual learning and then developed a teaching model to aid teachers in the analysis of the conceptual schemes necessary to integrate reading and science processes. They ascertained that "the goal of every good science teaching exercise is to be sufficiently open-ended as to cause the student to want to know more than the exercise alone provides." (p.3) The staff pointed out that the desire to read is stimulated by questions left unanswered during science experiments and that teachers tend to close these channels for inquiry by supplying answers when they should be posing more questions. They also identified the need for a wide range of books and materials to be available in the classroom maintaining that teachers should promote the use of these books to extend knowledge, answer questions, share knowledge, and substantiate information. According to this staff, when teachers jump too quickly to answer student's questions, quite often curiosity is stifled and the teacher's answers do not fit within the conceptual framework of the student. If the student is allowed to work out his/her explanations within his/her own conceptual background, the concept or generalization is more likely to become a part of his/her usable conceptual patterns. The staff cautioned that teachers should be careful not to allow hollow labels to get in the way of meaningful concept attainment.

The Georgia staff also identified four areas of intellectual content--
symbolic, figural, behavioral, and verbal -- which must be developed to maximize the student's ability to receive and assimilate all forms of stimuli. They felt that science "represents a common ground where all forms of intellectual stimuli may be utilized and become mutually reinforcing." (p. 8) They recommended the design of science activities that allow students to master skills in communication via symbols, figures, words and actions. The teaching model designed by the Georgia staff is based on the use of all four types of communication and includes three phases: identification of the science processes involved in the activities, identification of the reading skills involved; and the synthesis of the two lists -- reconciling and relating them. The model is intended to establish an awareness of the relationship of science and reading that will enable teachers to develop and use more appropriate strategies.

Thelen (1976) conducted a comprehensive analysis of the teaching of reading in science outlining what she felt to be the most effective strategies. She maintained that the normal approach of bringing reading instruction into the science class but maintaining a dichotomy between reading and science is a major detriment to improving reading in science. She proposed strategies "based on the idea that reading instruction in science means to teach simultaneously the science content and the reading and reasoning processes by which that content is learned." (p. 6)

Several of the strategies recommended by Thelen warrant further attention primarily because they reflect her view that thought processing
is the common ground for the simultaneous teaching of reading and science. First she pointed out the effectiveness of the advance organizer in preparing students for new material and then proceeded to explain the use of guided material in leading students through prescribed thought processes as they read. She recommended that teachers use the advance organizer not only for the introduction of new vocabulary or reading assignments but also as a prelude to films, demonstrations, experiments, and field trips. Guides are recommended to provide the student with "simulators of the process of thinking."

(p. 37) Thelen outlined the means for constructing guides pointing out that the first step is the identification of the purpose of reading and the thought processes needed to achieve that purpose. She then described the procedures to design a guide that would walk students through the desired thought processes as they read. The guides progress in difficulty from requiring students to read the lines (literal comprehension), to reading between the lines (interpretation), to reading beyond the lines (application).

Thelen included in her monologue the description of an informal study conducted with science students. Students in an experimental group were given a short course in thinking while students in the control group did not receive this added instruction. The course included a study of how people think, analytical thinking, intuitive, and the relationship between words and thinking. Students in the study group achieved higher levels of comprehension of science reading material than the students in the control group. These findings indicated that
the teaching of thought-processing does enhance learning in both science and reading. Thelen pointed out that the study was limited in scope and extremely informal so it merely indicated possible support of her theories.

Reading, Science, and the Problem Reader: Theory

The general difficulties with the reading of science are augmented when applied to the problem reader. Dechant (1973) emphasized that "as the student advances through the school grades, it becomes increasingly difficult for him to be weak in reading and strong in the content subjects." (p. 311) Moore (1962) identified three specific problems pertaining to the teaching of problem readers:

1. The textbooks in science, which often are too difficult even for the average or above-average reader, are especially handicapping to the slow-learner.

2. Textbooks written for the slow learner do not match the junior high-school reader's interest and maturity.

3. Since appropriate texts are not available, and since the extension of the reader's vocabulary is secondary to the acquisition of science concepts, the teacher may have to prepare materials. [p. 556]

Moore's suggestions for handling these problems involved traditional approaches such as the use of simple and familiar vocabulary, fewer different words, short sentences, repetition of ideas, cues to main ideas and details, and the use of readability formulas to evaluate reading materials. Warren (1975) suggested that the teacher merely prepare tapes of all of the reading material and place them in the
library so that students can read the text while listening to the tapes. The purpose of this strategy was to facilitate the translation of written words to oral words with little attention to the problem of comprehension.

Palmer (1975) presented a discussion of strategies for teaching reading in the content areas. He described the efforts of a reading teacher in a vocational-technical school by explaining the strategies and the rationale used by the unidentified teacher. The rationale for the activities stemmed from the desire to lessen "the gap between the student's spoken language, experiences, and the infinite variety of patterns within printed language." (p. 48) First, the teacher established oral communication that enabled students to conceptualize prior experiences and knowledge of language and to process this information within their existing cognitive structures. Second, instruction was built on this framework by identifying the degree of language facility of individual students and implementing strategies to increase the ability of students to facilitate language. According to Palmer, language facility involves the student's ability to deal with varieties of words, word patterns, and sentence structures. "As the student with limited language facility interacts with print, he is likely to experience difficulty in understanding concepts when they are expressed in unfamiliar or complicated grammatical forms, and the teacher needs to clarify these for him." (p. 48)

The final step was to use the student's spoken language ability to teach reading. Students were asked to complete oral tasks describing
activities and experiences within their vocational classes. Transcripts of their responses were then used to teach reading. "By combining their oral language with a written form of it, the teacher hoped to lead his students on to a greater understanding of concepts behind print and the complex patterns needed to express them." (p. 49)

Oral tasks varied so that students were required to define, list, classify or generalize. As a work was read aloud, students were encouraged to question each other until they understood what their classmates were trying to say. Thus, each student was required to clarify or elaborate orally. Written revisions were made during or after each session. At times group tasks were designed which required a small group of students to prepare a description of observations or sequence of events jointly. Again the oral tasks were transcribed, read and revised. The purpose of the activities was to enable the students to perceive reading as a form of communication. Although Palmer did not document the specific progress of the students, the examples of student work at various stages did support his claim that this approach was effective in teaching problem readers in content areas.

Reading, Science, and the Problem Reader: A Study

Zorn (1973) described a study that integrated reading and science for the purpose of aiding problem readers. He pointed out that traditional methods of instruction need to be modified for problem readers by lessening or eliminating the use of "notetaking, technical vocabulary, research reports; grade level science textbooks, free reading materials; commercially published science curricular programs requiring independent
The methods devised for this program involved the use of three teachers (science, English, and reading) teamed up to provide a block of instruction for eighth-grade students reading at the lowest levels at Cooke Junior High School. Identification of the thirty students in the study group was based on scores from the *Iowa Test of Basic Skills* and the recommendation of their teachers.

The unique organization of the program involved the use of a weekly block of twelve periods (six in science, four in English, and two in reading) with the additional advantage of having two teachers available in the classroom during at least three periods a week. This plan allowed for greater teacher flexibility so that they could maximize individualization within the program.

The rationale for the strategies used in the Zorn study is basically the same as that outlined by Palmer. The primary method of instruction was based on the development of an interaction between written and oral communication. Students taped their own accounts of experiments, demonstrations, and observations and these were transcribed to provide a collection of "student experience stories". "Being based on similar student experiences and written at the oral vocabulary level of students, the experience stories were suited for class reading and became a substitute for the textbook." (p. 410) Each student received copies of these stories along with comprehensive questions prepared by the teachers. The stories were read, questions discussed, and topics expanded using methods similar to those outlined by Palmer but with the science teacher playing a major
role in the development and expansion of the science material.

Sight vocabulary was developed via student-made flash cards that included 260 science terms as well as the 220 Dolch Basic Sight words. Student tests were designed with these terms in mind and students were required to read all test materials themselves. Science tests covered comprehension of science experience stories, comprehension of expanded science content provided by the science teacher, and science vocabulary recognition.

Overall assessment of the program was incomplete due to the limitations of the test design and the fact that only seventeen of the original students completed the program. Most of these students improved their reading level by at least one grade while five students improved two to three grade levels in reading skill. Additional assets of the program included the growth in self-image and improvement of attitudes toward both reading and science. Zorn considered the findings of this study to be significant in laying the groundwork for further development of methods designed to aid problem-readers via the integration of reading and science.

**Conclusions**

This writer concludes from the review of the literature that there is a need for further investigation and documentation of the relationships between reading and science. There is also a need for increased research of the effectiveness of strategies for teaching science and, especially, of strategies designed for teaching problem readers in science classes.
The following is a summary of the ideas of the authors reviewed in this paper:

1. Reading is similar to thinking and should be learned as a cognitive process.

2. Science students need to study the investigative processes used by scientists.

3. The role of the teacher is a major factor in establishing the learning processes that actually occur in the classroom.

4. Thought-processing skills learned in science can and often are transferred to other academic areas, ie. reading.

5. The reading of science poses special problems and, therefore, require special strategies.

6. The unique needs of problem readers can be identified and coped with in the science classroom.

7. Interaction of thought-processing and communication skills can aid the problem reader.
CHAPTER III

THE CURRICULUM PACKAGE

INTRODUCTION

The purpose of this chapter is to outline what is to be taught and explain how that can be accomplished. First, the behavioral objectives will be listed. These include both science and reading objectives derived from the following goals:

1. Science goals: For the student to understand and apply knowledge of the processes and products of scientific methods including experimentation, theorizing, technology, scientific law and cause and effect relationships.

2. Reading goals: For the student to understand and apply knowledge of word attack skills, main ideas, concept attainment, following directions, and organizing ideas.

The science goals center on the nature of science and the use of scientific methods. This content was chosen because it is pertinent to all science classes and, therefore, can be easily incorporated into existing curriculum programs. The reading goals were chosen for their pertinence to science and their usefulness with the proposed teaching strategies.

In the second section of this chapter, information will be provided concerning two categories of teaching strategies: information-processing models and communication development via science experience stories. The
models that will be outlined include:

1. the Ausubel Model, a deductive model developed by David Ausubel, educational psychologist, to teach concepts and generalizations;

2. the Concept Attainment Model, an inductive model created by Joyce and Weil based on psychologist Jerome Bruner's research on the learning of concepts.

3. the Taba Model, a series of inductive phases conceived by Hilda Taba, noted curriculum theorist, to teach concepts and generalizations;

4. the Suchman Inquiry Model, a combination of inductive and deductive processes designed by J. Richard Suchman to aid students in understanding explanations of problems.

The preparation, implementation, and evaluation techniques for each model will be outlined in the section on strategies and examples of the models will be included in the section on learning sequences later in this chapter.

The discussion of communication development strategies will focus on the use of science experience stories to increase oral communication and reading skills. Science experience stories are oral, tape-recorded accounts of science activities prepared by students and then transcribed to provide reading material for the science class. The preparation of the stories requires the students to use their oral skills to communicate their ideas. The written stories resulting from this activity will provide science reading material written with the oral vocabulary and sentence structure of the students. The science experience stories will be used to teach the student to read at the level of his/her oral language. The two categories
of teaching strategies (information-processing models and science experience stories) do not represent a dichotomy of isolated components but are more like strands of interwoven fibers: when properly interwined, they obtain greater strength to pull together toward common goals. The integration of the strategies may take many forms as the information-processing skills are applied to the science experience stories and the stories become integral components in the information-processing lessons.

In the third section, the learning sequences will be presented and serve as the basis for demonstrating the ways the two strategies interact with activities to achieve the desired objectives. The learning sequences provide a guideline for the teacher and are keyed to the behavioral objectives. Although the chronology for the sequences may be altered to adapt to the needs of individual classes, the chronology within each sequence should be maintained. Each sequence is designed to identify the relationship of the science experience stories to the information-processing lessons. The science experience stories may be prepared or used at the beginning, in the middle, or at the end of the information-processing lesson. The oral preparation of the story may be part of one lesson while the reading and analysis is incorporated into a different type of lesson. The following paragraphs provide illustration of some of the varieties of combinations that may be used.

Before a Suchman Inquiry lesson, the teacher might present the following demonstration: show the students two beakers containing clear liquid (one water and one alcohol); drop an ice cube in each beaker (one sinks while the other floats). The teacher would then ask the students to make a science
experience story describing all their observations and identifying the problem. The teacher should also ask them to pose several hypotheses. The stories could be read aloud in class to start the Suchman Inquiry lesson. The teacher could then continue the class with the inquiry in the manner outlined by the model.

To begin phase 1 of a Taba lesson, the teacher might give each group of students a picture showing various types of erosional landforms: the Colorado River running through the Grand Canyon, waves breaking on rocks, dust blowing across sand dunes, icebergs breaking off a glacier into the sea, or similar types of phenomena. The teacher would then ask the students to prepare science experience stories describing the pictures. The students would be instructed to include all observations as well as inferences of action. The resulting stories could serve as the basis to fill in a data retrieval chart on the agents of erosion:

<table>
<thead>
<tr>
<th>Agent of erosion</th>
<th>source of power</th>
<th>method of erosion</th>
<th>landforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Streams</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Wind</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Waves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Glaciers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The science experience story could be used in the middle of an Ausubel lesson based on the advance organizer: machines make work easier by changing the amount, direction, or speed of a force. After the organizer is presented, the
teacher should ask the students to analyze simple machines provided at various learning stations throughout the room. Each station should have a tape recorder with instructions for activities in working the machines. The teacher would then ask the students to prepare a science-experiment story that explains the generalization by describing the machines and how they work. The stories should include examples of machines that were not used in class as well as those that were used in class. The stories would then provide the information for dissecting the generalization and building a structural diagram of the relationships. After the stories are read aloud, the teacher continues the lesson according to the Ausubel Model, using the information in the stories to develop the specifics. These same stories could be used with the Concept Attainment Model to provide positive and negative exemplars of specific categories of machines, ie. pulleys.

An example of a science experience story being used at the end of a lesson would be a Concept Attainment lesson on work. After the students have attained the concept, work (the application of a force through distance), the teacher should ask them to prepare a science experience story defining work and providing examples of forces involving work and forces not involving work. The stories would then be read aloud in class to reinforce the concept or to evaluate concept attainment. These stories could also be used as the impetus for a new lesson on the concept of motion.

The fourth section, the management plan, has been provided to clarify the logistics of implementing the curriculum. This section will include a discussion of the handling of the preparation of the science experience stories, the transcribing of the stories, time schedules, and suggestions for transition from high-structured activities to low-structured activities. The primary
purpose is to eliminate potential hazards to the success of the program by providing the teacher with a variety of feasible suggestions.

The final section of this chapter will provide information for evaluating the success of the program in enabling the students to achieve the desired objectives. This section will include criteria for three components of the evaluation:

1. the science experience stories
2. quizzes
3. a unit test.

Because the quizzes and test are dependent on the content of the science experience stories, formats and examples will be presented with instructions to the teacher for their implementation.
Mrs. Minge gave us all some paper. It looked like rolling paper only it was too tiny. George got two. Then, we all tasted it but it didn't taste like anything. Then, we got some more paper only this one was red, no, pink. It tasted yukky, like hairspray, no, bitter, no, salty. Nobody can make up their mind but it was pretty yukky. Everybody yelled and wanted to get some water but Mrs. Minge said no. Then, she gave us some blue paper and it was yukky, too. Except for Tom, he couldn't taste anything and Linda because she was chicken. The yellow piece was the worse, ick, it tasted like a sewer. Mr. Owens has really weird, strange tastebuds. He only tasted the yellow one and that blew his mind. He said we were weird because we could all taste the paper, except Tom. This package says, hey let's read this. Only 50% of us are supposed to taste this junk. The bell is going to ring, quick what are some questions? How come it tastes so bad? and How come Tom didn't taste anything? oh, Yeah, and how come I had to taste it?

Figure 1. The above is a first try at a science experience story by three ninth-grade students at Orange Park IX.
BEHAVIORAL OBJECTIVES

1. The student will understand the following concepts so that he/she can correctly identify critical attributes, definitions, superordinate, coordinate, and subordinate concepts, examples and nonexamples, and/or relationships with the other concepts listed below:

a. science
b. product of science
c. process of science
d. problem solving
e. hypothesis
f. problem
g. experiment
h. observation
i. inference
j. experimental group
k. control group
l. theory
m. law
n. technology
o. scientist
p. cause
q. effect
r. superstition
2. The student will understand and apply the methods used to discover scientific knowledge (stating problems, collecting data, forming hypotheses, testing hypotheses, accepting or rejecting hypotheses, drawing conclusions, communicating results) so that he/she can correctly identify examples of each of these processes as well as use these processes in individual and group projects.

3. The student will gain knowledge of scientific discoveries and inventions so that he/she can correctly identify the sequence of events leading to the discovery or invention and state the impact on existing and future societies.

4. The student will understand and apply knowledge of main ideas so that he/she can correctly identify the main idea of a written passage and identify the statements that support the main idea.

5. The student will understand and apply knowledge of following directions so that he/she can correctly follow one-, two, or three-step directions accurately and in sequence as well as read and follow directions for laboratory experiments so that each step is done accurately and in sequence.

6. The student will understand and apply knowledge of how ideas can be organized so that he/she can correctly identify the sequence of events within a passage, prepare a diagram or chart showing relationships among concepts, and identify the relationships shown in a diagram or chart.
GENERAL EXPLANATION OF STRATEGIES

INTRODUCTION

The purpose of this section is to familiarize the teacher with the types of teaching strategies that must be applied during the implementation of this curriculum. Two major classifications of strategies are included: information-processing models and communication development. Four information-processing models will be used: the Ausubel Model, the Concept Attainment Model, the Taba Model, and the Suchman Inquiry Model. Communication development will be based on the use of science experience stories to provide a means of bridging the gap between the oral communication skills and the reading skills of the students. The components of each strategy will be analyzed so that the teacher will be able to use them effectively. However, the strategies will not be applied separately but will be intermixed so that each may aid and reinforce the success of the other. The intent is to foster the simultaneous development of information-processing and communication skills so that each may be applied to the learning of both reading and science.

INFORMATION-PROCESSING MODELS

Introduction:

The individual discussions of the information-processing models are intended to provide the teacher with a step-by-step summary of the three aspects of each model: preparation, implementation, and evaluation.
The use of examples is critical to the success of the lessons based on the models and the teacher is encouraged to include as many examples as possible whenever applicable. The teacher must also note that the models are interactive in nature. The students are required to participate in the lessons and to interact with the teacher by following the thinking formats structured by the teacher. The teacher must provide an atmosphere of acceptance for each student's ideas and ensure that as many students as possible participate in the activities.

No attempt has been made to provide an in-depth analysis of each model in this paper. The following references were used for the development of this section and will provide more detailed discussions of each model as well as dialogues illustrating the implementation of each model if the teacher requires further assistance:

1. Strategies for Teachers by Eggen, P.D., Kauchak, D.P., and Harder, R.J. (1979)


This section of the curriculum package should serve as a reference for the teacher whenever the models are recommended for use with activities.
The Ausubel Model:

The Ausubel "advance organizer" is a deductive model and, therefore, begins with the most general concepts and proceeds to the more specific. It is designed to assist students in relating new material to their existing knowledge and assimilating the new material into their cognitive structure in a manner that is usable. The model is designed to involve maximum interaction between the teacher and students while eliminating excessive false steps.

Preparation

1. Identify concepts and generalizations to be learned.

2. Arrange concepts and generalizations in a hierarchy that illustrates superordinate, coordinate, and subordinate relationships. This can easily be done in the form of a structural diagram.

3. Design an "advance organizer" that will link the new information with pre-existing information. The organizer should provide a general overview that includes the subconcepts to be learned and, therefore, is always more general than the material to be learned. The organizer may take several forms:
   a. diagram or chart showing relationships;
   b. analogy--comparison of new material with familiar material such as: the earth is like a spaceship;
c. expository—a statement or paragraph, film, demonstration, etc. that reveals the relationship of the new material to existing knowledge and provides a broad foundation for anchoring material that is completely new to the students.

Implementation

1. Present the advance organizer to the students by writing it on the board, showing it, reading it, etc. Be certain that the students understand the organizer before proceeding with the lesson. The organizer should remain in front of the student throughout the lesson and referred to frequently.

2. Methodically break down the broad idea encompassed in the organizer to reveal the narrower concepts (subordinate concepts). This can be done by a mixture of questioning the students and presenting material that is totally new. During this process the teacher should construct a diagram on the board to visually illustrate the hierarchical relationships of the concepts.

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**Figure 2:** Sample structural diagram.
3. Progressive differentiation: As the concepts are presented, they should be analyzed to identify their similarities and differences. Examples of each concept should be provided by both the teacher and the students. These examples should be analyzed for the attributes that qualify them to be placed in each category. Examples should also be compared and contrasted to emphasize their role in the hierarchy.

4. Integrative reconciliation: After the structural outline is completed, the concepts are analyzed to identify the relationships of the concepts to one another. Again the similarities and differences are exposed but this time to reveal the nature of each concept's position in the hierarchy: Superordinate, coordinate, and subordinate.

Evaluation:

The students should be asked to:

1. identify similarities between concepts;
2. identify differences between concepts;
3. identify superordinate, coordinate, or subordinate concepts;
4. apply knowledge of concept relationships to solve a problem;
5. arrange a list of concepts in a hierarchy by drawing a structural diagram.

[See: Eggen, Kauchak, and Harder, 1979, 260-309, or Joyce and Weil, 1972, 165-179]
The Concept Attainment Model (Bruner):

The Concept Attainment Model is an inductive model based on the work of Bruner but created by Joyce and Weil. It is designed to teach concepts. Students are asked to form categories based on the similarities of items and to transfer that information to new situations.

Preparation

1. Identify concepts to be learned.

2. Analyze concepts to determine the critical attributes, superordinate concepts, coordinate concepts, subordinate concepts and to write a concept definition. The concept definition should include the superordinate concept and the critical attributes. The critical attributes should indicate the similarities of all the subordinate concepts while excluding all coordinate concepts.

3. Identify positive exemplars that encompass all critical attributes and, therefore, illustrate the subordinate concepts.

4. Identify negative exemplars that reflect the distinction between the coordinate concepts.

5. Sequence the positive and negative exemplars to provide for maximum thought-processing. Use the broadest exemplars first and then narrow in on the concept.

6. Select an appropriate medium for presenting the exemplars. The most desirable medium is the actual item. If this is not feasible, pictures may be substituted. Use words or verbal descriptions only as a last resort.
<table>
<thead>
<tr>
<th>Positive Exemplars</th>
<th>Negative Exemplars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. apple</td>
<td>1. cigarette smoke</td>
</tr>
<tr>
<td>2. baby</td>
<td>2. coca cola</td>
</tr>
<tr>
<td>3. cloud</td>
<td>3. computer</td>
</tr>
<tr>
<td>4. creek</td>
<td>4. gasoline</td>
</tr>
<tr>
<td>5. egg</td>
<td>5. hamburger</td>
</tr>
<tr>
<td>6. gold nugget</td>
<td>6. ice cubes</td>
</tr>
<tr>
<td>7. tornado</td>
<td>7. lumber</td>
</tr>
<tr>
<td>8. water</td>
<td>8. bracelet</td>
</tr>
<tr>
<td>9. sunlight</td>
<td>9. paper clip</td>
</tr>
<tr>
<td>10. dog bark</td>
<td>10. rock music</td>
</tr>
</tbody>
</table>

Figure 3. Sample Exemplars for the Concept, Natural Phenomena
Implementation

1. Give instructions to the students. Be sure that they understand the task. The following dialogue compares the activity to the work of a detective and may be helpful:
   a. "I am thinking of a mystery category. You are the detectives who must figure out the mystery."
   b. "I will give you 'yes' clues (positive exemplars) that will be examples of items that are in the category. I will also give you 'no' clues that are examples of items that are not in the category."
   c. "Examine each clue carefully and tell me what categories you suspect. Be sure that each suspect category includes all the 'yes' clues but none of the 'no' clues.
   d. "When you think the clues show that a category is no longer a suspect, ask that it be erased and explain why."
   e. "If you think of new suspects, suggest that we add them to our list."
   f. "I will continue to give you clues until you have solved the mystery. When you think you know the mystery category, state your solution and check to see that all the 'yes' examples are in your category but none of the 'no' examples are in the category."
2. Prepare a column on the board for the "yes" clues and a column for the "no" clues. If actual items are being used, they should be displayed in an area for the "yes" clues and an area for the "no" clues. Each area should be properly labeled and the clues visible to the students at all times.

3. Present the first two clues to the students and ask the students to identify possible suspect categories. List each hypothesis on the board.

4. Ask the students to analyze each suspect category to be sure that each includes all the "yes" clues but none of the "no" clues. Be sure to accept all hypotheses that fit this criteria.

5. Continue to add clues to each column. You may add one clue at a time or several at a time.

6. Ask students to analyze the new information revealed by the clues and to cross off any suspect categories that no longer fit the criteria outlined in step 4. Students should explain why a category is no longer a suspect. If there is disagreement, a suspect may be held until more information has been gathered via new clues.

7. Ask students to add any new suspect categories that might have been uncovered by the additional clues.

8. Continue repeating steps four through seven until the students have attained the concept. They may not word the concept exactly the way you had anticipated but accept their ideas if they have arrived at the critical attributes of the concept.
You may supply the label later.

9. Ask the students to define the category by listing the characteristics necessary for an item to be included in the category (critical attributes). Write these on the board and supply the label if the students do not know it.

10. As the students to suggest more examples that are in the category and explain why each would be included.

**Variation**

Concept Attainment II involves the same basic steps as Concept Attainment I except that the examples are all presented at the same time. One positive and one negative exemplar are identified but then the students decide which exemplars they want to choose to test each hypothesis. The student suggests that a particular exemplar must be a "yes" or a "no" in order to test a particular hypothesis. The teacher then identifies the status of that exemplar and the list of hypotheses is revised accordingly. This continues until the students arrive at the solution and are able to properly classify each remaining exemplar as well as supply examples of their own.

**Evaluation**

Ask the students to:

1. identify new examples of the concept;
2. identify the critical attributes of the concept;
3. define the concept;
4. identify relationships of the concept to other concepts.

[For further information see: Eggen, Kauchak and Harder, 1979, pp. 142-189, or Joyce and Weil, 1972, 109-122]
The Taba Model:

The Taba Model utilizes inductive reasoning to teach concepts and generalizations. Teacher questioning guides the students through a sequence of thought processes (phases) which include generalizing, explaining and predicting. A data retrieval chart forms the basis for the questioning. The model emphasizes both content and process goals.

Preparation

1. Identify the generalizations to be learned.
2. Construct a data retrieval chart. This may be filled in by the teacher and/or the students. The information in the chart should be facts or data (not generalizations). The chart must have at least four cells but may have many more. The charts are intended to compare the various characteristics or two or more coordinate concepts. Maps, diagrams, graphs, etc., may be used in place of the traditional data retrieval chart.
3. Determine the beginning phase. The teacher may begin with phase 1, with the gathering of data by the students, or with phase 4 (using a chart already prepared by the teacher). The starting phase should be determined by the amount of time desired for the lesson and the nature (complexity) of the data to be gathered and analyzed.

Implementation

Phase 1. Listing: The teacher provides a stimulus (collage, film, trip, demonstration, etc.) and asks the students to list observations learned from the stimulus.
Phase 2. Grouping: Ask the students to group the items (listed in phase 1 into categories based on common properties. Students should identify the properties of each category.

Phase 3. Labeling: Ask the students to provide names for the groups developed in phase 2.

Data Retrieval Chart: At this point the data retrieval chart is introduced. The students may collect information to fill in the chart or the teacher may present the chart with the data already provided. The remaining phases consist of an analysis of the completed chart.

Phase 4. Generalizing: Ask the students to analyze each cell in the chart and create generalizations based on the data in the cell.

Phase 5. Comparing: Ask the students to compare information in two or more cells. Students should create generalizations that encompass information in more than one cell.

Phase 6. Explaining: Ask the students for explanations of the generalizations created in phases 4 and 5. Questions should begin with "why."

Phase 7. Predicting: Ask the students to make predictions based on the information gathered in the previous phases. Questions should begin with "what would happen if..."

Phase 8. Closure: Ask the students to summarized the information gathered throughout the lesson and to try to create broad generalizations that encompass the entire subject area of the lesson.
<table>
<thead>
<tr>
<th>Mineral</th>
<th>Color</th>
<th>Streak</th>
<th>Luster</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Calcite</td>
<td>white</td>
<td>white</td>
<td>nonmetallic</td>
</tr>
<tr>
<td>2. Fluorite</td>
<td>yellow</td>
<td>white</td>
<td>nonmetallic</td>
</tr>
<tr>
<td>3. Galena</td>
<td>silver</td>
<td>black</td>
<td>metallic</td>
</tr>
<tr>
<td>4. Hematite</td>
<td>black</td>
<td>red/brown</td>
<td>metallic</td>
</tr>
<tr>
<td>5. Hornblende</td>
<td>green/black</td>
<td>black</td>
<td>metallic</td>
</tr>
<tr>
<td>6. Pyrite</td>
<td>gold</td>
<td>black</td>
<td>metallic</td>
</tr>
<tr>
<td>7. Quartz</td>
<td>pink</td>
<td>white</td>
<td>nonmetallic</td>
</tr>
<tr>
<td>8. Talc</td>
<td>white</td>
<td>white</td>
<td>nonmetallic</td>
</tr>
</tbody>
</table>

Figure 4. Sample Data Retrieval Chart.
Evaluation

To test for content, ask the student to:

1. explain a generalization using examples;
2. identify examples that fit a generalization;
3. identify the reason an example fits a generalization.

To test for process, ask the student to:

1. apply a generalization to a problem;
2. analyze an unfamiliar data retrieval chart and make generalizations, explanations, and predictions.

[For further information see: Eggen, Kauchak, and Harder, 1979, 191-258, or Joyce and Weil, 1972, 123-136]
The Suchman Inquiry Model:

The Suchman Inquiry Model involves the use of both inductive and deductive reasoning in an effort to seek explanations to problems. The major emphasis is on process rather than content. The investigative processes used by the students reflect the relationships between data gathering and explanations of problems.

Preparation

1. Identify goals that involve developing explanations for problems.

2. Design the problem so that it presents a specific set of circumstances that illustrate a conflict to be explained. The specifics may be created by the teacher and may be in the form of a problem statement, a chart or diagram, demonstrations, experiments, etc. There should be broad possibilities for explanations although the problem is very specific.

3. Determine the explanation that will be deemed "correct" for this particular lesson. Since there are many possible explanations for an event, the teacher may focus on a single explanation or a combination of explanations. The choice of explanations should be based on the complexity of the problem and the sophistication of the processing skills of the students in the class.

4. Determine the medium for presenting the problem. The problem may be in the form of a statement, a film, a demonstration, experiments, graphs, pictures, case
studies, etc. The purpose should be to select a mode that will reflect the conflict and provide enough data to begin the inquiry.

Implementation

1. Present the problem to the students. Write the problem to be solved on the board and be sure that the students clearly understand the problem.

2. Ask the students to list all the possible hypotheses (solutions) for the problem. Write all of these on the board. Accept any feasible hypotheses.

3. Ask the students to collect data to test their hypotheses by asking questions that meet the following criteria:
   a. all questions must be answerable with "yes" or "no".
   b. all data must be observable (not calling for an inference or conclusion by the teacher). Note: to emphasize this point, ask the students how the data might be observed.

4. As data is collected the information should be written on the board. Answers to questions are made-up by the teacher to conform with the solution to the problem. Students may work together and a single student or group may continue a line of questioning until it is exhausted.

5. The hypothesizing and data gathering form a cycle with each step providing stimuli for the other. During this cycle, students should eliminate hypotheses when the data indicates the explanation no longer applies. Any student may propose
that a hypothesis be crossed off the list by stating the data that supports this conclusion. Hypotheses may also be added to the list, revised, or combined at any time. The cycle of gathering data, hypothesizing and evaluating the results should continue until the students have determined the correct explanation.

6. Closure: When the cycle has been completed, the students are asked to accurately state the explanation and analyze the data to be certain that it is consistent with the explanation. All remaining hypotheses must be resolved based on the data. The students may need to gather more data to reject the remaining hypotheses and resolve all the details of the problem.

Evaluation

Ask the students to:

1. identify possible hypotheses, data-gathering questions, and observations that could be used for a specific case study (not formerly used in class);

2. identify data that supports a given explanation and data that does not support the explanation.

[For further information see: Eggen, Kauchak and Harder, 1979, 311-346, or Joyce and Weil, 1972, 137-151]
Problem: Mr. Smith and Mr. Brown are weathermen. They both launched weather balloons to take readings in the upper atmosphere. Mr. Smith's balloon soon fell to the ground while Mr. Brown's went on to carry out its task. What was the difference?

Explanation: Mr. Smith filled his balloon too full. As the balloon rose, the air inside expanded and popped the balloon.

Figure 5. A Sample Suchman Inquiry Problem.
COMMUNICATION DEVELOPMENT

Introduction:

Communication development is based on the student's increased needs to communicate ideas as his/her cognitive structure is expanded via the information-processing models. The strategy to be used involves the interaction of two components:

1. the development of oral communication skills to increase the ability of the student to facilitate language; and

2. the development of reading skills based on the reading and analysis of transcriptions of student oral exercises (science experience stories).

The interaction of these components during information-processing lessons serves to narrow the gap between oral and written communication while increasing the student's abilities in both areas.

Oral Communication Development:

The development of oral communication is fostered by the oral activities required in the implementation of information-processing lessons and enhanced by the application of oral skills in preparing tape-recorded science experience stories. Because the stories are prepared in conjunction with information-processing lessons, many of the goals are the same. However, the production of the science experience stories also includes additional oral communication goals:

1. ability to pronounce and apply new science words correctly;
2. ability to follow directions accurately to create the proper type of story;
3. ability to organize ideas to form a story that is clear and has a logical sequence.

Science experience stories may be prepared before, during, or after the lesson involving the model. A story might be used as the basis for identifying the problem for a Suchman Inquiry lesson or as an advance organizer for an Ausubel lesson. For a Taba lesson, the stories may be used in the beginning of the lesson to provide stimuli for phase 1, during the lesson to construct the data retrieval chart, or at the end of the lesson to reinforce the processing skills learned. The stories may be used at the end of any of the lessons to evaluate attainment of the goals or to reinforce these goals.

The types of science experience stories that may be associated with lessons utilizing each model include:

1. the Ausubel Model
   a. explain a concept or generalization using examples and providing the reasoning for the inclusion of each example;
   b. describe the solution to a problem by applying knowledge of concept relationships or generalizations;
   c. compare and contrast concepts;

2. the Concept Attainment Model
   a. explain a concept using examples and providing the
reasoning for the inclusion of each example;

3. the Taba Model
   a. describe observations from stimuli such as picture, experiments, demonstrations, field trips, films, etc.;
   b. describe data about a concept including each characteristic requested by the teacher (this may later be used as the basis for constructing a data retrieval chart);
   c. explain a generalization using examples and providing the reasoning for the inclusion of each example;
   d. describe the solution to a problem by applying knowledge of generalizations;
   e. compare and contrast information related to concepts to form generalizations;
   f. analyze information and make predictions (support the predictions with the data);
   g. summarize information and list broad generalizations;

4. the Suchman Inquiry Model
   a. describe observations from stimuli such as pictures, experiments, demonstrations, field trips, films, etc. (these stories could serve to identify the problem for an inquiry lesson);
   b. identify data that supports, does not support, or refutes an explanation.

The preparation, implementation, and evaluation of oral communication
development activities are inseparably lined to the same aspects of the information-processing models. The following summary of each of these aspects refers only to the oral preparations of the science experience stories. The aspects that are directly correlated with the models have been discussed earlier and will not be repeated.

**Preparation**

1. Correlate oral communication goals with these for the information-processing lessons.

2. Identify the activities to be used for science experience stories.

3. Determine at what point in the activity the tape-recording should be made. This will depend on the nature of the activity and the goals for the science experience story.

**Implementation**

1. Instruct students on the use of the tape recorders. Check to see that each student can work the recorder properly. The students should work in groups of three or four depending on the size of the class and the availability of tape recorders. It is not necessary that each group use the tape recorder at the same time.

2. Ask students to prepare a tape recording of a specific assignment. Be sure to give careful directions. Directions should be oral, pictoral, or tape recorded so that the students can understand them. Be sure the students have a clear understanding of the assignment.
3. As the students to listen to their story and to revise it if necessary.

Evaluation

Listen to the tapes to be certain that the students have accomplished the following:

1. voices are clear and words are pronounced correctly;
2. directions were followed correctly;
3. ideas are well-organized;
4. the goals related to the information-processing model were met.

Reading Skills Development

The development of reading skills is linked to activities that require students to read and analyze the science experience stories. Because they are written in the student's oral language, these science experience stories provide the foundation for linking oral communication skills with reading skills. Each student should receive a copy of each story which should be placed in a notebook and used as the primary reading material for the science class. (Supplementary material--textbooks, library books, pamphlets, etc.--may be used as long as they are not overly frustrating to the student.)

Many of the reading goals associated with the reading and analysis of the written science experience stories are the same as goals for information-processing lessons. The specific reading goals emphasized in reading the science experience stories include:

1. sight-recognition of new science vocabulary words;
2. identification of the main idea and supporting data in
3. identification of a sequence of events so that the events may be listed in order of occurrence.

The relationship of reading skills goals to each model is reflected in the application of the information-processing skills to the reading material as well as the use of the reading material as an integral element in the implementation of the model. The science experience stories provide the foundation for the following reading activities for each model:

1. the Ausubel Model
   a. identify the relationships of the concepts and/or generalizations included in the story;
   b. construct a structural diagram showing the relationships of concepts presented in the story;

2. the Concept Attainment Model
   a. identify the critical attributes of a concept;
   b. identify examples of a concept;
   c. identify the relationships of concepts;
   d. define a concept;

3. the Taba Model
   a. prepare a data retrieval chart based on the data in the story;
   b. follow phases 4 through 8 based on information obtained by reading the chart;

4. the Suchman Inquiry Model
   a. analyze the story and identify a problem, possible
hypotheses, data-gathering questions, and observations;

b. identify data that supports an explanation and data that
does not support the explanation.

The preparation, implementation, and evaluation of reading skills
development activities using science experience stories are summarized
below. The aspects that have already been discussed in the section on
information-processing models have not been repeated.

Preparation

1. Have the tape recordings of the science experience stories
   transcribed and reproduced. Proof-read each story to be
   sure there are no typographic errors.

2. Determine the reading goals for each story and correlate
   the goals with the information-processing lessons.

Implementation

1. Provide the students with copies of each story.

2. Ask the students to read the story aloud in class.

3. Identify new words in science and prepare flash cards. Ask
   the students to drill with the flash cards to practice sight-
   recognition of the words. Discuss word attack skills that
   will help them in this task: prefixes, suffixes, roots, etc.

4. Ask the students to identify the main idea and the supporting
   data for the story. At first, you may provide them with a
   choice and have them choose the main idea. Later, they should
   identify the main idea without this help.
5. Ask the students to list the sequence of events in the story.

6. If the information in parts 4 and 5 are not clear in the story, the students should ask the authors questions about their task until the ideas are clarified. The authors should then revise the story to make it clear and organized.

7. Apply the information-processing skills to the story or use the story within an information-processing lesson.

**Evaluation**

Ask the student to:

1. read aloud science vocabulary words or identify the written word when it is pronounced by the teacher;

2. identify the main idea and the supporting data in a story they have never before seen;

3. identify the sequence of events in a reading passage they have never before seen;

4. respond to appropriate evaluation items related to the information-processing lesson.
LEARNING SEQUENCES

The learning sequences outlined below serve to illustrate the application of the strategies to the behavioral objectives. These sequences involve both teaching strategies and student activities. They are designed to clarify the method of blending the strategies. The management of the implementation of the learning sequences will be covered in the next section.

SEQUENCE I. (objectives: la,b,c; 4,5)

A. Story 1: Make up a story describing what you see in the college.
   (College shows pictures, words, cartoon, articles, etc. related to science.)

B. Teacher-directed lesson: Concept Attainment I, processes of science positive exemplars: ask students to:
   - look through microscope
   - describe a crystal
   - listen to a tone
   - measure the height of a desk
   - taste a piece of halite

   negative exemplars: show students:
   - a triple beam balance
   - a science textbook
   - a card with H₂O on it
   - a fact in the book (write on board)

C. Teacher-directed lesson: Concept Attainment II, products of science
positive exemplars: write on board: Newton's Law of Gravity
(others similar to the negative shown in B above)
negative exemplars: ask student to measure the temperature of water
(others similar to positive exemplars in B above)

D. **Teacher-directed lesson**: Ausubel; advance organizer: science is the
study of natural occurrences. Read Story I aloud in class.

```
SCIENCE

PRODUCTS        PROCESSING

laws            experimenting
theories        observing
inventions      measuring
```

Develop the hierarchy shown above by using information in the
science experience stories. Be sure to add examples of each
subconcept.

E. **Student Activity**: prepare flashcards for the science words listed
in the diagram; drill with the words so you can recognize them by
sight.

**SEQUENCE II** (objectives 1h,i; 4, 5)

A. **Story 2**: Make up a story describing what you see in the picture.
   (Each group receives a picture showing activity in nature.)

B. **Student Activity**: read stories aloud in class; identify the main
   ideas and the supporting data.

C. **Teacher-directed lesson**: Concept Attainment I, observations
   Choose exemplars from stories, i.e. positive: there is snow on
   the ground; negative: a car drove through the mud.
D. Teacher-directed lesson: Concept Attainment I, inferences
Choose exemplars from stories, ie. positive: there was a landslide; negative: the cliff has layers of red rock.

E. Student Activity: classify the rest of the items in your story as observations or inferences and explain your reasoning.

F. Story 3: (outside in the schoolyard) Make up a story describing the surroundings at your school. Group your items as observations or inferences and explain the reasoning for your grouping.

G. Student Activity: read the stories aloud in class; discuss your groupings.

SEQUENCE III (objectives: ld,e,f; 2,4,5,6)

A. Teacher-directed lesson: Suchman Inquiry: Demonstration: Show the students two beakers of clear liquid (one water and one alcohol); place an ice cube in each beaker (one floats and the other sinks). Ask the students to identify the problem and write it on the board. Proceed according to the Suchman Model. Explanation: the ice cube is lighter than water but heavier than alcohol.

B. Story 4: Make up a story describing the inquiry activity. Include the problem and each method used to solve it. Provide examples of each method.

C. Student Activity: Read stories aloud in class. List the sequence of events used to solve the problem.

D. Teacher-directed lesson: Concept Attainment I, hypothesis
(positive exemplar: the car crashed because the tire blew out; negative exemplar: what causes waves?)
E. **Teacher-directed lesson:** Concept Attainment I, problem
   (positive exemplar: do female mice learn faster than male mice?
   negative exemplar: glaciers carve U-shaped valleys.)

F. **Teacher-directed activity:** Give each student taste paper. Instruct
   them to taste the paper and communicate the results to each other.
   Write the results on the board showing the numbers in the class who
   could or could not taste the paper.

G. **Story 5:** Make up a story describing the demonstration with the
   taste paper, indentifying the problem and listing possible hypo-
   theses and data-gathering questions.

H. **Teacher-directed lesson:** Suchman Inquiry using Story 5 as the
   problem statement (these should be read aloud in class). The
   explanation is that some people have inherited genes that prevent
   them from tasting the paper.

SEQUENCE IV (objectives: ld,e,f,g; 2,4,5,6)

A. **Teacher-directed lesson:** Ausubel: advance organizer: "the methods
   of a scientist are like those of a detective."
   concepts to be included:
   1. identify the problem (crime)
   2. gather data (clues)
   3. state hypotheses (identify suspects)
   4. test hypotheses (check out suspects)
   5. accept or reject hypotheses (decide who did it)
   6. communicate results (book him)
   (Compare the steps with those used in the Concept Attainment and
   Suchman Inquiry lessons.)
B. **Student Activity:** each group will conduct their own experiment.
   1. Does air expand when it is heated?
   2. Do sand and water heat up at the same rate?
   3. Do light and dark objects heat up at the same rate?
   4. Does evaporation cause cooling?

C. **Story 6:** Make up a story describing each part of your experiment; include all your procedures and all your observations.

D. **Student Activity:** Read stories aloud in class. Identify the parts of the experiment. List in sequence.

E. **Student Activity:** Make flashcards for new vocabulary words and use them to drill so that you can recognize the word by sight.

SEQUENCE V (objectives: le, 2,3,4,5,6)

A. **Teacher-directed lesson:** Taba, using prepared data retrieval chart listing scientists down the side and the following characteristics across the top: contributions to science, when and where they worked, methods of discovery, impact of their contributions.

B. **Story 7:** Make up a story describing the methods used by the famous scientists and compare them with the methods described earlier in class. Make up a broad generalization about how society reacts to new ideas and support your statement with examples.

C. **Student Activity:** read stories aloud in class; identify the main ideas and the supporting data.

SEQUENCE VI (objectives: la,n; 4,5,6)

A. **Teacher-directed lesson:** Ausubel: advance organizer: "technology is the application of science to solve practical problems."
B. **Story 8**: Make up a story describing how technology affects you in every aspect of your everyday life from the time you get up until you go to bed.

C. **Student Activity**: Read the stories aloud in class; identify the main ideas and list the supporting data. Explain why each example is technology.

**SEQUENCE VII** (objectives 1p,q,r; 2,4,5,6)

A. **Teacher-directed lesson**: Concept Attainment II, cause and effect
   positive exemplar: the book fell because I pushed it (demonstrate)
   negative exemplar: toads cause warts or long hair causes bad grades
   (List true cause and effect relationships, faulty cause and effect relationships, and superstitions.)

B. **Story 9**: Design and describe the steps for two different types of experiments:
   1. test a true cause and effect relationship;
   2. test a superstition.

C. **Student Activity**: Read the stories aloud in class; identify the proper sequence of events; revise the experiments if necessary.

D. **Student Activity**: Carry out your experiment. Report your results to the class.

E. **Student Activity**: Complete the review sheet to help you study for the test.
The learning sequences have been designed to be fairly self-contained but there are several aspects of the management of the program that require clarification. This section will provide information concerning procedures and suggest solutions to problems that seem inherent in the proposed approach. The following areas will be discussed:

1. preparation of the science experience stories;
2. transcriptions of the science experience stories;
3. time schedules;
4. transition from high-structured activities to low structured activities.

Preparation of the Science Experience Stories:

The preparation of the science experience stories requires the availability of tape recorders, tapes, and space for students to work. The number of recorders and tapes needed can be adapted by grouping students and requiring a different member of the group to do the talking each time. The members may want to make up a name to identify their group (such as the names of rock groups). The names of all the members of the group and the name of the speaker should be provided at the beginning of each story. If several students do the speaking for a story, each student should be identified before he/she begins.

The grouping doesn't completely solve the problem of equipment. The teacher can arrange the daily schedule so that the groups do not have to use the tape recorders at the same time. In this way, it is feasible that three or four recorders will be necessary at a given time. Cassette tapes may be used and labeled with the group name. Since the
groups will be sharing tape recorders they can also share tapes. A group may be assigned to use one side of a tape and another group the other side as long as they are using the tapes at different times. It is recommended that the same group use the same side of the same tape each time. This will avoid problems of one group erasing or interfering with the work of another group.

Special areas of the room should be set aside for use during recording. If the situation is crowded, the rearrangement of the desks might provide enough isolation for the students to work uninterrupted. It is also possible that the library can provide areas for the students to work. Effort should be made to see that groups using tape recorders have as much privacy as possible.

Transcription of the Science Experience Stories:

The transcriptions of the tapes provides the most obvious obstacle to the program. Teacher-time is too limited for it to be feasible for the teacher to transcribe all the tapes. Several possibilities are available. First, if the school is part of a high school, juniors and seniors who can type well might be used as aides. A recommendation from the typing teacher might insure success with this approach. It is also possible that the typing teacher might be willing to allow the advanced classes to type the stories from their dictaphones once a week. Local colleges or business schools might also be willing to provide this type of help. If these options are not open to you, it is possible to obtain federally-paid typists via the Senior Citizen Employment Program or the Handicapped Worker Employment Program. These federal programs are designed to pay the salaries for workers employed with non-profit organi-
zations. These suggestions provide a variety of possibilities for aid in transcribing the tapes. Be certain that you have listened to each tape before it is transcribed. This will eliminate any embarrassment regarding foul language.

The stories may be typed on regular typing paper and then thermofaxed to make a ditto for duplication. If your school does not have this process, the stories should be typed on a ditto master. It is desirable that all students get copies of each story but, if this poses a problem, you might choose the best story from each assignment and have that one reproduced. Be sure you do not choose the story from the same groups repeatedly. Competition can be healthy as long as each student has positive experiences from the procedures.

Time Schedules:

The learning sequences do not provide time limits for either the activities and lessons within them or for the sequence itself. The teacher should adapt the time to the needs of the class. More time will be required in the beginning in order for the students to become accustomed to these types of activities. Students should be allowed enough time to complete the tasks. The teacher should be careful in the beginning to supervise each group to keep them on task and avoid wasting time. As the sequences proceed, less time will be needed and the use of the tape recorders will become routine.

Transition from High-Structure to Low-Structure Activities:

The information-processing lessons involve a high degree of structure (teacher control) while the preparation of science experience stories
involves a low degree of structure (maximum student freedom). Some students may need help in moving from one type of situation to another. The teacher can minimize these difficulties by providing structure for those who need it while allowing others more freedom. The teacher can facilitate this transition by using mini-Ausubel lessons to teach the students to handle the changes in situations. These may be directed to the entire class or simply to the individual students requiring help. In the beginning it might be wise to involve the entire class then encompassing smaller groups as the students learn to adapt. Some students may never adapt.

When moving from high-structure to low-structure situations, some students become frustrated and either become disruptive or simply do nothing. This is especially true of problem readers who are not task-oriented or self-motivated. The directions for the story can be considered the advance organizer. The teacher may then discuss specific procedures by asking the students to help develop a structural diagram showing the group task. An example of such a diagram might be:

```
MAKE UP A STORY

List Items  Decide which to include  Sequence Make items  Make tape
```

When bringing students back from low-structure to high-structure some students might be reluctant to relinquish their freedom. As a result, those students may waste much of the class time with disruptive behavior in an attempt to retain more freedom. First, the teacher should be careful not to allow the students to get so far away that they cannot be brought back. Secondly, the teacher should bring them back gradually by allowing them to discuss what they
had been doing but in an orderly way. Finally, the teacher can use a mini-Ausubel lesson to introduce the procedures of the next lesson. For instance, before a Concept Attainment lesson the teacher might say: "Now, we're going to play a game." This provides an implied analogy and the following structural diagram can be made:

```
GAME

How you win  Rules  How you play
```
EVALUATION PROCEDURES

Evaluation of the objectives should include three components:

1. the Science Experience Stories;
2. quizzes at the end of each sequence, and
3. a final test at the end of the unit.

The evaluation of the science experience stories should comprise 20% of the total grade. Each story should be critiqued based on the following criteria:

1. following directions
2. organization of ideas
3. content
4. accomplishment of the task
5. improvement

Students should be allowed to make two revisions of their stories: first, they may revise the tape-recording based on teacher feedback and then the written copy after it has been read in class.

A quiz should be given at the end of each sequence and should be written in the language used by the students during that sequence. The exact content of the quizzes will depend on the science experience stories and depend on the science experience stories and the exact examples used in the class. The quizzes should contain examples not already used in class. These examples should reflect the characteristics of the concept and, therefore, the actual object or a demonstration provide the best medium. If necessary, pictures may be used but word examples should be used only as a last resort and in a descriptive manner that reflects the critical attributes of the concept. The quizzes will represent 30% of the grade.
The following is a sample quiz for Learning Sequence I:

Part I: For each examples, write process or product to identify the category of the concept:

1. (Measure some liquid in a graduated cylinder.)
2. (Show students sulfur: the example is the sulfur is yellow.)
3. (Taste a sugar cube.)
4. (A man named Einstein developed the theory of relativity. This is what his formula looks like: $E=MC^2$ (Write the formula on the board.)
5. (Say: "I wonder what would happen if I mix these?" Then, pour some vinegar into a beaker containing baking soda.)

Part II: "Identify the word I say by placing the number next to the letter:"

___A. experimenting
___B. invention
___C. law
___D. measuring
___E. observing
___F. process
___G. product
___H. theory
This unit test comprises 50% of the grade. The test may be given over a period of several days at the end of the unit. It should be constructed similar to the quizzes and should contain the following sections:

I. Identify the word said by placing the number next to each word. (List words in random order)

II. For each category, identify the example that fits the concept. (Show three examples for each concept and label them A, B, C.)

III. Fill in the diagram to show the relationships of the following words:

   a. law
   b. observing
   c. processes of science
   d. products of science
   e. science
   f. stating hypotheses
   g. theory
   h. provide your own examples for each of the words at the bottom of the diagram.

```
  1.  
  |   |
  2.  3.  
  |   |
  4.  5.  6.  7.  
  |   |   |
  8.  9.  10.  11.  
```
IV. Observe the experiment demonstrated by the teacher. For each step, list the process being used. 

Note: As the experiment is demonstrated the teacher should say step 1, step 2, etc. to illustrate the following:

1. identifying a problem
2. gathering data
3. forming hypotheses
4. testing hypotheses
5. accepting or rejecting hypotheses
6. communicating results

V. List five examples of technology found in this classroom. Explain why each is included.

VI. Match the scientist with the invention or discovery. (List those that were used in class)

VII. Choose one of the scientists, listed in Part VI. Write a story explaining how they made their discovery.

VIII. Provide a reading passage based on the science experience stories. A story about a scientific discovery not used in class would be a good example.
BIBLIOGRAPHY


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