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AUTHOR	Balajthy, Ernest
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ABSTRACT

This paper considers the integration of reading and writing into elementary science teaching by way of the implications of two leading theories pertaining to literacy: metacognitive theory and whole language theory. Discussion of the implications of metacognition includes attention to the issue of helping to overcome readers' nonscientific preconceptions by teacher modeling of text reading, use of graphic organizers for teaching text structure, and the use of semantic feature analysis for teaching science vocabulary concepts. Discussion of whole language centers on a suggestion to redesign research report units to capitalize on student interest and to develop expertise on focused topics, and on a suggestion to use problem-solving journals in the elementary science classroom. Attached to the paper are nine figures detailing particular learning activities, a competency assessment worksheet, and a 4-item annotated bibliography of literacy in the sciences. (Author/RS)

FROM METACOGNITION TO WHOLE LANGUAGE:

THE SPECTRUM OF LITERACY IN ELEMENTARY SCHOOL SCIENCE

Ernest Balajthy, Ed.D.
Department of Elementary & Secondary
Education & Reading
State University of New York at Geneseo
Geneseo, New York 14454

Abstract

The purpose of this booklet is to consider integration of reading and writing into elementary science teaching by way of the implications of two leading theories pertaining to literacy: Metacognitive theory and whole language theory. The discussion of the implications of metacognition includes attention to the issue of helping overcome readers' nonscientific preconceptions by teacher modeling of text reading, use of graphic organizers for teaching text structure, and use of semantic feature analysis for teaching science vocabulary concepts. The discussion of whole language centers on a suggestion to redesign research report units to capitalize on student interest and to develop expertise on focused topics, and on a suggestion to use problem-solving journals in the elementary science classroom.

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Introduction

The purpose of this booklet is to consider integration of reading and writing into elementary science teaching by way of the implications of two leading theories pertaining to literacy: Metacognitive theory and whole language theory. The bulk of this booklet explains how both theories offer important rationale for specific strategies to use in teaching science. Additional parts of this booklet provide materials for use in training elementary science teachers to integrate these reading and writing activities into their instruction.

Metacognitive Approaches

One of the major concerns arising out of the field of cognitive psychology (usually called "schema theory" in the field of reading education) has been the issue of metacognition. Metacognition refers to executive control over cognition. Components of metacognition are often referred to as "knowing that you know," or "learning to learn."

If schema theory were to be summed up--and an understanding of its principles is important to my later discussion--it could perhaps be summarized in three basic principles.

1. Knowledge is connected in the learner's mind.

2. New knowledge must be connected to old knowledge for learning to occur.

3. Connections are best made when learners become actively involved in making them.

Metacognition is involved in the third principle. The basis for metacognitive theory is the assumption that learners learn best when they understand and exert some control over their learning. The following discussion deals with some practical ways teachers can help students become more aware of their metacognitive processes in order to help them become better learners.

The Influence of Preconceptions

How do we see a tree? There are two common explanations. The one is the commonplace explanation, suggesting that we directly see objects. The second, the scientific explanation, is in direct conflict: We do not see objects directly, but rather we see reflected light.

Only five percent of fifth graders know this scientific explanation, according to a study carried out by Charles W. Anderson and Edward L. Smith (1984). In fact, after reading an explanation of the phenomenon, only 25% of the students will understand the explanation. Even direct explanation by the teacher will raise this percentage to only 35%.

This example illustrates one metacognitive problem. Readers tend to interpret what they read--correctly or incorrectly--according to their existing knowledge structures. They tend to disregard statements that challenge their beliefs.

Anderson and Smith suggested that teachers identify concepts that require what schema theorists have called "restructuring"--significantly changing an existing schema (that is, knowledge structure) or creating an entirely new schema to interpret new information. By identifying these concepts and creating conceptual conflict by explicitly contrasting preconceptions with scientific explanations (such as in Figure 1), Anderson and Smith improved student learning of the light concept to 81% success.

Yet the actual teaching represents only half the battle. Students need to be aware that science reading commonly requires such restructuring. A metacognitive awareness can be developed in students by alerting them to examples in their readings, and by the teacher modeling his own mature thinking processes for the students. Far too little mature modeling of comprehension processes goes on for students. In fact, Dolores Durkin's (1978-1979) research indicated that less that 1% of instructional time is spent on such modeling, even in reading classes.

The ReQuest Procedure is well designed to help teachers model appropriate text-thinking behaviors (see attached description, Figure 2). As the teacher asks questions of students and provides feedback on the quality of student-generated questions, they learn appropriate strategies for remaining alert to the specific problems involved in reading science textual material.

Graphic Organizers for Teaching Organization and Summarization of Text

One important aspect of metacognitive ability is the skill of using text organization to improve retention of information. Researchers have long known that those readers who recognize how an author has organized his or her ideas will better remember the textual information.

On a series of eight studies, Weisberg and Balajthy (1985; 1987) have investigated the ability of reading disabled children to recognize and use text structure to improve retention and summarization ability. Graphic organizers have helped the students learn how text is organized, and have served as an aid in writing effective summaries (Figures 3 and 4).

Vocabulary/Concept Learning

Harold Herber has pointed out the impossibility of teaching the vast technical vocabulary associated with each scientific specialization. Instead of a doomed attempt to teach large lists of words, he suggested that teachers select a limited number of key words to teach, and teach those words well. By modeling to students how to learn vocabulary, we give them the ability to independently increase their vocabulary as they read and study.

One important metacognitive skill pertaining to science vocabulary learning is the ability to identify from text the distinctive features of otherwise similar words. In a vocabulary-reading exercise known as a Semantic Feature Analysis

Lesson, students read a passage rich with terminology and, in class discussion, identify the distinctive features that distinguish each term.

In a typical exercise, students will list the terms (usually identifiable in a textbook due to their bold print) on the top of a sheet of paper. Then, as they read the selection, they list the characteristics described along the left side. A plus (+) indicates that the term has the characteristic, a minus (-) that it does not, a question mark (?) that sometimes it does and sometimes it doesn't, and a blank indicates that the characteristic was not identified in the text. More complex schemes can be used when indicating degrees to which a term might include a certain characteristic (see Figure 5).

A variation on this exercise (Cunningham & Cunningham, 1987) includes a prereading exercise in which the semantic feature analysis grid is presented to students, who fill it in with their predictions. A teacher-led postreading discussion helps students develop a final version of the grid, and then students use the grid as the basis for writing a summary.

Whole Language Approaches

What do we mean by a "whole language" approach to literacy in the sciences? Jane Hansen, (1987), a researcher at the University of New Hampshire and a leader of the whole language writing process school of thought, has suggested that five principles must hold true when developing a classroom environment in which written language becomes an integral part of the lives of teachers and students:

1. Adequate and uninterrupted time
2. Student choice
3. Meaningful response
4. Effective structure
5. Sense of community

As much as possible, science teachers need to think in integrative ways. A first questions must be,

*** How can teachers and students work together to learn about science in ways that are meaningful to their lives?

A second question that follows is,

*** How can literacy activities be incorporated in the classroom activities to enrich science learning?

Report Writing

Whole language advocates have been far more effective in applying their ideas to the primary grades than to the middle grades. In fact, very little attention has been given to the unique problems of the middle grades by these advocates.

In her book The Art of Teaching Writing, Lucy McCormick Calkins perceptively noted that,

> "The irony is that in a field where everyone is saying, 'We need to see how real writers go about composing. and to let our students participate in these processes,' few people are suggesting that we also need to study how real researchers go about their work, and to use this as the basis for units on report-writing." (pp. 272-3).

Those concerned with the teaching of science need to ask themselves the same kinds of questions. How do "real" science researchers go about their business? Perhaps if we are to deal with science learning in a serious way, we need to examine this issue.

Science researchers--indeed, scholars in any field of expertise--have as a basis for their scholarship the key ingredient of "expertise." Without that key ingredient, scholarship and research do not take place. The first step in adding to the body of knowledge of a scientific specialization area is to become an expert in the existing body of knowledge. This allows originality--the originality needed for publication.

The traditional science curriculum places a far greater emphasis on breadth of experience than depth, just the opposite emphasis as in the practice of "real" science. There is no doubt, of course, that breadth of experience is important. The problem comes when students are deprived of the benefits of depth.

Why, for instance, are student-generated reports generally copied directly from encyclopedias and other secondary or terciary sources? At best, when teachers require more than one source, the students alternate copying paragraphs from one source, then another. When teachers require writing "in your own words," a few students paraphrase--a somewhat more sophisticated form of copying. Why can't students "use their own words"?

True authorship (what whole language people today call "ownership") comes from one's own store of expertise. That is why, at the primary level, almost all writing process is carried out on topics directly from the students' own experience background. This general principle ought not to be violated in the middle grades: Writing process in science must be carried out based on the students' expertise with science.

Expertise can only be developed with concentrated time and effort. Science teachers need to provide opportunities for students to specialize, to become experts on topics of their own choice. It is this approach that will lead to meaningful and motivational experiences with reading and writing in the sciences.

Suggested Sequence for Research-Writing

1. Choose a research area
2. Become an expert on the topic

Note that this involves far more than simply reading enough information to write a report. This involves true expertise--knowing far more than the minimum. This step must involve teachers in careful guidance. It must also allow sufficient time for establishment of the foundation for expertise.

Bear in mind also that expertise does not develop in rigidly scheduled fashion. Expecting an entire class to be at the same stage in this sequence on any given day imposes an artificial definition of expertise on students.

3. Focus on a specific topic

4. Carry out more research

5. Publication process

This could involve students in the usual steps of writing process, including prewriting, draft writing, conferencing with peers and with teachers, revising, editing, and final publication. It might also include "publication" in some other way. such as a class presentation or an informative project of some sort.

Bear in mind that true expertise is not self-contained within a person. Expertise is only real insofar as it interacts with others. This includes other experts; hence the importance of group work. It also includes informing the general public, hence the importance of publication.

6. Recycle for additional research on another specific topic.

True expertise does not have an endpoint. It is ongoing. In fact, expertise does not develop in a strictly linear fashion, with a clearly defined end product. Expertise is developed in a spiral, circling back and spiraling upward.

FIGURES

Figure 1. How Light Enables Us to See

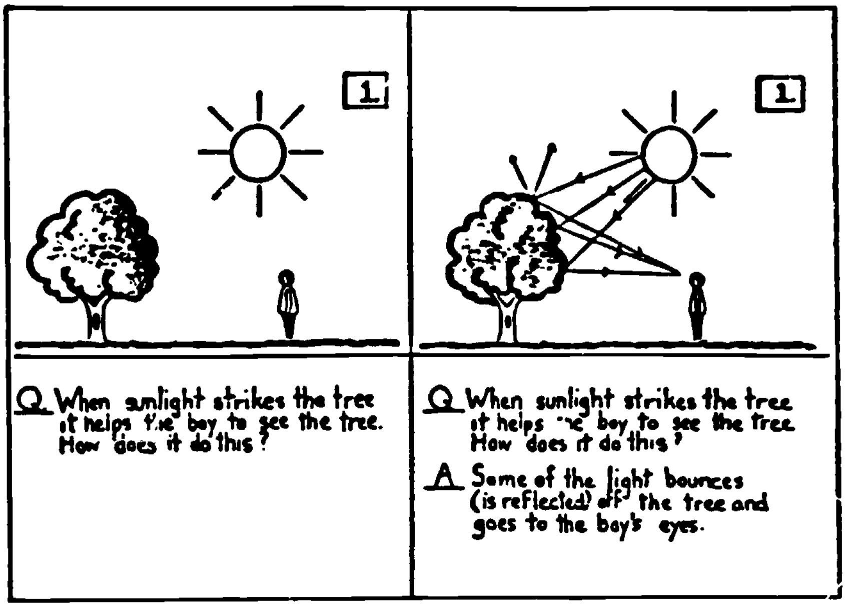

Figure 2. ReQuest

RECIPROCAL QUESTIONING: ReQuest

Manzo, A. V. The ReQuest Procedure. Journal of Reading, 1969, 13, 123-126.

PURPOSES:

To enable students to develop an interactive, questioning attitude toward text
To develop purpose in reading
To promote careful reading

PROCEDURES;

Provide students with an understanding of the rules involved.

1. Student and teacher both read the first sentence of the selection silently.
For better or more mature readers, a longer section may be read.
2. The teacher closes his/her book, and the student questions him/her about the section.
Unclear questions should be clarified.
3. The teacher then has the student close his/her book and answer questions.
Ask as many questions as prove useful in adding to the student's understanding of the material.
4. The next segment of the passage is read silently and steps 2 and 3 are repeated.
5. At an appropriate point in the material, when the student has read enough to make a prediction about the rest of the material, the teacher asks speculative questions: "What do you think will happen?" "Why do you think so?" "Read the line that proves it."
6. This procedure is continued into the second or perhaps the third paragraph, after which the student finishes the selection silently.
7. Follow-up activities.
To compare predicted content with actual content.

ADDITIONAL SUGGESTIONS

In a whole class activity, alternate the role of questioner after each question to involve more students.
Teams may be used to question each other.
Don't be concerned about not knowing an answer--it proves you are human.
Encourage students to use higher order questions by being an appropriate role model in your own questioning.
A preliminary discussion of key concepts or important vocabulary may be useful.

Figure 3. Activity Instructor Guide for Graphic Organizer Exercise

ACTIVITY INSTRUCTOR GUIDE

1. Distribute copies of passage. Briefly explain that participants are to read the passage in Figure 4, recognizing and marking the major comparison/contrasts and their components.

2. Read.

3. Using input from the group, draw a sample graphic organizer on the chalkboard, in telegraphic speech, following general outline below.

4. Use the main components of the graphic organizer to write a summary.

<u>Coal</u>

<u>Peat</u>   <u>Lignite</u>   <u>Bituminous Coal</u>   <u>Anthracite</u>

<u>Appearance</u>

n/a   <u>Results</u>

<u>Location of use</u>   n/a

<u>Type of Rock</u>

Figure 4. Passage for Graphic Organizer Exercise

Coal

(From Focus on Earth Science, Charles E. Merrill)

Coal forms during the decay of plants in the absence of oxygen. Plants in swamps decay under water without oxygen. Bacteria that live on submerged plants use oxygen from the dying plants and release carbon and hydrogen. Eventually, these hydrocarbons form coal. Coal goes through several changes during its formation. Each step removes some impurities and moisture. In the swamp where coal forms, layers of silt gradually are deposited over the dying plants. The weight of the silt presses down on the organic material beneath and squeezes out moisture. Gradually most of the moisture and much of the nitrogen are lost.

Peat is the first step in coal formation. Many twigs and leaves can be recognized in this stage. Peat burns, although some moisture is present. Peat is an important fuel in Ireland and Russia. The next stage is lignite. Lignite, or brown coal, has lost most of its moisture, oxygen, and nitrogen. People use lignite to heat homes in many places. Bituminous coal is more compact than lignite. It has lost most of its original moisture and impurities. Bituminous coal is an efficient heating material, but it has one disadvantage. Smoke, ash, and sulfur are produced during its burning. Cities like Pittsburgh, Pennsylvania, London, England, and St. Louis, Missouri, have had smoke-blackened buildings and badly polluted air because of the use of coal. Now they have cleaner air and buildings.

Anthracite, or hard coal, is the final stage in coal formation. Peat, lignite, and bituminous coal are sedimentary rocks. Anthracite is a metamorphic rock. It is found only in areas of mountain building where heat and pressure were great. Because of the way it formed, anthracite is the cleanest of all coals with the least impurities. Anthracite is mostly carbon. It does not produce as much heat as bituminous coal, but it is preferred since it burns cleaner and longer.

Coal supplies should last for hundreds of years. As the supplies of oil and natural gas decrease, coal is again becoming an important source of energy. We must find ways to reduce the amounts of sulfur, ash, and smoke which burning coal produces.

Figure 5. Semantic Feature Analysis Grid

	Earth	Jupiter	Mars	Mercury	Neptune	Pluto
Closer to sun than Earth						
Larger than Earth						
Has moon						
Has rings						
Orbits the sun						
Inner planet						

Figure 6. Activity Instructor Guide for Discussion of Whole Language Principles

ACTIVITY INSTRUCTOR GUIDE

1. Meet in small groups for 10 minutes. Discuss these general principles, and (discounting temporarily the "realities" of your classrooms) brainstorm suggestions for how teachers can redesign their curricula to meet the demands of these principles.

2. Get back together as a large group and put suggestions on the board:

<u>General Suggestions</u>

Unit approach
Project approach

<u>Meeting Specific Goals</u>

1. Adequate and uninterrupted time
   - Unit approach--entire day's curriculum centered on theme
2. Student choice
   - Individualized.
     - Yet within bounds of state curriculum and project ideas that teacher has been able to plan.
     - Perhaps have "teacher experts" on science areas who can work with groups of students outside their own specific class
3. Meaningful response
   - Class discussion
   - Group presentations designed to "Publish" findings--to teach the rest of the class
   - Desktop publishing
4. Effective structure
   - Teacher planning necessary to provide appropriate guidance.
5. Sense of community
   - Group work--sense of colleaguiality and "authorship" in publication

Figure 7. Discussion Guide for Discussion of Whole Language Principles

DISCUSSION GUIDE: Applying Whole Language Principles to Literacy in Elementary Science Instruction

Instructions: Brainstorm ideas for meeting each goal. Be as specific as you can.

1. Adequate and uninterrupted time

2. Student choice

3. Meaningful response

4. Effective structure

5. Sense of community

Figure 8. Discussion Guide for Discussion on Research Reports

ACTIVITY GUIDE

Valuing Expertise

Background: Perhaps the key hurdle in promoting in-depth, literacy-rich study of science is motivational in nature. That is, how can we help our students appreciate the value of knowledge, of expertise? To some extent, this has been the concern of recent books such as Allan Bloom's Closing of the American Mind and E. D. Hirsch's Cultural Literacy.

Instructions: In a small group, discuss this issue. How can we help our students value expertise in science? Try to deal with the larger concerns--the linch pins of the issue--rather than gimmicks or specific techniques.

Figure 9. Instructor Guide for Discussion of Research Reports

ACTIVITY INSTRUCTOR GUIDE

1. Explain the importance of developing a value system among students that values expertise.

2. Read Activity Guide and assign small groups for discussion.

3. Follow-up discussion by listing ideas on chalkboard.

Some ideas for follow-discussion:

The importance of publication--whether newspaper, report, display, etc.

The importance of student choice on areas of expertise.

Parental involvement in the development of the expertise.

On-going role as an expert. Publication is not simply a one-shot deal.

Development of the concept of the classroom as a community of scholars.

Teacher modeling of expertise.

Modeling of expertise by members of community.

COMPETENCY ASSESSMENT: READING IN THE SCIENCES

E. Balajthy
SUNY-Geneseo

1= Poor 3= Satisfactory 5= Excellent

A. Instruction is planned so that students know how to deal with their reading.	1	2	3	4	5
B. Students actively respond to their science reading.	1	2	3	4	5
C. Students write in response to their science reading.	1	2	3	4	5
D. Students speak and listen in response to their science reading.	1	2	3	4	5
E. Students are encouraged to read science literature.	1	2	3	4	5
F. Attention is paid to the organization of science text material.	1	2	3	4	5
G. Technical vocabulary is reinforced by provided opportunities for repeated use in varying contexts.	1	2	3	4	5
H. Difficulty levels of material are matched to student abilities.	1	2	3	4	5
I. Units are planned to integrate math and literacy skills, as well as content areas other than science, a variety of strategies, and different media.	1	2	3	4	5
J. Teacher discussion questions are preplanned to be at varying levels of comprehension.	1	2	3	4	5
K. Instruction and assignments are differentiated according to student ability.	1	2	3	4	5
L. Reading skills specific to science materials are assessed and, as necessary, taught.	1	2	3	4	5

Literacy in the Sciences: Annotated Bibliography

Fulwiler, Toby. 1987. The Journal Book. Portsmouth, NH: Heinemann.

This collection of articles, based on whole language principles, contains several on science teaching, both at the elementary and secondary levels. Each article describes one teacher's experience with incorporating journal writing into the content curriculum.

Thelen, Judith. 1976. Improving Reading in Science. Newark, DE: International Reading Association.

Discusses diagnosis in teaching science, use of various types of study guides, and vocabulary development.

Cornett, Charles, and Claudia Cornett. Reading Science: Concepts and Skills Activities. Portland, ME: J. Weston Walch, 1977.

This is a collection of exercises centered on science materials. It presents a wide range of sample exercises which science teachers can use to adapt to their own reading materials.

Bechtel, Judith, and Bettie Franzblau. Reading in the Science Classroom. West Haven, CT: National Education Association, 1980.

While there are few original ideas in this book, the authors do show how many standard reading techniques can be used in science reading (such as SQ3R, interest inventories, content area reading inventories, and study guides).

Ideas for interesting children in science literature and lists of books:

- "Beyond the Textbook: Science Literature for Young People." Janice A. Dole & Virginia R. Johnson. 1981. Journal of Reading, April, pp. 579-582.
- "Using Popular Books and Magazines to Interest Students in General Science." Cathy L. Guerra & DeLores B. Payne. 1981. Journal of Reading, April, pp. 583-586.

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