Reading & Writing Quarterly, 17: 105–125, 2001
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1057-3569/01 $12.00 + .00

LITERACY PROFICIENCY AND SCIENCE FOR STUDENTS WITH LEARNING DISABILITIES

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The purpose of this article is to describe program alternatives in science for students with learning disabilities and their implications for reading and writing. We review opportunity to learn, the science performance of students with learning disabilities, science textbook instruction, literacy and science, and alternatives to reading-dependent science programs. Finally, we present an alternative framework for science and literacy as related to students with learning disabilities. The proposed alternative emphasizes the teaching of science with only minimal dependency on literacy skills and processes. In addition, we recommend the integration of the teaching of literacy skills and processes into the content of science after the science has been learned.

Reading and writing are dominant concerns within the field of learning disabilities. Reading and writing are also important concerns in the teaching and assessment of school science. Given the difficulties that students with learning disabilities evidence in reading and writing and with the textbook as the major tool in the teaching of science, conventional teaching and assessment of science present a problem for these students.

In this article, we recommend an alternative to current textbook practices in the teaching of science. The alternative is based on two assumptions. The first assumption is that students do not need to know how to read to be taught science or to be assessed for science knowledge and skill. The second assumption is that reading and writing can be taught and enhanced within the context of science.

Preparation of this paper was made possible, in part, by a grant from the National Science Foundation, TPE-9055527. The views expressed are those of the authors and do not necessarily reflect the views of the National Science Foundation.
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These two assumptions raise the question: Should the field of learning disabilities modify its current practice from teaching reading and writing as a means for students to learn science to teaching science independent of reading and writing?

The purpose of this article is to discuss contemporary practices in science relative to students with learning disabilities and to describe ways that science can be taught within an alternative literacy context. As such, we begin with an overview of opportunity to learn and the science performance of students with mild disabilities, followed by science textbook instruction, literacy and science, and alternatives to reading dependent science programs. Finally, we present an alternative framework for science and literacy as related to students with learning disabilities.

OPPORTUNITY TO LEARN

Opportunity to learn is an important consideration in the development and implementation of the science program. The science standards established by the National Research Council (NRC, 1994) highlight the importance of opportunity as follows: "Equal attention must be given to the assessment of opportunity to learn and to the assessment of student achievement. Students cannot be held accountable for achievement unless they are given adequate opportunity to learn science" (pp. IV–11).

Opportunity to learn in science may be defined as providing students with a set of experiences that include important science concepts, processes, and skills as well as presenting lessons in a manner that allow the student to acquire knowledge, process, and skill capability. When considering assessment, students must have an equivalent opportunity to demonstrate their capabilities. To meet the unique needs of students with learning disabilities, the science program should be one that is capable of being modified to parcel out the effects of a disability in one area (e.g., reading) from the performance in another (e.g., science).

Opportunity to learn is also a function of the extent to which the student brings prior knowledge to the learning experience and the extent to which the student can activate this knowledge and connect it to the ongoing lesson. It is not sufficient to assume that prior opportunities to learn resulted in the student acquiring content, skill, and process knowledge or that the student can activate and connect them. Instead, it is necessary, as stated in the science standards (NRC, 1994), to determine whether the student has acquired the prior

knowledge and the extent to which it is activated and connected. Students who have limited proficiency in reading and writing may not be able to acquire or demonstrate new science knowledge when the activities require prior knowledge of important content. At the same time, when the science program is text-based, it is unlikely that students who do not substantively comprehend the text can create the episodic relationships that will assist them to retrieve and connect essential knowledge. These are important considerations, as the 1997 amendments to the *Individuals with Disabilities Education Act* (IDEA, 1999) stipulate that students with learning disabilities have access to the general education curriculum and that involvement and progress in the general education curriculum be validated. As such, it is important to carefully examine student performance in science.

STUDENT PERFORMANCE

According to teacher judgments, science performance of students with learning disabilities is less than satisfactory. A study by Donohoe and Zigmond (1988) showed that 69 percent of the grades received by students with learning disabilities were D or below for 9th grade science. Cawley, Kahn, and Tedesco (1989) noted that 50 to 60 percent of high school (grades 9–12) for students with learning disabilities were Ds or Fs. Harnisch and Wilkinson (1989) reported that the relative performance of students with disabilities is lower for science and math than it is for reading, vocabulary, and writing at the secondary school level. Gregory, Shanahan, and Walberg (1985) reported a comparison between science test scores of 673 students with learning disabilities who were high school sophomores and 26,407 students without learning disabilities. The science test scores of the latter were significantly greater than the former. Therefore, research indicates that students with learning disabilities are not learning science in school settings as evaluated by school criteria.

The state of New York administers a program evaluation science test to all fourth-grade students, including students with disabilities. Typically, test modifications are recommended based on student needs. However, test modifications without previous instructional adaptations may not benefit some students. Results of the program evaluation indicated that fewer than 50 percent of students with disabilities passed the science content and skill sections of the test, whereas 69 to 75 percent of students without disabilities passed the content and skill sections, respectively. Both groups of students

scored relatively better on the manipulation section of the test, with 77 percent and 67 percent of students with and without disabilities, respectively, passing the test. It should be noted that the test used to assess students' performance in this study includes two objective measures of science content and skills and one measure of manipulative science. Although the manipulative section of the test is judged to be "hands-on," it requires the student to read the directions and write a report or synopsis of the activity and its results. Evaluators typically judge the written report.

Janczak (1993a, 1993b) undertook two examinations of ninth-grade science performances of students with and without disabilities on New York's ninth-grade Regents Competency Test in Science. The subtests included life science, earth science, physical science, and science processes. The pilot study examined the performance of small samples of students with severe emotional disturbance, students with learning disabilities, and those not having a disability (Janczak, 1993a). Ninety-four percent of the students with severe emotional disturbance passed the text. The criterion for passing is a 65 percent accuracy. In contrast, only 77 percent of students with learning disabilities and 86 percent of students without disabilities passed the same test. The pattern of students passing was the same for each of the four subtests, with a greater percentage of students passing the science processes subtest.

Janczak's second study (1993b) examined the performance of 88 students with learning disabilities and 88 students without disabilities. Seventy-six percent of the students with learning disabilities passed the test, whereas 97 percent of students without disabilities passed it. Again, the pattern of performance was similar across the subtests, with the higher percent passing the science processes tests and fewer students passing the earth science test. The tests require students to both read and write, and student performance is evaluated primarily on the basis of the written product. The manipulation section requires the student to read a set of directions, conduct the activity, and then submit a written summation of the activity. It is the written summation that is used to judge performance. While these data indicate that a high percentage of students with learning disabilities passed the science tests, more students passed who had no disabilities.

Shepard and Adjogah (1994) compared the performance of students with learning disabilities and students without disabilities on the *Science Picture Meanings Test*. This test consisted of a set of 11 pictures depicting science situations. Each student was asked to examine the picture and describe or tell about the best science idea or meaning depicted by the picture. The test was scored using a four

point scale, with 0 indicating incorrect information, 1 indicating information about the picture that was not stated in scientific terms, 2 indicating a scientific description that included specific science terminology, and 3 indicating a response that provided a mature scientific explanation. From an aggregate of 836 possible responses, not a single score of 3 was recorded. A subset of 7 pictures was administered to students without disabilities. From the aggregate of 532 possible scores of 3 for each sample, none was recorded for students with disabilities, and only 14 were recorded for students without disabilities. Neither sample responded adequately to the level of scientific explanation. No reading or writing was required.

SCIENCE TEXTBOOK INSTRUCTION

Proficiency in literacy skills and processes is undoubtedly an important instructional concern, especially for a subject as text-based and vocabulary-dense as science. For example, in an evaluation of science textbooks, Mastropieri and Scruggs (1992) identified 750 new vocabulary words in one series and 1,831 in another. These figures may be even greater for mainstreamed special education students when other difficult or unfamiliar words are considered. Unfortunately, students who engage in an inordinate amount of time on learning new vocabulary words are less likely to devote sufficient time to master science content.

Wood and Wood (1988) point out that the primary characteristics of expository text that affect comprehension are content, text structure, and reading level. Ten fourth grade science texts were ranked in terms of the percent of text that could be read with at least 50 percent comprehension by students reading at a specific grade level. Wood and Wood concluded that seven of the ten texts were too difficult to comprehend for fourth grade students reading in the lower quartile and for low SES students reading at grade level. A major reason for the discrepancy seems to be that comprehension of science texts requires a connection between the content knowledge and text structure to the student's prior knowledge. To date, written textbooks continue to dominate instruction in science.

Driscoll, Mahanz, Dick, and Kirby (1994) examined the use and implications of a science textbook in an eighth grade classroom. The three-week observational study focused on the topic of *Light and Lenses*. The chapter included eight specific objectives, and the teacher used the textbook as the dominant means of instruction. About half the students brought their books to class each day, and

considerable prompting was necessary to get them to open their books. Students generally had difficulty understanding the text and were unable to locate the answers to questions. Classroom observations and interviews confirmed that students did not use much of the text. Despite the amount of time (3 weeks) spent on the unit and repetition of information in the chapter, students' end-of-chapter test scores were deemed to be low. The end-of-chapter tests focused mostly on factual information. The match between the textual information, instruction, and assessment was not clear.

Nolet and Tindal (1994) report a study of two sixth-grade science classes. In this study, the researchers conducted a total of 18 observations and examined instruction in terms of key science concepts that teachers targeted for instruction. In addition, an analysis of the book chapter used, end of chapter test of 19 items, student essays, and student perception probes were conducted. Student essays were quantitatively evaluated in terms of the number of words written, percent spelled correctly, average T-unit length, and frequency count of teacher identified concepts. Qualitatively, the essays were examined to determine the extent to which students made a clear recommendation, provided a rationale in support of the recommendation, used correct information, and made a logical argument. The key findings showed that general education students had a higher percentage of correct scores for the chapter test, did somewhat better on the essay, and included all but one of the important concepts listed by the teachers. In contrast, low-achieving students omitted eight concepts. The researchers noted that low-achievers were less aware of concepts and that general education students not only used the concepts, but manipulated them in complex intellectual operations.

More important than literacy may be the issue pertaining to the propositional structure and composition of science texts. Staver and Bay (1989) compared the number of propositions and cognitive levels involved in a study of elementary school science textbooks. In one illustration involving the topic of weather at the first grade level, one series included 28 propositions and five levels of a cognitive hierarchy (e.g., interactional reasoning), whereas another contained only 11 propositions and three cognitive levels. These instances are illustrative of cognitive overload in traditional science textbooks. The result is that students may not be able to sift through the mass of information to reason or apply the information.

To compensate for various learning difficulties, some general education science textbooks contain recommendations that attempt to help teachers make adaptations for students with learning disabilities. An examination of two series clearly indicated a lack of any

serious interest on the part of the developers, or at the very least a misguided conception of students with disabilities in general education classes (Parmar & Cawley, 1993). The recommendations were often irrelevant and placed excessive demands on the classroom teacher. For example, recommendations from teachers' manuals of some science textbooks were as follows:

1. When performing experiments to study mass, volume, length, and density, assign the visually impaired student a partner to assist in making observations.
2. Ask the student with learning disabilities to make drawings of everyday chemical changes.
3. Take students with learning disabilities to a grassy meadow to observe an ecosystem.

None of the recommendations consider the fact that some classrooms may include both children with learning disabilities and visual impairments for science instruction. Moreover, the location of the school or the availability of resources, such as the case of an inner-city school teacher trying to get to a grassy meadow are not considered (Parmar & Cawley, 1993). Overall, the recommendations do not represent specially designed instruction for students with disabilities.

LITERACY AND SCIENCE

It may be that many students with learning disabilities have reading deficits that hinder their ability to generate and construct meaning from text. Lovitt, Horton, and Bergerud (1987) noted that middle school students with learning disabilities must be able to read orally at about 135 words per minute to comprehend science content. Cawley, Miller, and Carr (1990) examined the oral science reading performance of 13-year-old students with learning disabilities and students with educational handicaps (mildly retarded). Using the Deno (1985) method of counting the number of words read in one minute, oral reading rates for students with educational handicaps and learning disabilities were 69.04 and 65.84, respectively. These rates were comparable to the second grade reading level. Of a total of 18 comprehension questions, students with educational handicaps and learning disabilities answered an average of 4 and 7 comprehension questions, respectively.

Again using the Deno method (1985), oral reading rates of elementary aged students with mild disabilities were compared to those of students without disabilities for *science* and *prose* texts (Parmar,

DeLuca, & Janczak, 1994). Results indicated that reading rates of nondisabled children were about twice those of students with disabilities across all grade levels. In addition, reading rates for science were less than those for prose.

DeLuca (1993) compared the performance of a sample of junior high students with learning disabilities and those not having a disability on a spoken and written picture vocabulary science test. In the spoken form, the examiner stated a term and required the student to point to a picture that represented the term. The written form presented a printed word and had the student identify the picture that represented the term. Students without disabilities performed significantly better on both forms than students with disabilities. Students with disabilities performed significantly lower on the written form than on the spoken form.

Lovitt, Rudsit, Jenkins, Pious, and Benedetti (1985) adapted reading materials in physical science for middle school students with learning disabilities. The adaptations included providing precision teaching (PT) and study guides (SG). Students in either condition left their classroom for a tutorial setting over a 10-day period. Students in the PT condition were paired, and one member of each pair was asked to read isolated words from a see/say vocabulary sheet to the partner and vice versa. Students then began see/write activities in which sentences with words blanked out were completed (e.g., a cloze type task). Students in the SG condition were presented with two types of worksheets. One was a framed outline consisting of a sequenced list of main ideas of a chapter in which key words were blanked out. The other worksheet contained vocabulary exercises in which students supplied omitted vocabulary words. Results indicated significant differences between each experimental condition and the control condition, favoring the experimental groups. However, differences between experimental conditions were not significant.

Continuing their work on material modification, Bergerud, Lovitt, and Horton (1988) compared the effects of graphics, study guides, and self-study in life science for students with learning disabilities. The base materials were three 1000-word passages on life science. A modification included diagrams with 20 parts of the pictures or labels missing or sets of 20-item study guides containing open-ended questions related to main ideas and vocabulary. Results indicated that students in the graphics condition outperformed those in the study guide and self-study conditions on the posttest.

Other studies by Horton and Lovitt (1989) examined the effects of more and less teacher direction and the influence of study guides and self-study on science and social studies achievement. Secondary stu-

dents in social studies classes benefited more than those in science classes and those at the middle school level. Student-directed procedures seemed to benefit some children (e.g., middle school students with learning disabilities) more than others. These studies support other research indicating the general effectiveness of study guides in enhancing the performance of students with learning disabilities and other students. In sum, study guides may be valuable tools for content area teachers who serve a variety of children.

Darch and Carnine (1986) contrasted a visual display method with a text study method for presenting content to students with learning disabilities. Posttest scores for the visual display condition were significantly different from those for the text study condition, favoring the visual display condition. The transfer scores of the two groups were not significantly different.

McFarland and Shepard (1995) studied oral and written storytelling performances of students with disabilities using four pictures from the *Science Picture Meanings Test*. In addition to the common discourse analysis, the study examined references to science content and cognitive processes. The science content was scored for oral and written discourse using the procedure described in the Shepard and Adjogah (1994) study. Cognitive processes were tabulated by calculating references to cognitive acts. For example, "I have some apples and some pears and I can make a set of fruit," would be assigned a classification score, because combining apples and pears to yield fruit is a classification act. Findings indicated that the number of references to science content was greater in the oral format than in the written format. In addition, significantly more sentences, although shorter, were used in writing than in telling. No substantial evidence of cognitive processing was found.

Clearly, the literature indicates that classroom dependency on textbook programs is misguided. Although students with learning disabilities may lack essential reading and literacy skills, numerous studies indicate that these students can learn science content when effective adaptations (e.g., study guides, graphics) and modifications (oral versus written responses) are made to meet individual student needs.

ALTERNATIVES TO READING-DEPENDENT SCIENCE PROGRAMS

For students in general, the historical indicators show that science is the area most likely to be omitted from the daily scope of instruction (Raizen, 1988), yet it is the area that teachers have long expressed

ease with when including students with disabilities (Atwood & Oldham, 1985). However, once in those science classrooms, the majority of instruction focuses on the acquisition of factual knowledge in spite of the fact that conceptual knowledge that is well developed and organized is more likely to be generalized than factual information. The conceptual approach views scientific knowledge as meaningful only when it helps learners make sense of their surroundings (Roth, 1989). By taking a conceptual approach to science instruction, the teacher views science as an activity (Wheatley, 1991) in which the students interact with objects in their environment, thereby providing an episodic background for comprehension.

Not only does reading pose a problem for children with learning disabilities, but the general emphasis on reading seems in opposition to the available data relative to program effectiveness (Lovitt et al., 1985; Darch & Carnine, 1986). Shymansky, Kyle, and Alport (1982) conducted a qualitative analysis of research in classrooms using "hands-on" approaches to science with those using the textbook. Students in the "hands-on" classrooms outperformed those in the textbook-based classrooms on every criterion measured. Bredderman (1982) synthesized the results of 27 studies involving 100 science process test comparisons between students in "hands-on" and textbook programs. Children in textbook programs did not perform as well on process measures as those in activity programs.

A study by Bay, Staver, Bryan, and Hale (1992) compared the effects of direct instruction and discovery teaching. Instructional content focused on displacement and flotation and the relationship between controlled experimentation and scientific prediction. The general outcome was that students taught in a discovery method outperformed those in the direct instruction method.

Scruggs, Mastropieri, Bakken, and Brigham (1993) compared two approaches: a textbook and a "hand-on" (2 FOSS units) approach to the science performance of students with learning disabilities. Each treatment lasted only one week. Results indicated significant differences between conditions favoring the "hands-on" program. In another study, Scruggs and Mastropieri (1994) evaluated the construction of scientific knowledge by students with mild disabilities using the FOSS Environmental unit. The data consisted primarily of field notes and led the researchers to the following conclusions:

- Students actively constructed knowledge;
- Positive outcomes were associated with teacher implementation;
- Numerous teacher-made adaptations (e.g., added activities or increased redundancy) were included;

- Behavioral techniques and expectancies are important;
- Structured coaching by teachers is related to knowledge construction;
- Peers are helpful in social activities, but not in learning.

Students performed significantly higher on immediate and delayed unit tests when they learned via the activity-based approach than the reading approach. Vocabulary development was limited in both conditions. Students reported a preference for activity-based learning. In this study, the *constructivist* perspective seemed to be a valid assumption for teaching science to students with disabilities. When students actively reason, they learn, remember, and comprehend more via active exploration with materials that facilitate knowledge construction.

MacDougall, Schnur, Berger, and Vernon (1981) found that a group of students with mild disabilities did not demonstrate behaviors characteristic of their handicapping conditions when participating in an activity-based science program in the general education classroom. However, when activities returned to a non-hands-on approach, their behaviors were more characteristic of their handicapping conditions.

For example, students with learning disabilities were found to be distractible, off-task, and displaying difficulties with social interactions, whereas students with emotional handicaps were seen to be acting out, aggressive, or withdrawn. In summary, a reasonable body of evidence suggests that when students with learning disabilities learn science via a "hands-on" program, science achievement exceeds that of students taught from a textbook-based curriculum (Nolet & Tindal, 1994; Scruggs, Mastropieri, Bakken, & Brigham, 1993; Bay, Staver, Bryan, & Hale (1992). Apparently, all students can acquire knowledge, processes, and skills relative to science in programs that are grounded in "hands-on" instruction.

AN ALTERNATIVE FRAMEWORK FOR SCIENCE INSTRUCTION

At the beginning of this article, we noted that science may be presented to students with limited proficiency in reading and writing. In addition, we proposed that a science knowledge base could be used to enhance literacy. As such, one alternative framework for organizing the presentation of science is the *Interactive Unit* (IU) (see Figure 1).

The IU is a system of 16 teacher-student or teacher-student-materials interactions. The IU provides the teacher with four ways to present science. These are (1) *manipulations*, which may include

The Interactive Unit

Manipulate .... Manipulation of objects (piling, arranging, and moving).
Display .... (Instructor Interaction) Presentation of displays (pictures, arrangements of materials).
Say .... Oral discussion.
Write .... Written materials (letters, numerals, words, signs of operation) and marking of these types of materials.
Identify .... (Learner Interaction) Selection from multiply chioces of nonwritten materials (pictures, objects).

INSTRUCTOR

LEARNER	MANIPULATE	DISPLAY	SAY	WRITE
MANIPULATE	Watch me. Do what I do.	See this picture. Do what it shows you.	Listen, and do what I say. "Lift the rock"	Read this, and do what it says. "Lift the rock"
IDENTIFY	Watch me. Mark the one thats alike.	See this picture. Mark the one thats alike.	Listen. "Mark the picture that shows the boy lifting the rock"	Read this. "Mark the picture of the boy lifting the rock"
SAY	Watch me. Tell me what I am doing ?	See this picture. Tell me what you see?	What does it mean when I say: "Lift the rock"	Read this and explain what it says:"Lift the rock"
WRITE	Watch me. Write a sentence telling what I did.	See this picture. Write a sentence telling what you see.	Listen to what I say and write a sentence to tell me what I mean.	Read what I show you and write a sentence to tell me what I mean.

FIGURE 1 The interactive unit.

teacher demonstrations or movements by the students as they conduct experiments, (2) *displays* or fixed representations of three-dimensional (e.g., real models) or two-dimensional (e.g., picture of a model) stimuli, (3) *verbal statements*, or (4) *written statements*. Also, the IU provides the student with four options to respond (i.e., *manipu-*

late, *identify* or point, *state*, and *write*). Within each of these broad categories, there are a multitude of distinct tasks and numerous combinations of tasks that are integrated within a lesson. For example, a lesson might include an experiment where the student must read directions (write input), complete the activities described in the directions (manipulate output), and then require the student to provide a written record of the results or summary of the experiment (write output). The teacher can use the IU to select various modes of presentation. For example, a teacher who uses the manipulate, display, and state options to present the lesson and who then uses the manipulate, identify, and state options in assessment has bypassed reading and writing. Once the teacher determines that the students have a knowledge of science and can express this knowledge, the teacher can focus on reading and writing by including the various *write* combinations within the same content. Ten of the 16 cells in the IU can be used to create worksheets in varying formats.

The IU is *not* hierarchical. That is, manipulation is not associated with the *concrete* nor is manipulation considered to be of higher or lesser level of abstractness than the written form. The IU is content-free and can be used across many topics at a variety of age levels. Therefore, it is possible to deliver the science content without being dependent on the textbook. At the same time, it is possible to integrate literacy skills to meet student needs.

The IU lends itself to any general instructional theory and variations in teacher-pupil or teacher-pupil-material interactions. For example, the *write/manipulate* interaction is common in science. Illustrative of this interaction is a laboratory activity in which the student follows written directions to conduct the activity. The IU was formulated based on the work of Jerome Bruner (1963) who described three stages of activity as *enactive*, *iconic*, and *symbolic*. The Bruner model was modified based on (a) the experiences of the senior author with respect to aphasia (Cawley & Vitello, 1972), where attention is directed to both receptive and expressive domains, and (b) a need to separate written and oral symbolic activities from one another (i.e., Bruner's *symbolic* was altered to state and write).

To realize high quality science outcomes (outcomes in which the student would act like a scientist) it is necessary that the science program integrate literacy, cognitive acts, and science skills and processes. In effect, science activities serve as the means by which students learn to become problem solvers, understand cognitive principles, and express themselves accurately and creatively. The acquisition of science content knowledge per se is a secondary outcome. A key to attaining these forms and levels of outcomes is to

confront students with problems and assist them to acquire the "know-how" to become problem solvers. Let us examine some simple problems and the manner in which science processes and literacy skills can be integrated.

Problem Solving

Problem solving tasks might consist of the student utilizing reasoning to predict or explain the solution to a problem. For example, The Ice Cube Problem involves the floating of ice cubes in different liquids (e.g., water/alcohol). It asks the student to predict whether the ice cube will float in other liquids if it floats in water. The student places the ice cube in the water (i.e., manipulates). Students record (i.e., write or orally state) their predictions, prepare a plan to examine these predictions, carry out the plan, and record (write or state) the results. They may be encouraged to explain reasons for their results and develop hypotheses (Eggen & Main, 1990). The activity may be extended by presenting students with a problem on *flinking*. Flinking requires taking certain objects and modifying them so they will float/sink at certain levels in the liquid. One group might *flink* its object one-half the way, while another might *flink* its object two-thirds of the way. Considerable manipulation would be required while modifying the object. Comprehensive records about modifications and details regarding object features (e.g., mass) could be recorded and compared among groups.

Piagetian Activities

Piagetian activities may be similar to those used in a study of children with learning disabilities by Riley (1989) or extended to science propositions and reasoning based on the work of Staver and Bay (1990). Activities may involve conservation of area, mass or volume, transitive relations, or a variety of other cognitive concepts. Applying the IU to a topic such as conservation of area would involve an activity in which the student might create a region using a set of tiles. The student would determine the area and perimeter of the region by counting or measuring. The student would then be asked to use the same tiles and create a different region and to determine the perimeter and area of the new region. The student would find that the perimeter changed, but the area remained the same.

Tasks might include the conservation of volume in which a student pours material (i.e., manipulates) from one large container into two or more smaller containers and recognizes that the amount remains

the same. For example, a group of students could be engaged in a task in which they are provided with cones and cylinders of different sizes and required to (a) pour material from a cone into a cylinder and determine the relationship of the number of cones to a cylinder, (b) record observations on a chart, and (c) discuss the outcomes in terms of a generalization of the relationship between cones and cylinders. Next, students could be asked to hypothesize or predict the number of cones to be filled if they were to pour the contents of the cylinder into the cones. The relationship could be confirmed by pouring the materials. Task cognition may be enhanced by examining two sets of cones and cylinders with the same base and height, but containing different materials, in this case sand and water. Students could be instructed to pour three cones of sand into one cylinder and three cones of water into another cylinder and record their observations. Then, they could be asked to predict the outcome if they were to pour two cones of sand and one cone of water into one cylinder and 2 cones of water and one cone of sand into another cylinder. Their predictions and observations could be recorded and discussed to correct any misconceptions.

Integrating Literacy into Science

Problem solving activities in science that integrate cognition and literacy are abundant. It is our belief that any aspect of language, including reading and writing, can be integrated into a science program. Given the language difficulties of students with learning disabilities, language activities should be integral to all aspects of science. Language comprehension activities can readily be incorporated with science content (see Table 1).

Developing proficiency across the components of literacy and integrating these skill components within a subject such as science is a complex undertaking. For example, there is a distinction between *making notes* during observations and *taking notes* during lectures. The former assumes that the student is a competent observer who is able to detect the essential elements of what is being observed and that the student can make accurate and detailed notes. The notes must be clear enough for the student to be able to use them to justify observations, especially if other students report different interpretations of the same observations. Taking notes during a lecture assumes that the student can interpret the oral, written, and illustrative components of the lecture as intended by the lecturer. In many instances these notes will be used again to guide discussions or to respond accurately on exams.

TABLE 1 Integrating Language Comprehension and Science Activities

Listening Comprehension
Following Directions
Recall and summary of a passage
Understanding and completing an experiment
Reading
Rate of reading from text
Recall and summary of text
Answering specific questions
Reading to complete an experiment
Writing Production
Writing the results of an experiment
Writing directions to conduct an experiment
Writing a report
• Making notes during observations
• Taking notes during classes or lectures
• Outlining or summarizing
Speaking
Describing the procedures for an experiment
Describing the results of an experiment
Interpreting spoken or written text to others

Fundamental components of reading such as phonological awareness, basic reading principles, and extended work in comprehension can be undertaken within the context of science. As stated, our preference is that the teacher conduct "hands-on" science activities, provide the student with an opportunity to learn, and develop a knowledge base in science content, processes, and skills. Later, the teacher can base language comprehension activities on science experiences. A brief illustration of the use of science text to evaluate student application of basic processes and principles for reading and comprehension activities are shown in Figures 2 and 3. Figure 2 illustrates that science content can be a medium in which the most basic of reading principles can be emphasized (e.g., pronunciation of letter names). Figure 3 lists various forms of inquiry that can be used to direct student comprehension. The format for the comprehension activities involves multiple readings of the same passage, with each encounter requiring the student to complete a different type and level of task. As students reread the passage and it becomes more familiar to them, the demands of each of the comprehension activities can become more challenging. Each of the "comprehension" assessments is designed for a specific purpose. For example, the *true/false* assessment yields the highest probability of correct responses. The fourth activity introduces students to questions of varying types and rele-

There are millions of plants in a glass of seawater. They are tiny green plants called algae. The picture shows the algae are much larger than they are. You cannot see algae, but all the animals of the sea depend upon them. The algae float in water. They take minerals from the water. They also take in carbon dioxide that is dissolved in water. The sun shines on the green algae. They make food and grow.

Specific Sound-Symbol Principles

A. Letter names usually contain cues for pronunciation (exception: short vowels, h, w)

1. The name of a vowel is its long sound: sea, tiny, green, see, float, dioxide, shines
2. The letters c and g have two pronunciations, depending on the subsequent letters: green/algae/glass

B. A single vowel medial in a one-syllable word usually has its short sound: plants, sun.

A final e is generally a marker to indicate the long sound of the preceding vowel: shine

C. Consonant digraphs: shows, shines, they

Initial consonant blends: plants, green, float

Some consonants seldom appear singly at the end of a one syllable word or accented syllable: glass

FIGURE 2 Science near and far: Basic skills.

vance. The fifth activity involves writing and asks students to prepare a set of appropriate questions. Questions can be collated, and each student can answer the questions of other students and judge the merits of various questions. The activities conclude with a class-wide discussion, with the strong likelihood that all students will be prepared to participate. Neither Figure 2 nor Figure 3 is intended to represent lessons. They are included only to demonstrate how numerous components of reading can be applied to expository text.

Most students are taught reading through the use of a reading program of some type. It is expected that the student will become proficient with the basic principles of reading and then use them while reading expository text. Many students do not see the connections between what they learned in reading and do not recognize or

There are millions of plants in a glass of seawater. They are tiny green plants called algae. The picture shows the algae are much larger than they are. You cannot see algae, but all the animals of the sea depend upon them. The algae float in water. They take minerals from the water. They also take in carbon dioxide that is dissolved in water. The sun shines on the green algae. They make food and grow.

First Reading: Teacher prepares True/False comprehension assessment.

Second Reading: Teacher prepares multiple-choice comprehension assessment.

Third Reading: Teacher prepares comprehension assessment in form of open-ended questions.

Fourth Reading: Teacher prepares comprehension assessment by giving student list of questions and having student mark best questions to ask.

Fifth Reading: Teacher prepares comprehension assessment in a form that asks students to write set of questions for passage.

Sixth Reading: Teacher prepares comprehension assessment in a form that asks students to rewrite the passage.

Seventh Reading: Teacher prepares comprehension assessment in a form that asks students to write to author and pose certain concerns about passage.

Eighth Reading: Teacher prepares comprehension assessment in the form of a class discussion about the passage.

FIGURE 3 Science near and far: Comprehension.

apply the basic principles to expository text. The illustrations in Figure 2 show how selected principles of reading can be applied in science text. The teacher can use elements from both the reading and the science text to illustrate the connection.

SUMMARY

The general purpose of this article was to relate selected facets of literacy to science for students with learning disabilities. The illustrations provide support for an orientation that suggests teaching

science via procedures that are minimally dependent on literacy skills and processes and integrating literacy into science after the student acquired a science knowledge base. Therefore, it is not necessary to deprive students of an appropriate science program simply because their proficiency in literacy skills and processes is limited. This view is consistent with the general assumption that students learn about reading and writing when they are reading and writing about things they know. This is an important consideration for the teacher, because many students may know a great deal about science, but may not be able to read or write well enough to demonstrate this knowledge. For example, a teacher who wants to measure vocabulary might ask the student to write a sentence containing a specific term. The student may know the term, but may not be able to write. In contrast, a teacher who wants to measure writing may ask a student to write a sentence that contains a specific term, but the student may not know the term. In either case, the performance of the student may be misjudged.

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