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ABSTRACT

Designed to tap the rich collection of instructional techniques in the ERIC database, this compilation of lesson plans focuses on reading and writing activities for use in the high school science and math classroom. The 43 lesson plans in this book cover writing about science, reading about science, the vocabulary of science, short scientific writing assignments, long scientific writing assignments, and science and the imagination. The book includes an activities chart which indicates the focus and types of activities (such as small group activities, journal writing, poetry, vocabulary development, etc.) found in the various lessons. A 27-item annotated bibliography contains references to research and additional resources. (RS)

Reading and Writing across the High School Science and Math Curriculum

Roger Sensenbaugh

ERIC®
Clearinghouse on Reading and Communication Skills

EDINFO PRESS

Reading and Writing across the High School Science and Math Curriculum

by Roger Sensenbaugh

EDINFO Press

in cooperation with

ERIC Clearinghouse on Reading and Communication Skills

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ERIC (an acronym for Educational Resources Information Center) is a national network of 16 clearinghouses, each of which is responsible for building the ERIC database by identifying and abstracting various educational resources, including research reports, curriculum guides, conference papers, journal articles, and government reports. The Clearinghouse on Reading and Communication Skills (ERIC/RCS) collects educational information specifically related to reading, English, journalism, speech, and theater at all levels. ERIC/RCS also covers interdisciplinary areas, such as media studies, reading and writing technology, mass communication, language arts, critical thinking, literature, and many aspects of literacy.

TRIED is an acronym for Teaching Resources in the ERIC Database.

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Series Introduction

Dear Teacher,

In this age of the information explosion, we can easily feel overwhelmed by the enormity of material available to us. This is certainly true in the field of education. Theories and techniques (both new and recycled) compete for our attention daily. Yet the information piling up on our desks and in our minds is often useless precisely because of its enormous volume. How do we begin to sort out the bits and pieces that are interesting and useful to us?

The TRIED series can help. This series of teaching resources taps the rich collection of instructional techniques collected in the ERIC database. Focusing on specific topics and grade levels, these lesson outlines have been condensed and reorganized from their original sources to offer you a wide but manageable range of practical teaching suggestions, useful ideas, and classroom techniques. We encourage you to use the citations to refer to the sources in the ERIC database for more comprehensive presentations of the material outlined here.

Besides its role in developing the ERIC database, the ERIC Clearinghouse on Reading and Communication Skills is responsible for synthesizing and analyzing selected information from the database and making it available in printed form. To this end, we have developed the TRIED series. The name TRIED reflects the fact that these ideas have been tried by other teachers and are here shared with you for your consideration. We hope that these teaching supplements will also serve as a guide or introduction to, or reacquaintance with, the ERIC system and the wealth of material available in this information age.

Carl B. Smith, Director
ERIC Clearinghouse on
Reading and Communication Skills

USER'S GUIDE for
Reading and Writing across the High School Science and Math Curriculum

LESSON DESIGN

These lessons offer ideas that were first tried and tested in the classroom environment, and then reported in the ERIC database. The ED numbers for sources in *Resources in Education* (RIE) are included to enable you to go directly to microfiche collections for the complete text, or to order the complete document from the ERIC Document Reproduction Service (EDRS). The citations to journal articles are from the *Current Index to Journals in Education*; these articles can be acquired most economically from library collections or through interlibrary loan.

Beginning with the resources as found in the ERIC database, these lessons have been redesigned with a consistent format for your convenience. Each lesson includes the following sections:

Source (your reference to the original in the ERIC database)

Brief Description

Objective

Procedures

Results

space for your own Notes/Comments

The lessons are addressed to you, the teacher. In many instances, the TRIED text also addresses your students directly. These directions to the students are bulleted "•". Read these instructions to your students, or revise them, as you prefer.

You know your students better than anyone else does. Adapt these lessons to the ability levels present in your classroom. Some of the lessons were specifically written for certain levels, but they can be easily modified. Some lesson plans were developed for science classrooms but are equally applicable in the mathematics classroom. Think of these lessons as recommendations from your colleagues who TRIED them and found that they worked well. Try them yourself, improve on them where you can, and trust your students to respond with enthusiasm.

Table of Contents

Using Language to Learn Science and Math

Students enter mathematics and science classrooms in middle and secondary schools knowing, for the most part, how to read and write. They expect to be told which parts of the chapters have to be read by which dates. They expect that what little writing they will have to do will be restricted to those detestable "story problems" that we all hated in math classes, lab reports, multiple-choice exams, and the occasional essay question on science quizzes. They expect that the vocabulary they must memorize will be highlighted in the text, and that all they have to do to learn those words is to find them in their textbooks and copy down a definition on a separate piece of paper.

Recognizing this sorry state of affairs, this breakdown between scientific thinking and the intelligent use of language, I have compiled this collection of lesson plans by drawing tried and tested material from the ERIC database. These lesson plans were originally designed by science and math teachers who realized that student expectations like these are not the basis of effective instruction. I have redesigned these lessons somewhat to assist you and your students in the following ways:

1. Effective reading strategies have been developed so that you and they can get the most out of textbooks.

2. Effective writing strategies help your students learn the science presented in lectures, demonstrations, films, discussions, and laboratory exercises.

3. These reading and writing strategies can add up to an effective vocabulary-learning effort.

To use these lessons, you do not have to become a reading teacher or a writing teacher, nor do you necessarily have to make room in an already crowded curriculum for new, special reading-and-writing activities. I am not proposing that you drop instruction in scientific topics to make room for English. Instead, these lessons let you build good language usage into your already existing science and math curriculum; they help you get the content across, rather than obstructing your efforts. The potential benefit to your students makes the adjustment of your teaching worthwhile.

Our Common, Slow Start

The science and math instruction that I received in high-school and college conformed to typical, low-level expectations. In spite of the lackluster instruction that I received, I maintained my interest in science and math by spending afternoons in the library. I read Einstein's popular writings, and glimpsed the mysteries of quantum mechanics through articles in *Scientific American*. In college, science instruction improved somewhat with the addition of a term paper in upper-division courses, yet most students' papers were perfunctory. We were still expected to read and understand science textbooks on our own.

I was not introduced to "writing across the curriculum" until, quite early in my teaching career, an enthusiastic colleague shared with me his ideas on using writing and cognitive skills to help students learn science and math. I tried some of his ideas, liked the results, and started learning more about content-area reading and writing. My education continues to this day, and this book is based on what I have learned so far.

The following lesson plans need not be implemented exactly as presented. You know your students' needs, abilities, and experiences better than I do. For this reason, each lesson presents a *number* of options concerning implementation. If, however, you are not particularly expert at using reading strategies, the writing-to-learn approach, and teaching vocabulary through direct instruction, then I suggest that you follow these lessons fairly closely at first.

This book does not provide the theoretical bases that undergird the techniques included, nor does it replace in-service teacher education. If you want to learn about recent developments in content-area reading or writing across the curriculum, and to incorporate these practices into your teaching, then you need more than what this, or any other, set of lesson plans offers: You need the support of administrators, the guidance of teacher educators, and the collegiality of your fellow teachers. Sooner or later, you will want to get a theoretical grounding as a foundation for the implementation of lessons like these and others that you yourself might devise. Meanwhile, following these lesson plans will get you off to a running start.

Three Issues at Stake

1. active learners *versus* passive learners
2. class discussion and small-group instruction *versus* the lecture method and rote learning
3. direct vocabulary instruction *versus* students writing down dictionary definitions of words

1. Student Involvement

Encourage your students to become active and involved readers and learners. The reading strategies presented in this book are designed with as much student involvement as possible in mind. You do not want your students merely to read the text once through, and then look over end-of-chapter material prior to the exam. Instead, you want them to draw on their prior knowledge of what they are about to read, make predictions about the concepts they are encountering, use their imaginations to visualize representations of ideas that they read in the text, correct their predictions while reading the text and as their knowledge base grows, and then return to the text after reading, discussing, and thinking to compare their own conclusions with the author's.

You want your students to use writing in a variety of contexts to help them learn the material. Worksheets, fill-in-the-blank lab-report forms, and similar teacher-generated materials that reduce students to passivity in learning, are nowhere to be found in this book! Instead, I propose that you set the example before your students in your own daring display of new strategies, your monitoring of existing strategies, and your invention of variations on existing strategies. Be an active, independent, inventive teacher, and you will help your students to become active, independent, inventive learners.

1 1

2. Class Discussion

Class discussions can be an exciting and effective way for students to learn science. While an occasional formal lecture can be quite useful to get across detailed and complicated subject matter, exclusive reliance on the lecture method as a steady diet is to be avoided. A considerable amount of talking things over is called for in these lessons, and it is important for you to lead, but not to dominate, the discussions.

As a teacher, I myself have experienced the disappointment when a carefully prepared lesson involving class discussion degenerated into the echo of my monologue drifting back to me from the bored faces of my students. I have also experienced the thrill of my students getting so wrapped up in an all-out group discussion that, before anyone noticed, the class period had ended.

Science is fascinating and math is challenging, and both can be great fun. I guarantee that if you turn on your students' minds to the active acquisition of scientific knowledge and mathematical reasoning, the discussions prompted by these lesson plans will cause enthusiasm among your students to run high. The memory of one lively, satisfying discussion with your students will sustain you through many a stale question-and-answer session and lecture monologue.

Some of these lesson plans call for students to work together in small groups. Students working in small groups experience a social interaction that is often lacking in the classroom. A few suggestions are in order to keep the groups working effectively:

- ☞ Give the groups a clearly defined task to complete.
- ☞ Do not let the same students form the same groups every time.
- ☞ Move from group to group to monitor progress.
- ☞ Have the groups complete some form of a written document as concrete evidence that something was accomplished in the groups.

3. Direct Vocabulary Instruction

Effective vocabulary instruction is essential, particularly in science and mathematics where the vocabulary is specialized. Scientific and mathematical terminology, because it is often built on Latin, Greek, and other foreign-language loan words, is difficult for students who do not read much. Scientific and mathematical language is also precise. Precision in language, however, may quite possibly be a new experience for teenagers accustomed to sloppy thought and lax speech.

Don't leave your students on their own to look up the definition of terms highlighted in the text; they need your direct instruction in how to find the meaning of these terms in ordinary dictionaries and specialized glossaries. A sentence lifted from the text including the highlighted word is not an adequate approach to the definition of complex terms. Arriving at the meaning of scientific and mathematical concepts is not simple.

The vocabulary-development strategies included in this book offer a variety of ways for students to relate new concepts to their existing knowledge and to the textbook. Students actually *use* their new vocabulary instead of merely copying a definition from a book. Students *experience* the vocabulary words in a variety of contexts.

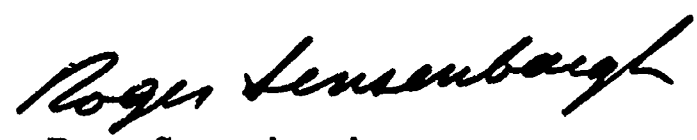
One issue that has haunted me through the production of this book is the tenacity of incorrect prior knowledge. Many teenagers in today's schools have bought into an idea prevalent in psychology and the "soft" sciences that if something is true or right "for me," then it must be true and right. This rather over-generalized, slippery application of Relativity Theory to the thinking process is unacceptable in disciplines in which precision of measurement and reporting, verifiability and falsifiability of concepts, and testing and reformulating of hypotheses are essential to method. If geography is the subject matter, Moscow may not be located in the Crimea, no matter how right it may "feel" to a given student; nor are feelings enough to go on when mixing up an experiment in the chemistry lab, either. To be asked to think, perceive, and speak with a concern for objectivity may come as a surprise to some of your students, and it will involve them in getting over the subjectivities of their own incorrect prior knowledge.

Science Is an Endeavor to Distinguish between Fact and Falsehood

Many of the lessons in this book call for students to activate their prior knowledge as the first step in learning science. Important as prior-knowledge activation is, however, the danger exists that incorrect prior knowledge will be reinforced despite refutation in the text, explicit classroom instruction, and your students' own empirical observations and rational reflection.

I witnessed reinforcement in false knowledge for the first time when I was a high-school physics student. A question on an exam asked us to draw the path of an object after it was dropped by a person traveling at a constant velocity. Many of the students thought that the object would fall straight down. They could not be convinced that the path was parabolic, and that the object would fall ahead of the point directly below where the object was dropped.

Years later, while discussing the production of this book with an intelligent, adult non-scientist, this issue of incorrect prior knowledge came up. She insisted that she had learned in high-school physics class that such an object would fall straight down. She even insisted that she had proved her theory on the school bus later that day. This tenacity of falsehood demonstrates just how careful and assiduous you must be in recognizing, and then in eradicating, your own and your students' incorrect prior knowledge.



Roger Sensenbaugh

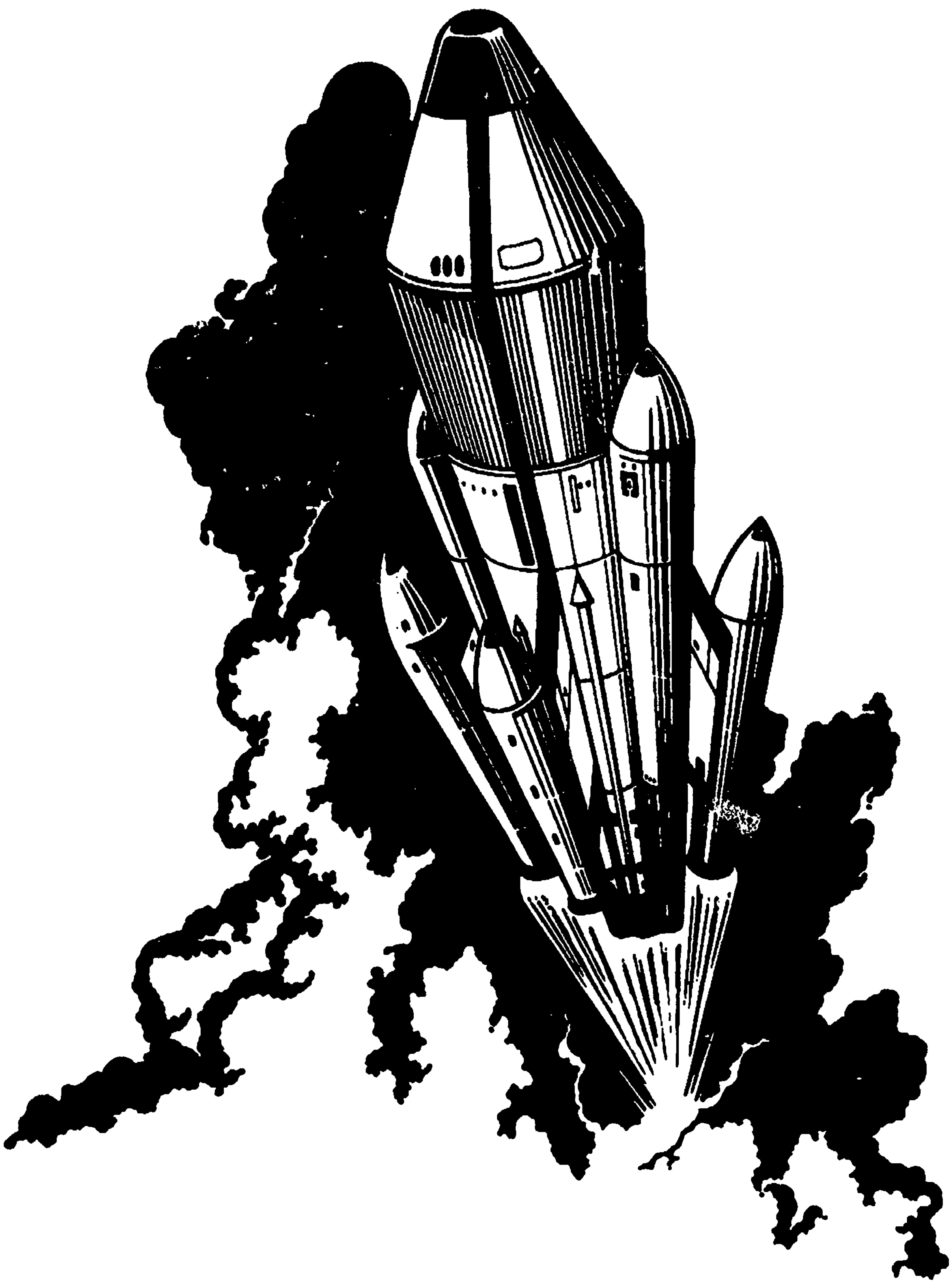
Activities Chart

	Science	Math	Small-Group Activities	Writing Assignments	Reading . . .	Vocabulary Development	Journal Writing	Outside Reading	Visual Aids	Discussion	In-class Writing	Science Fiction	Poetry	Study Guides
Part One: Writing Science														
Writing-to-Learn (p. 2)	X			X										
Biology and English (p. 4)	X					X				X				
Journal Writing (p. 6)	X	X					X				X			
Class Logs (p. 8)	X	X		X							X			X
Part Two: Reading Science														
Framing Science (p. 11)	X	X			X				X		X			X
Generic Frames (p. 15)	X	X			X				X	X	X			X
Clustering (p. 20)	X	X		X					X	X	X			
Higher-Order Geometry (p. 23)		X			X					X	X			
SQ3R in Science and Math (p. 27)	X	X			X					X	X			X
Analogical Study Guides (p. 31)	X	X			X					X	X			X
Overcom'ıg Incorrect Prior Learning (p. 34)	X				X					X				
Flatland: Geometry (p. 39)		X			X			X		X				
Humanizing Science (p. 41)	X			X	X			X		X				
Part Three: Wording Science														
Vocabulary Selection (p. 45)	X	X				X								
Using Graphic Organizers to Teach Vocabulary (p. 48)	X	X			X	X			X					X
List-Group-Label (p. 50)	X	X	X		X	X			X	X				
Possible Sentences (p. 52)	X	X	X		X	X				X	X			
Feature Analysis (p. 54)	X		X		X	X			X	X	X			
Concept Maps (p. 56)	X				X	X			X	X	X			X
Part Four: Short Scientific Writing Assignments														
Science Fiction Stories (p. 59)	X			X								X		
Interrelationships (p. 61)	X			X							X			
Brief Writing Assignments (p. 63)	X			X			X						X	

Activities Chart (continued)

	Science	Math	Small-Group Activities	Writing Assignments	Reading . . .	Vocabulary Development	Journal Writing	Outside Reading	Visual Aids	Discussion	In-class Writing	Science Fiction	Poetry	Study Guides
Short Writing in Math (p. 65)		X		X		X				X	X			
Expressive Writing (p. 69)	X		X	X			X				X			
Variety in Short Writing (p. 72)	X			X										
Writing to Learn Algebra (p. 76)		X									X			
Writing Dialogues (p. 79)	X	X		X										
Error-Filled Essays (p. 83)	X	X		X	X			X		X				
Problem-Solving Methods (p. 85)		X	X	X	X		X							
Part Five: Long Scientific Writing Assignments														
Existing Knowledge (p. 90)	X			X				X						
Science/Science Fiction (p. 92)	X			X				X		X		X		
Writing a Term Paper (p. 95)	X			X										
Descriptive Writing (p. 98)	X			X										
Science and Metaphor (p. 100)	X			X	X		X	X						
Long-term Writing in Math (p. 102)		X		X				X						
Part Six: Science and Imagination														
Writing Poetry (p. 105)	X			X									X	
Turning Images into Poetry (p. 106)	X		X	X									X	
Poetry Writing (p. 108)	X			X									X	
Drilling for Oil (p. 111)	X		X	X				X		X				
Audio-Visual Materials (p. 113)	X		X	X										
Consumer Values (p. 115)	X		X	X							X			
Writing a Laboratory Report (p. 117)	X		X	X						X	X			
Collaborative Writing (p. 120)		X	X	X						X	X			

Writing Science



Writing-to-Learn: The Wedding of Science and English

SOURCE

Kirkpatrick, Larry D. and Adele S. Pittendrigh, "A Writing Teacher in the Physics Classroom," *Physics Teacher* v22 n3 March 1984: pp 159-64.

Brief Description

Students write weekly essays following a suggested format in which they explain to a knowledgeable peer a given physical concept.

Objective

To improve students' comprehension of scientific concepts by writing an essay that is clear in its meaning, logical in its construction, and relatively easy to read.

Procedure

A science teacher and an English teacher collaborated to invent a way for writing to help their students learn science and math. The approach, designed initially for students who were not scientifically inclined, benefited not only the less-willing scientists but also the science buffs.

The science teacher's course—an introductory, college-level, non-mathematical physics course—had involved essay-writing as part of the one-hour exams, but the resulting exams were often so wretched that the teacher could not tell whether the students had failed to grasp the concepts or were stymied by the act of writing.

Teamwork between the science teacher and the English teacher led to a shift away from writing only as a test-taking means to writing also as a means to learn.

This change from writing as an examination of students' knowledge—a threat—to writing as a help to master course content—a blessing—is basic to the concept of writing-across-the-curriculum.

Many students have the necessary skills to write in an acceptable fashion, but they are so lacking in experience that they never learn to apply their language skills outside of an English class. Their writing skills are typically called upon only in those rare encounters with an essay question on an exam. In order to help students to construct logical, clear, and concise prose, offer them a RAFT, to define the writer's Role, Audience, Format, and Task.

- Role: What role do you, the student writer, play? Are you a knowledgeable expert, a humble enquirer, a bright and witty critic, a struggling researcher?
- Audience: For whom are you writing? For another student who does not understand the problem? For someone who understands a little physics? For someone totally ignorant of physics?

(Hint: You have already written for the teacher as your audience. Try writing for a different audience.)

- Format: Here is a suggested format for your essay:
  1. Present a "key idea" in the first sentence that will indicate to the reader right away that you know the answer to the question.
  2. Present the main ideas, terms, and relationships of the scientific discipline involved in your answer to the question.
  3. Apply these ideas and terms to the specific case with which you are dealing.
  4. Add additional insights that may further explain the scientific information. Use similes, metaphors, and analogies to get your ideas across.
- Task: Your task is to answer the question as clearly, logically, and completely as possible.

Since students need practice in implementing this approach, have them work in pairs or small groups to collaborate and come up with an answer to sample questions. Reproduce and disseminate student-written answers to the sample questions as a model to guide other students in their writing. The important element in this part of the procedure is to make the helpful experience of writing-to-learn as different as possible from the unpleasant experience of writing-to-be-tested.

Results/Benefits

Students' performance on essay exams tends to improve greatly after they become proficient at writing-to-learn. Poor answers caused by lack of understanding of the concepts, rather than by problems with writing, can more easily be improved. Most students become convinced that writing helps them learn.

Evaluation

A wide variety of options is available for evaluation. The method you choose depends on the size of your class, the performance of your students, your own estimation of the relative importance of these exercises in determining the final grades, and the amount of time you feel you can spend grading the essays. If you assign ten essays to be written throughout the term, only some of these need to be graded, and the students do not need to know which essays will be graded and which not. Score the essays holistically on the basis of organization and clarity of the writing, as well as on the accurate presentation of the scientific concepts.

Cooperative Teaching: Biology and English

SOURCE

Greene, Joyce G. "Broadening the Scope of Biology Education," *American Biology Teacher* v39 n8 1977: pp. 491-94.

Brief Description

Four specific ways in which English and biology teaching can be combined.

Objective

To broaden the scope of biology education by helping students bridge the gap that many see between biology and the language arts.

Procedure

The activities described in this lesson were developed for a joint "bio-English" class in which the expository writing teacher and the biology teacher shared the same group of students. Most of the time, the class periods were taught separately. Some activities require a cooperative English teacher.

I. Greek and Latin roots

Many scientific terms have Greek or Latin roots, and some combine both Greek and Latin. Some examples include these:

anthropod	arthropod	exoskeleton
endoskeleton	deoxyribonucleic acid	hyperthermia
hypothermia	heliotropic	aerobic
anaerobic	endomorphic	ectomorphic

Choose some difficult polysyllabic words; then during a class discussion, break the words into syllables. Discuss the Greek and Latin roots from which the words are derived. Teaching your students the meaning of common Greek and Latin roots can help them to understand better the concepts which lie behind the words. For example, students sometimes confuse "anthropod" and "arthropod." Knowing the difference in meaning of the roots "anthro" and "arthro" will go a long way in helping them to avoid confusing these terms.

II. Clear, dynamic, concise writing

Assign students short essays on a particular unit of study. These essays can then be graded by you for scientific accuracy, and by a cooperative English teacher for grammatical accuracy. This interdisciplinary approach might allow students to receive credit in their English class for their essays. The English teacher might suggest more imaginative vehicles for student compositions than the usual essay. For example, students may write poetry using topics drawn from their current unit of study in their science course. Another approach is to have students write humorously, fictionally, or futuristically about a particular topic they are studying. Students have responded to this assignment with amusing flights of fancy while using correct scientific terminology and accurate scientific understanding.

III. Research paper

Perhaps with the cooperation of an English teacher, you can assign your students to research and write a term paper on a scientific topic. The English teacher can assist the students in the procedures for researching and writing the paper, while you assist them in choosing a topic, clarifying the scientific content, and expressing their perceptions in a scientific manner. Your students will have the incentive to write better papers if they can receive credit in both classes for their work. Of course, receiving double credit also means that they will be expected to do double the work, that is, satisfy your requirements of producing good science writing while satisfying the English teacher's requirements of producing good writing and research form.

IV. Towards Orientation on Problems in Contemporary Science and Society (TOPICSS)

The capstone of the "bio-English" class, TOPICSS is a Humanities approach to the problems of science and society consisting of class discussions based on literature, films, and magazine and newspaper clippings. Present to your students the many sides of issues such as genetic engineering, organ transplants, over-population, destruction of the environment, global warming, nuclear power, and so on. Encourage your students to remain receptive to the ideas of their fellow students. Discussions among the students and the teacher of a "bio-English" class can easily become heated; you will find that some of your students are stimulated to search for more information on a subject that has personal, ethical, religious, or other commanding interest for them.

Results

Biology comes alive for students when they see the interrelatedness of biology and English. Through small-group work; frequent, short, creative writing assignments; lively class discussions; and the writing of research papers on a scientific theme, science instruction can be broadened.

Jourı ıal Writing

SOURCE
ED 238 725
Wotring, Anne Miller and Robert Tierney. "Two Studies of Writing in High School Science. Classroom Research Study No.5." Developed by the Bay Area Writing Project, 1981.

Brief Description

Students write in journals when they are confused about course material or when difficult material is covered.

Objective

To help students reflect on their thoughts, to take responsibility for their own learning, and to begin to raise, and answer, their own questions.

Procedure

Have your students obtain a durable notebook, loose-leaf binder, or other device in which thoughts written down can be saved. Durability is important because your students will be using the journal throughout the year.

Opinions differ about how often, and for how long, students can write effectively in their journals. Options include the following: five minutes at the beginning or end of class, every day or once in a while; out-of-class once a week; before, during, or after reading; or whenever the mood strikes them. The decision on how often, and in what context, your students will write in their journals, is up to you. At first, it may be best to use class time to write in the journals. Then, when the students have gotten into the habit of writing, you can have them write out of class.

This activity consists of two parts: getting your students to write in a journal, and having you respond to their journal entries.

A. Student Input

It is important to make clear to your students the purpose of keeping a journal. Suggest that they use it to do the following:

☞ To discuss concepts or vocabulary that they do not understand

☞ To comment on the material in their textbook

☞ To document something new that they learned, or something they want to understand better

☞ To ask direct questions of you, the teacher

☞ To figure out why they are having problems learning the material

☞ To offer suggestions concerning how the class is run

☞ To respond to a topic that you suggest

A good way to make clear to students how to keep a journal is for you to keep one yourself, and share excerpts from time to time with your students.

The purpose of journal-writing is to help your students clarify their thinking, and to learn the subject better by working through the difficult material. Unless students stick to using journals to sort out their ideas, however, journal-writing can easily degenerate into an exercise in filling up paper with random thoughts, or into an exercise in trying to impress the teacher.

B. Teacher Response

Opinions also differ on how often, and to what extent, teachers can most effectively respond to student journal-writing. How often you choose to collect the journals, and read them, depends primarily on your own perception of your workload. Responding to student journals need not take a great deal of time, but periodic response is important for the students to realize that writing in a journal has some merit. Writers write to be read by readers. Too-infrequent or overly-terse response from you will discourage your students from using their journals effectively.

When reading student journals, avoid correcting students' errors in grammar and spelling. Write responses to their journal entries in the form of a journal entry, i.e. engage in a running dialogue with your students. Respond to a question that the student raised; suggest ways that a student might improve his or her performance; relate something that one student says in a journal to something another student says in a journal, and propose that they talk it over. Temper criticism with praise (when praise is deserved), and phrase criticism as positively as possible. Journal-writing builds students' self-esteem when what they write is taken seriously and not just marked up and returned.

Results

One teacher analyzed her students' journals and found that journal-writing was successful in provoking students to reflect on their own thoughts, take responsibility for their own learning, and begin to raise and answer their own questions. Anecdotal evidence of the usefulness of journal-writing appears often in professional periodicals and in presentations at professional conferences.

Class Logs

SOURCE

Socha, ˈ san C. "Math C.ass Logs," *Mathematics Teacher* v82 n7 October 1989: pp. 511-13 .

Brief Description

One student each day is responsible for keeping a detailed account of the lesson and the homework in a class log.

Objective

To provide a record of lessons and homework for students who miss class, to help students improve their note-taking skills, and to provide a record of how at least one student each day grasps the content of that day's lesson.

Procedure

Obtain a separate notebook for each class in which a log is to be kept. On the inside cover, attach a list of your students' names. You write the first log entry, demonstrating to your students what is to be included in each log entry. Discuss the log entry with your students. Give the log book to the student whose name is at the top of the list. The next day, that student passes the log book to the next student on the list, and so on.

Exactly what you decide to have your students include in the log is up to you. Suggestions for items to be entered into the log include the following:

☞date of entry

☞homework assignments

☞record of announcements

☞copies of any handouts

☞clearly written examples of problems presented in class

☞the log keeper's own comments

☞examples of diagrams used in class

Even when students include all that you ask, expect that your students' log entries will differ considerably in both quality and format.

For the first few days, you may wish to discuss with your students how the log is progressing. Encourage your students to consult the log if they have questions or doubts concerning material that was covered in class. Tell them that seeing how their peers put the material into words and symbols may clear up problems or questions that they have. If you use the log in more than one class for the same subject, allow your students to see those logs as well. The number of turns each student takes in keeping the log will depend on the length of the term and the number of students in the class.

Your students will be able to develop their own note-taking strategies better if you do not prescribe a detailed format to follow for the log entry. Allow your students some freedom in presenting the material that you require them to include. Even when students are not absent, encourage them to look over the log to see how their fellow students take notes, and to provoke discussion of topics and issues. Keep the log in an area easily accessible to the students.

Consider keeping a supply of carbon paper in the log so that the student keeping the log can have a copy of the entry. At the end of each day, evaluate the entry and award credit. One teacher who uses this technique developed a simple checklist to apply in evaluating each entry, determined a certain number of points for the entry, and added those points to the student's lowest quiz score. You can determine your own reward system.

Results

Students can review quickly, in the language of their peers, what occurred on any particular day in class. Students improve their note-taking skills by taking notes themselves and by seeing how their fellow students take notes. You can see how at least one student per day perceives that day's lesson. Students absent for long periods can be provided with a complete record of class activities with no additional effort on your part.

Comments

Reading Science

Framing Science

Brief Description

A visual representation ("frame") of passages from science texts are fashioned by teachers working with their students. These frames can then be used before, during, or after reading a given passage.

Objective

This strategy is designed to help students identify and use the structure of their textbooks to understand better the main ideas of particular passages. The relationships among the subordinating ideas is also brought out as the frame is enlarged.

Procedures

The term "frame" may be unfamiliar, but the concept is familiar. Graphical representations of main ideas, and relationships among ideas, can appear as charts, tables, or matrices. Semantic maps and graphic organizers can also be frames. The important characteristic of a frame is that it is a graphic representation of main ideas and relationships among ideas.

As with many of the lesson plans on reading in this book, this lesson begins with the teacher demonstrating the strategy several times and then gradually shifting the burden of completing the strategy to the student.

Few students understand the structure of their own textbooks, and poorly written texts only make the task of teaching text structure that much more difficult. Restrict your early attempts at constructing frames to those passages of text that are clearly written and that contain fairly simple main ideas and related concepts.

You may choose to design the frame for a particular concept ahead of time and present it to the class; however, the students will benefit more if you work through the process of designing a frame in front of them, explaining your thinking as you go.

Framing usually begins by activating your prior knowledge of the concepts presented in a passage, and then by guessing at a provisional frame. Then, after reading the passage, alterations can

SOURCE

ED 331 022

Armbruster, Bonnie B. "Framing: A Technique for Improving Learning from Science Texts," in *Science Learning: Processes and Applications*, edited by Carol Minnick Santa and Donna E. Alvermann, 1991, chapter 11.

be made so that the frame more closely reflects the ideas in the passage. The particular form that the frame will take depends on the structure of the passage. The complexity of the frame depends on the complexity of the ideas contained in the passage.

Sample Frames

Machines

Definition: A simple machine is. . .				
	Simple Machines			
	Levers	Gears	Ramps	Wedges
Definition				
Diagram				
How they work				
How they are used				
Uses in/with other machines				
Examples in nature				

Types of Radiation Emitted from Uranium Ore (as investigated by Ernest Rutherford in the early years of the 20th century)

	Alpha Rays	Beta Rays	Gamma Rays
mass	about 4 mass units	5×10^{-4} mass units	0
ionizing ability	ionizes air	ionizes air	ionizes human flesh
speed	about 1/10 speed of light	almost speed of light	speed of light
penetrating power	weak—stopped by single sheet of paper	greater than alpha, stopped by thin sheet of aluminum	very penetrating, takes several centimeters of lead to stop

You may find that your students need practice in working with frames before they become proficient (or willing) to build and use them on their own. One key to effective instruction using frames is never to do the same thing twice. Vary the amount of student input into construction of the frame. Vary the complexity of the passages selected for frame construction. Vary the choice of graphical representation chosen to reflect the concepts. Model the process of framing in the presence of your students; have them design frames individually or in groups; hand out partially completed frames and require your students to complete them. Use frames at different stages of reading several passages—before, during, and after. (You do not necessarily need to use a frame before, during, and after reading for the same passage.)

A. Frame before Reading

Students can begin activating their prior knowledge of the material covered in a passage by trying to form their own frames. They then can check their frames against the text, and they can revise their initial frames to match the presentation in the text.

Warning: Convincing students who hold incorrect prior knowledge that they are wrong, can be tricky. Incorrect prior knowledge, when it appears in students' frames, needs to be corrected either by the students themselves or by you in as non-judgmental a way as possible.

An alternative way to begin is to pass out blank frames, and have your students brainstorm the content of the frame, drawing on their prior knowledge (whether it is correct or not). If students demonstrate little prior knowledge, instruction can shift to trying to build up their knowledge. When incorrect prior knowledge appears, instruction needs to be focused partly on chipping away at the false constructions.

However you begin, frames used as a pre-reading strategy focus the students' attention on the material they are about to read. They find out that, in most cases, they already know something about the topic. They may also begin to realize that what they know is not quite correct. They also can use the completed frames as a study guide during and after reading.

B. Frame during Reading

Used during reading, frames serve as a structure for note-taking. Frames, whether completed or not, showcase the information that is important—the first step in the note-taking process. Constructing a frame requires that the students discriminate between more-important and less-important information.

Filling in partially completed frames, or checking the information in completed frames, helps to make the process of reading a text an active one. Students are searching for information, comparing it to that in the frame, deciding whether or not the frame is adequate, etc.

Using frames during reading also helps to develop higher-order thinking skills. Students are classifying information, drawing inferences, and coming to conclusions as they figure out whether the information in the frame is correct.

C. Frame after Reading

After reading, students can use completed and verified frames as study guides. Also, blank or partially completed frames can be completed when reviewing for exams. Students (and teachers) can use the frames to generate questions that might appear on exams.

Results/Benefits

Many students lack an awareness of, or training in, recognizing text structure. It is difficult for them to identify the main ideas of science passages. These framing strategies are designed to serve students before, during, and after reading; to activate their prior knowledge, and graphically to portray sometimes complex concepts. If instruction is successful, the students will be able to develop frames independently for their own purposes.

Comments

Generic Frames

Brief Description

Students organize scientific information from books, newspapers, videos, magazines, filmstrips, etc. Presents four versions of two-column frames similar to those presented in the previous lesson, "Framing Science," but not so tied to text structure.

Objective

To help students organize scientific information from a wide variety of sources.

Procedures

In drawing each of the four frames described below, your modeling of the activity is essential. Once your students become adept at using the four frames, they can use them on their own to organize all kinds of information (scientific or otherwise).

SOURCE

ED 331 022

Harrison, Shirley. "Tools for Learning Science," in *Science Learning: Processes and Applications*, edited by Carol Minnick Santa and Donna E. Alvermann, editors, 1991.

A. Problem-Solution Frame

1. Topic Selection

   A good way to introduce this activity is to start with something familiar—ask your students to mention a problem that they find irritating, such as problems with parents, siblings, or a situation at school. Expect quizzical looks from your students at first, and then expect a flurry of suggestions. After choosing a problem for class treatment, write it on the board.

2. Effects

   Brainstorm with your students possible or known effects of the problem, and write these on the board.

3. Causes

   Brainstorm with your students logical or known causes of the problem, and write these on the board.

4. Resolutions

Brainstorm with your students possible resolutions of the problem, and write these on the board.

Problem-Solution Frame: Warm-up a Personal Issue

Problem	I always get bad grades.
Result	My parents ground me. I lose my freedom—car, entertainment. I lose my self-esteem.
Cause	I don't like teachers. The work is too hard. I don't do homework.
Solution	Pay attention during class. Take a study skills class. Do homework on a consistent basis. Change lab partners.

After warming up by dealing with familiar personal problems, the focus of instruction can turn to science. This activity works best when there is a fairly clear statement of the problem in whatever source of information is being read. In contrast to newspaper or magazine articles, textbooks rarely deal with timely or controversial issues.

Choose an article that is related to a science topic in the textbook. It is a good idea to model the activity for your students at least once, showing them the steps you go through in completing the problem-solution frame.

Problem-Solving Frame: Americans' Problems with Technology

Problem	Most Americans do not understand new technology.
Result	They're not informed on technological issues. Forty percent or more of Americans believe that flying saucers are real, rockets change the weather, and numbers bring good luck.
Cause	High-school graduates are unprepared to grasp day-to-day technological issues because they have not been adequately educated in school.
Solution	Require students to take more science. Emphasize technology in school. Educate teachers in science.

When students have become aware of how to structure and fill up their own frames, give them copies of another article, and ask them to develop a problem-solution frame. Next, demonstrate how a completed frame can be turned into a simple paragraph by using a sentence or two for the problem, effects, causes, and resolutions.

A good follow-up to this activity is to have your students complete frames on material presenting a different point of view. Once students realize that problems have more than one effect, cause, or resolution, expect a lively debate to ensue.

B. Theory-Evidence Frame

This activity is designed to help students begin to think like scientists. Students read an article and then write down in the first column what they think the author's theory is. Students then write down supporting evidence presented in the article. The last step in the theory-evidence frame consists of students writing down their own conclusions in the third column concerning the theory based on the evidence presented.

As before, it is best to model the activity for your students before having them develop frames on their own.

THEORY/EVIDENCE FRAME

Theory	Evidence to Prove Theory	My Conclusion
1. What the theory is: [Students write or summarize the author's theory.]	1. [Students list the evidence, usually in the same order as presented in the article.]	1. Did you modify your hypothesis?
2. Do you think the theory might be true? [Here students state opinions and hypotheses of their own.]		2. Why?

THEORY/EVIDENCE NOTES

Theory	Evidence to Prove Theory	My Conclusion
1. What the theory is: *Large asteroid about six miles in diameter crashed into earth, killing the dinosaurs.*	1. *Impact caused rise in earth's temperature; dust in atmosphere.*	1. Did you modify your hypothesis? *A little.*
2. Do you think the theory might be true? *The theory might be true. Dinosaurs would starve to death if there was no food to eat. But wouldn't there be a great big hole where the asteroid hit the earth?*	2. *Dust blocked off light; plants died, no food for dinosaurs; chilled the air and quick-froze the dinosaurs.*	2. Why? *The new discoveries in South America make the theory seem more probable, but they still haven't found the "big one" that could have killed the dinosaurs.*
	3. *Extinction was quick.*	
	4. *New evidence in Argentina.*	

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Completed frames, particularly based on different articles with contrasting points of view, can be used as a source of class discussion of the issue itself or as a means of seeing how scientists try to convince readers that their theory is correct.

Completed frames can also be turned into simple paragraphs that summarize the information contained in the articles.

C. Liked/Disliked Frame

Designed to help students activate their background knowledge and to support their opinions, this simple two-column activity focuses students' attention on the task. The source for the topic of the frame can be just about anything—lectures, films, videos, reading assignments, etc.

Students write down in one column what they liked, and in the other column what they did not like, about the material. These notes are then turned into a paragraph summarizing their reactions to the material.

LIKED/DISLIKED FRAME

Subject: Earth Science Film Evaluation

Title: "The Bridge"

What I Liked:	What I Disliked:
The way the narrator used metaphors and similes	Used words I didn't understand
The buffalo jump and the hunters	The first part about the bridge didn't apply to the rest of the film.
Place to escape	
Showed contrasting environments	

D. Question/Answer Frame

Designed to make reading of complex or poorly written material easier, this activity involves the students in writing down questions in one column based on textbook passages as they read, and then writing the answers in the other column. After reading, the students fold the paper in half, hiding the answers to the questions. They can now test themselves on how well they remember the material.

As with the other activities, teacher modeling is important to demonstrate to the students what the activity entails. You will probably find that most of the questions the students write require only very brief answers drawn from single sentences in the text. Your students will start writing better questions if you have them quiz each other using their questions. Students will begin to recognize the value of well-written questions after trying to answer their fellow students' poorly written ones.

To cut down on the number of questions looking for one-sentence answers from the text, ask your students to write questions requiring analysis, synthesis, and application. Start off by asking students to write only one such question, or encourage small groups to work together; then, as a class, discuss the features of a complex question. At this stage, the majority of questions will still require only the simple recall of information. You can motivate your students to write more challenging questions by offering more credit for more complex questions.

To keep this activity stimulating, vary the routine: Ask for a particular number of different types of questions. Use whole-class and small-group discussion techniques to analyze the questions. Have the students quiz each other. Have the students analyze the quality of each other's questions.

Results

These activities help students to deal with complex concepts. This approach teaches them to see through poorly written material. Students begin to think critically about science: They realize that a problem may have more than one solution; that sometimes supporting evidence for a theory is insufficient or just not convincing enough; that their opinions need to be supported by evidence; and that there are many types of questions that can be derived from a single text. These four frames also provide a variety of instructional approaches so that the word "boring" will be heard less often from students' mouths.

Comments

Clustering

SOURCE

EJ 428 278

Ambron, Joanna. "Conceptual Learning and Writing in the Sciences," *Teaching English in the Two-Year College* v18 n2 May 1991: pp. 114-20.

Brief Description

Students brainstorm words and phrases associated with a broad term around which a number of related terms can be clustered (words like "heredity," "genetics," and "cells") and then write a paragraph based on the connections made during the "clustering." This activity is well-suited to ESL students and to those with limited language skills.

Objective

Students gain access to their intuitive right brain through clustering, and then they use their discursive left brain to order the concepts logically.

Procedures

Designed as a supplement to the traditional lecture format, the clustering technique involves three steps:

1. selection of a nucleus word
2. brainstorming related words
3. writing a brief paragraph on an aspect of the resulting cluster of words.

1. Word Choice

After a lecture on some topic, you and your students choose a nucleus word. Generally, the nucleus word should be general enough that a wide variety of related words can be associated with it by the students. Write it in the center of the chalkboard (or on a transparency) and circle it.

2. Brainstorming

Next, have your students propose related words and phrases. Quickly write these on the board, circling those that associate with the nucleus word, and then connecting the new word to the nucleus word with a line. If some words proposed do not immediately fit, write them down anyway, but do not connect them yet. They may be connectable to the cluster later as other words are proposed.

Some of the words, in turn, suggest other words, and so a chain of connected words takes shape.

The key in this second step is speed: Do not give the left brain time enough (some seconds) to start ordering the words logically. Keep moving, and take advantage of the right brain's spontaneity and intuition to generate the concepts. Save the ordering of the words for the next step. At this stage, allow no criticism of any word proposed.

3. Writing

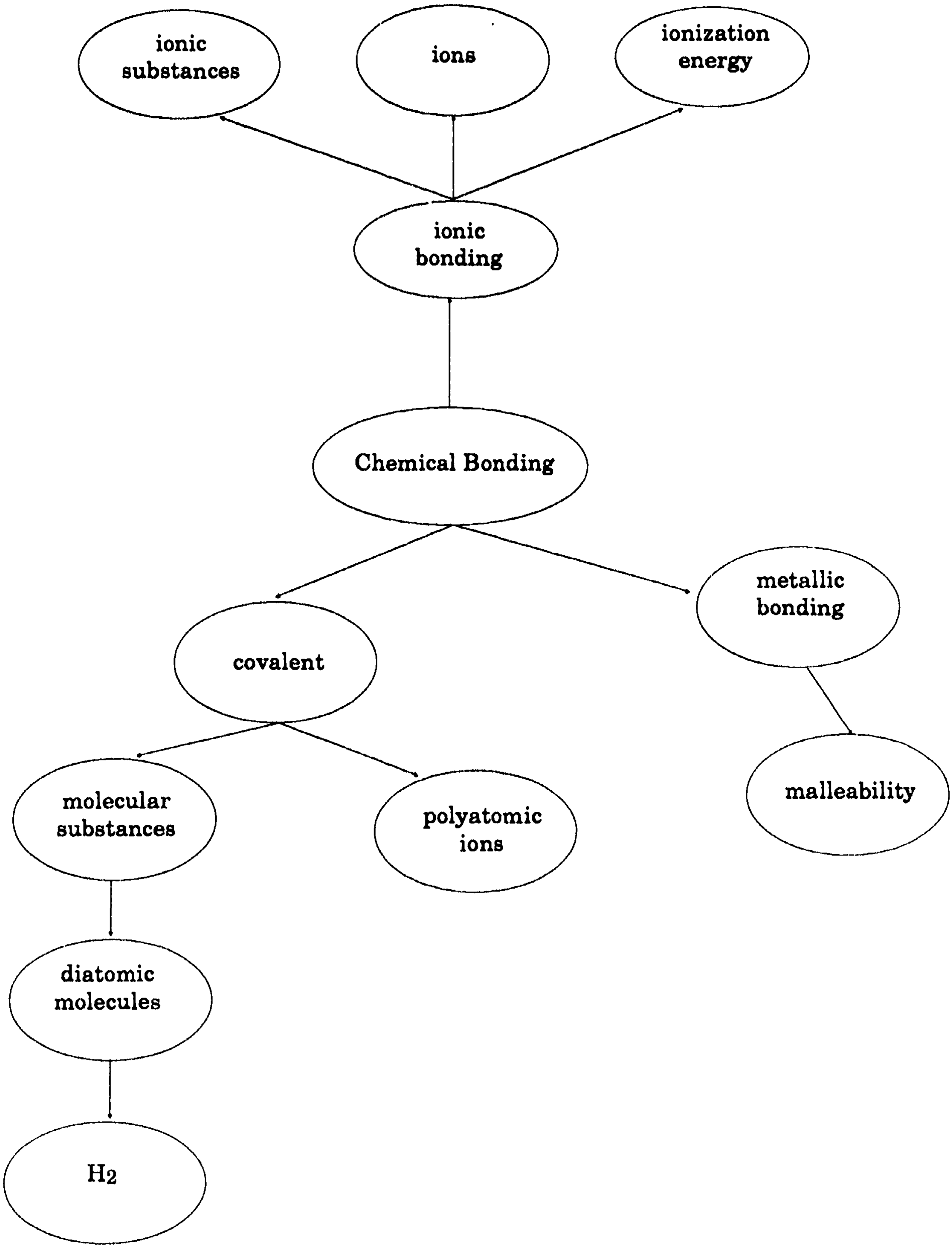
Allow about ten minutes of class time for the students to write on a particular aspect of the cluster that interests them. You will find that even students with limited language skills will be able to use a fair number of words correctly, although the grammar and spelling may lack polish. You will find your more advanced students using more terms with greater linguistic felicity.

The main point of the lesson is to separate the writing from the generation of the ideas represented in the cluster: The search for the appropriate linguistic conventions to link the words comes **after** the brainstorming; it must not get in the way of generating the words and ideas themselves. The students are free to let their minds churn out a stream of words and ideas based on the lecture they have just heard. Then, when it comes to writing something down, they have the ideas in front of them on the board, the screen, or their paper. All they have to do is impose some sort of order on the cluster of words in front of them.

Results

Clustering has been used in high-school and college science classrooms with great success. Students with limited proficiency in English are able to demonstrate proper use of scientific vocabulary in their writing. Students not burdened by limited proficiency also benefit from clustering as a prewriting activity. The completed cluster is also useful as a visual organizer.

A Cluster of Chemistry Words



Reading Science

Higher-Order Questions and Discussion of Geometry

Brief Description

Students and teachers ask each other questions requiring higher-order thinking skills as they discuss their geometry text and particular geometric proofs. Once familiar with higher-order questioning skills, students then attempt to write geometric proofs on their own.

Objective

To develop students' critical-thinking skills and higher-order self-questioning skills for use in analyzing and synthesizing the information required for writing proofs in geometry.

Procedure

A modification of a technique designed to help students improve their reading comprehension, this activity first develops your students' abilities to ask meaningful questions of the material in their textbook. Begin by engaging yourself in questioning techniques that move beyond literal-level questions to higher-level questions such as analysis and synthesis.

You and your students will be better able to ask questions requiring higher-order thinking skills if you keep in mind the following taxonomy (based on the work of Benjamin S. Bloom). Questions requiring simple recall of information to answer are at the bottom; questions requiring critical reflection for analysis are at the top of Bloom's taxonomy:

Bloom's Taxonomy
6. Evaluation
5. Synthesis
4. Analysis
3. Application
2. Comprehension
1. Recall

SOURCE

ED 307 121

Thornton, Karen. "Utilizing the ReQuest Procedure for Proof-Writing in Geometry."

Once your students become familiar with higher-order questioning skills, they can use them to analyze, synthesize, and evaluate the diagrams, given information, definitions, theorems, and propositions needed to complete geometric proofs.

A. Training students in questioning skills

You will need to establish the appropriate classroom environment before your students can feel comfortable asking the kinds of questions that will be necessary to complete this activity. Your students will be able to understand the questioning technique that you will be modeling if you use short sentences, speak slowly, and pause between utterances to allow time for the content of your model questions to sink in. Repeating, expanding, and rephrasing what you say will also help the students to understand. Your students can be encouraged to contribute their own questions if you acknowledge their verbal and non-verbal responses, and if you request information that only they can provide. As your students begin to ask questions of their own, you will need patience to let them rephrase their questions and correct themselves. Correct their questions and responses only when their errors interfere with meaning.

There may be times when your students run out of questions, and you, nevertheless, suspect that they have not yet understood the material. Try turning their statements into questions to give the discussion a boost. For example, the statement: "A and B are complementary" can be turned into the question: "If A and B are complementary, what can we say about them?" This question, asked of your students, should spur them to think of other questions as they try to answer your question.

B. Proof Writing

Now that your students are familiar (but perhaps not completely comfortable) with higher-order questioning techniques, they can begin to use the techniques to gather the information they need to complete the proof. Given a diagram and a statement of the proof to be made, your students begin by asking you questions related to completing the proof. Respond to these questions with just enough information to answer each question. Avoid elaborating on the questions—let your students follow up on any elaborations that you may leave unspoken. As your students uncover material relevant to completing the proof, write it on the board.

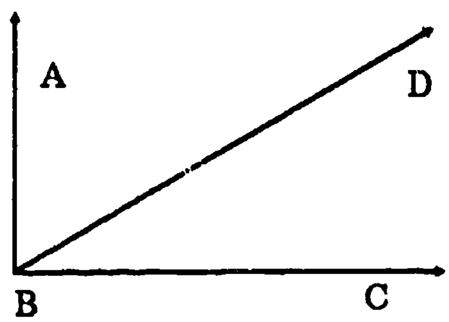
Once the students have asked all their questions, then it is your turn to ask them questions. Again, you should model higher-order questions for them. Design and formulate questions that fill in the information necessary to complete the proof.

Now that you and your students have gathered the information necessary to complete the proof, all that remains is for you and your students to write the proof in the standard two-column format. If you model the writing of the proof the first few times, then your students will become familiar with the process. You will find that most of your students will need less and less assistance in completing the proofs as they become more and more adept at asking (and answering) their own higher-order questions.

For example:

Given: $\angle$ ABD and $\angle$ DBC are complementary

Prove: $\angle$ ABC is a right angle.



Now have your students ask questions of you or of each other concerning how to go about proving the statement.

An example of a recall question (representing lower-level thinking) is this:

- "What does 'complementary' mean?"

A higher-order question (involving application) is this:

- "Of the many theorems we have studied on angles, which are of use here?"
- "What about the 'angle addition postulate'?"

Synthesis and evaluation questions will begin to appear as the board fills up with information.

- "What information do we really need to prove the statement?"
- "Do we have enough information yet?"

When you and your students have what you believe to be enough information, you can begin to fill in the standard two-column format for geometric proofs. Perhaps your students did not realize that they would need the transitivity property of equality to complete the proof. You knew it would be needed, but perhaps you were not successful in hinting that it would be needed. More questions can be asked at the stage of writing the proof. Ask them to write the proof in the standard two-column format.

Statement	Reason
1. ∠ ABD and ∠ DBC complementary	1. given
2. m∠ ABD + m∠ DBC = 90°	2. definition of complementary angles
3. m∠ ABC = m∠ABD + m∠ DBC	3. single addition postulate
4. m∠ ABC = 90°	4. transitive property of equality
5. ∠ ABC is a right angle	5. definition of right angle

While the end product of this activity is the traditional form for a proof, it is the process by which the proof was completed that is the crux of this activity.

Results

Students will learn one of the most difficult skills in geometry—writing a proof. They will also improve their critical-thinking skills by learning how to formulate higher-order questions based on material in their texts.

Comments

SQ3R in the Science and Math Classroom

Brief Description

Students survey the material in their text prior to reading; then they turn subheadings in the text into questions, read the text, recite the answers to the questions, and review the material.

Objective

To establish a purpose for reading the text by previewing it before reading; to monitor comprehension while reading; to summarize and review the content after reading.

Procedures

The SQ3R (Survey, Question, Read, Recite, Review) method has proved its worth since it was invented in the 1950s. Highly structured, yet easy to learn, SQ3R can be a powerful tool in helping your students understand and learn the material in the textbook.

SOURCE

EJ 378 628

Jacobowitz, Tina. "Using Theory to Modify Practice: An Illustration with SQ3R," *Journal of Reading*; v32 n2 Nov 1988: pp.126-31.

1. Survey

Students are to become familiar with the structure of the passage they are to read. Have them note the title of the section or chapter; read the first and last paragraphs; examine any graphs, charts, or other visual material. Also have them note subheadings, italicized or boldface words, and any summary material.

You may also ask your students to make some predictions concerning the material in the text. Some possible questions include these:

- What do you alread now about the topic?
- How does the late to the material already covered in the text?
- What are your thougnts about the topic?
-] the topic controversial?
- What do you think you will learn from this material?
- What do you want to learn about the topic?

The elements of questioning that have been included in the first step give added meaning to the act of reading the text. The students are now reading the text to answer these types of questions for themselves.

The rationale for this step is that students who are familiar with the macrostructure of the text generally get more information out of their reading of the material. The survey step also helps to trigger the readers' background knowledge.

2. Question

In this stage, your students turn chapter heading and subheadings into questions that they will answer later. The questions are typically based on the "who, what, when, where, why, and how" style of questioning. Work with your students to help them avoid writing down a series of trivial questions, or questions that require too brief, too simple answers. Encourage your students to write questions that involve application, analysis, synthesis, or evaluation of the concepts embodied in the chapter headings. (See Bloom's Taxonomy on p. 23.)

For example, in the left-hand column are headings for a chapter from a chemistry textbook on the liquid and solid phases of matter. In the right-hand column are questions based on the headings.

Chapter Heading:	**Questions**
The Kinetic Theory Applied to Liquids	How can we justify using a theory based on the gas phase to explain the liquid phase?
Subheads:	
evaporation	Isn't sweating like evaporation? If it is, then how, exactly, does sweating cool the body?
condensation	Is this just the opposite of evaporation?
vapor-liquid equilibrium	Does this mean that nothing is going on in a sealed vessel with liquid and vapor in it?
boiling	I think I understand "boiling," but there are pages and pages in this section. Why is it so complicated?
liquefaction of gases	Can you actually turn a gas into a liquid? It must take a great deal of effort to do that.
heat of vaporization	What does this term mean? I have no idea.
distillation	Now this I know about. Is it the opposite of "heat of vaporization" or is it more complicated?
sublimation	What does this term mean? I know a non-scientific meaning of "sublime," but I think that the text means something else.

Typically the most difficult step for students to master, the "question" phase involves turning chapter subheadings into questions. Some of your students lack prior knowledge of the material, and they find it difficult to generate questions. Others are not used to generating questions that require any but the simplest answers.

The thinking skills required to answer these questions will differ. You and your students want to avoid too many questions that require mere recall of information. Help students to rephrase some of the questions to incorporate application, analysis, synthesis, and evaluation of information from the book. (See Bloom's Taxonomy on p. 23.)

When completed properly, the question phase of SQ3R provides your students with questions to ponder, and answer, as they read.

3. Read

In this modified version of SQ3R, ask your students to predict the answers to the questions that they have formulated. Keep them actively involved as they read so that they will look for answers to the questions that they posed and be able to judge how well their predicted answers match the information in the text. Assure your students that guessing at the answers is acceptable at this stage.

As they read, have your students jot down any answers that occur. Encourage them to formulate more questions based on the material as they read it, and to write down these questions and their answers. This action keeps the students focused on the material, particularly those students who could not come up with very many questions before reading.

4. Recite

In this step, the students recite the answers to the questions developed in earlier stages. You can call for oral recitation of the answers to the questions, or have your students rehearse the material by writing and paraphrasing. Your students can incorporate the answers into an outline of the material developed from the headings and subheadings of the text. Encourage your students to write summaries of parts of the material. Writing these paraphrases forces them to pick out the main ideas and the supporting details, to clarify relationships among the concepts presented, and to reinforce the learning that has already taken place.

Oral, or written, recitation may at first seem strange to your students, but the effect of this stage is the transfer of the material from their short-term to their long-term memories through a process of rehearsal. The process is strengthened when it is accompanied by writing.

5. Review

Students reread each heading, and then they try to recall the questions and answers based on that heading. Summary writing is also useful at this stage because it reinforces transfer to long-term memory.

Results

With SQ3R, students become familiar with a highly structured, yet easy-to-learn, technique for reading their texts.

Comments

Analogical Study Guides

Brief Description

Students review an analogical study guide prior to reading their text. The guide can also be used during and after reading to assist the students in incorporating complex concepts into the framework of their existing knowledge.

Objective

To help students, especially low-achieving students, use reasoning by analogy to understand scientific concepts.

Procedure

A completed analogical study guide consists of three columns. In the left-hand column, make a list of the important concepts that are discussed in the text passage. Then, for each concept, choose a phrase for the middle column that describes the concept. In the right-hand column, come up with simple, concrete analogies for each of the concepts.

Because your students will need time and experience to devise and use their own 'ogical study guides, it is best for you to complete the i few guides yourself. Analogical study guides are devised by first choosing a topic from the text that you sense will be difficult for students to grasp, or important enough to warrant the time it will take you to complete the activity.

SOURCE

Bean, Thomas W. "Analogical Study Guides: Improving Comprehension in Science," *Journal of Reading* v29 n3 Dec 1985: pp. 246-50.

For example, the following analogical study guides assist students in relating cell structures to their particular functions and circuit elements to their functions.

The Cell as a Factory

Structure	Main Functions	Analogy
cell wall	support; protection	factory walls
cell membrane	boundary, gatekeeper	security guards
cytoplasm	site of most metabolism	the work area
centrioles	cell reproduction	*
chloroplasts	photosynthesis	snack bar
endoplasmic reticulum	intracellular transport	conveyor belts
golgi bodies	storage, secretion	packaging, storage, and shipping
lysosomes	intracellular digestion	clean-up crew
microfilaments	movement	*
microtubules	support; movement	*
mitochondria	cellular respiration	energy generation plant
nucleus	control; heredity	boss's office, copy machine
ribosomes	protein synthesis	assembly line
vacuoles	storage	warehouses

*I could not think of obvious analogies for these concepts. Can you?

Current Flowing in a Circuit Is Like Water Flowing out of a Hose

Concept	Function/Definition	Analogy
voltage	electromotive force expressed in volts; larger voltage forces a larger current through the circuit	water pressure
resistor	resists the flow of electricity	putting thumb over the hose opening
capacitor	stores electrical charge	filling a bucket with water
current	flow of electrons; electrons in motion	water moving through hose
electrons	carries the current	water molecules

You will not always be able to come up with an analogy for every concept, and some of the analogies you do come up with may not be understandable to every student. The first few times you use this strategy, ask for suggestions from your students to fill in the empty parts of the guide. Work through by elaborating a guide in front of your students to show them how it is done. Have them form small groups and work together to structure a guide of their own. The more experience students have in making the guides in a variety of contexts, the easier it will be for them to incorporate this strategy into their everyday educational toolkit.

Stress to your students that analogies are useful in associating a scientific term with everyday experience, but that all analogies have their limitations. (See p. 123 below, "Analogical Reasoning: From Science and Math to Words and Ideas, and Back Again"). The simple analogies incorporated in the study guide are designed to act as clues to the meaning of the scientific term, not as a replacement for the term.

Although designed as a prereading strategy, analogical study guides can be used during reading (to check on the utility or correctness of the analogy) and after reading (for reviewing the chapter). Successful implementation of this strategy results in students' realizing the usefulness of analogies. They begin to devise similar study guides on their own, thus taking one more step towards becoming active and independent learners.

Results

Low-achieving students seem to benefit more from the analogical study guides than do other students. Even average or superior students may benefit from the power of analogy to make comprehensible a welter of complex scientific terminology.

Comments

Overcoming Incorrect Prior Learning

SOURCE
ED 264 525
Hynd, Cynthia R. and Donna E. Alvermann. *The Role of Refutation Text in Overcoming Difficulty with Science Concepts.* College Reading and Learning Assistance Technical Report 85-08. Georgia State University, Atlanta, 1985.

Brief Description

Students, prior to reading a text, activate their prior knowledge, and then they have their incorrect knowledge corrected by reading and rereading the text, and through class discussion.

Objective

To identify, and then reshape, students' incorrect prior knowledge of scientific concepts.

Procedures

Research indicates that students tenaciously adhere to incorrect prior knowledge. Poor reading strategies, common but inadequate science teaching practices, and the textbooks themselves reinforce incorrect prior knowledge.

These two strategies can help your students change their minds about incorrectly held concepts:

1. use of an anticipation-reaction guide
2. a four-step model of conceptual change instruction

1. Anticipation-Reaction Guide

Prior to having your students read a portion of their text that contains concepts frequently misunderstood, write down a series of correct or incorrect statements based on your previous experiences with students' holding incorrect intuitive notions or incorrect prior knowledge. Among the most common misconceptions are the Newtonian and impulse theories of motion (i.e., that carried objects fall straight down when they are dropped). However, the range of student misconceptions is much wider than just the two competing notions of the theory of motion, so there should be no problem in coming up with a topic on which at least some of your students will have incorrect ideas.

Label the first column "Anticipation" and the second column "Reaction." Then write down the statements you have come up with. The students then individually, in small groups, or as a class, react to the statements, indicating approval or disapproval.

Anticipation/Reaction Guide

Anticipation (T or F)	Reaction (T or F)	
________	________	Objects are kept in motion by an internal force that gradually dissipates.
________	________	A projectile travels along a straight line for some time after it is launched.
________	________	Objects carried by a moving person fall straight down when they are dropped.

Next, have your students read the material, warning them that some of the concepts in the text contrast with what some of them believe to be true. Tell them that, after reading the chapter, they will have a chance to react by addressing the series of statements again. Some, but not all, students will be able to recognize inconsistencies between their prior knowledge and the material presented in the text. Those who are still not convinced have at least been confronted with the inconsistencies. Further instruction may still be required to win over the stalwarts in error.

A personal note: In my high-school physics class, a question on an exam asked us to draw the path (from the perspective of someone standing outside) of an apple dropped inside a moving school bus. I do not recall whether we had received any instruction in recognizing inconsistencies between our prior knowledge and the textbook presentation of projectile motion, but the results were dreadful: Only a few of the students even came close to drawing a parabolic path. My friend and I had many clashes over the path. He insisted that the apple fell straight down, whereas I insisted that the path would be curved. To this day, he still believes that the path would be a straight line to the floor of the moving bus.

Galileo Galilei's *Dialogue Concerning the Two Chief World Systems* includes a lengthy discussion of the path of a stone or cannon ball dropped from the mast of a moving ship. The intuitive, Aristotelian argument—that the object will fall behind the mast—is presented at length, as is also the argument that the object will fall at the base of the mast. Galileo's prose may not be scintillating, but it is straightforward and designed to convince his readers that their intuitive notions about motion are wrong.

excerpts from Galileo's *Dialogue*

Participants in the dialogue are Salviati (representing the Copernican world view but stating the Aristotelian view in the second, third, and fourth paragraphs), Sagredo (an interested layperson), and Simplicio (representing the Aristotelian, or Peripatetic, point of view).

Salviati: Yesterday we resolved to meet today and discuss as clearly and in as much detail as possible the character and the efficacy of those laws of nature which up to the present have been put forth by the partisans of the Aristotelian and Ptolemaic position on the one hand, and by followers of the Copernican system on the other. Since Copernicus places the earth among the moveable heavenly bodies, making it a globe, like a planet, we may well begin our discussion by examining the Peripatetic steps in arguing the impossibility of that hypothesis; what they are, and how great is their force and effect. [p. 9]

As the strongest reason of all [for the earth's being at rest] is adduced that of heavy bodies which, falling down from on high, go by a straight and vertical line to the surface of the earth....For if it made the diurnal rotation, a tower from whose top a rock was let fall, being carried by the whirling of the earth, would travel many hundreds of yards to the east in the time the rock would consume in its fall, and the rock ought to strike the earth that distance away from the base of the tower.

This effect [the Peripatetics] support with another experiment, which is to drop a lead ball from the top of the mast of a boat at rest, noting the place where it hits, which is close to the base of the mast; but if the same ball is dropped from the same place when the boat is moving, it will strike at that distance from the foot of the mast which the boat will have run during the time of fall of the lead, and for no other reason than that the natural movement of the ball when set free is in a straight line toward the center of the earth.

This argument is fortified with the experiment of a projectile sent a very great distance upward.... In its flight and return, this consumes so much time that in our latitude the cannon and we would be carried together many miles eastward by the earth, so that the ball, falling, could never come back near the gun, but would fall as far to the west as the earth had run on ahead....

Simplicio: Oh, these are excellent arguments, to which it will be impossible to find a valid answer.

Salviati: Perhaps they are new to you?

Simplicio: Yes, indeed, and now I see with how many elegant experiments nature graciously wishes to aid us in coming to the recognition of the truth....

Sagredo: What a shame there were no cannons in Aristotle's time! With them he would indeed have battered down ignorance, and spoken without the least hesitation concerning the universe....[p. 126-27]

Salviati: Very good. Now, have you ever made this experiment of the ship?

Simplicio: I have never made it, but I certainly believe that the authorities who adduced it had carefully observed it. Besides, the cause of the difference is so exactly known that there is no room for doubt.

Salviati: Anyone who does [the experiment] will find that the experiment shows exactly the opposite of what is written; that is, it will show that the stone always falls in the same place on the ship, whether the ship is standing still or moving with any speed you please. Therefore, the same cause holding good on the earth as the ship, nothing can be inferred about the earth's motion or rest from the stone falling always perpendicularly to the foot of the tower.

2. Conceptual-Change Instruction

Another approach to dealing with students' misconceptions is through the following four-step approach:

a. Develop student dissatisfaction with misconceptions.

Before your students have read the text, and using the example of dropping carried objects, have them sketch the path of such an object. In combating other misconceptions, ask the students to predict what will happen before they read the text.

b. Determine whether the new conception is understandable.

After your students have read the text, have them draw the path of the object based on the information presented in the text. The students may not yet be ready to relinquish their incorrect notions, but at least they should be able to sketch the correct path based on information from the text. If not, more instruction may be required.

c. Determine whether the new conception is plausible.

Students who cannot yet draw the correct path (and those who only guessed at the correct path) need to reconcile the information from the text with their previous conceptions. One way to do this is to present the students with another way of explaining the concept, perhaps taken from other source materials. Also, students may like to know that they are not the only ones who hold misconceptions. Suggest to them that they ask friends and family to draw the path of falling objects. The inability of most people to draw the correct path can assuage feelings of inadequacy that your students may harbor.

d. Invent a situation for making use of the new conception.

Presenting "real-world" examples of the dangers one may face if one does not believe in Newtonian mechanics, ought to help your students vanquish their misconceptions. For example, discuss how someone in a helicopter might most effectively drop relief supplies to people on the ground.

From Galileo to Airplanes

- As you reflect on Galileo's *Dialogue*, which argument seems to you to be *intuitively* correct? Why?
- Which argument seems to you to be *scientifically* correct? Why?
- How might one demonstrate empirically that one argument is better than another?
- As you reflect on Galileo's *Dialogue* mark T or F in the "Anticipation" column in the Anticipation/Reaction Guide below.

Anticipation/Reaction Guide

Anticipation (T or F)	Reaction (T or F)	
________	________	A projectile travels along a straight line for some time before it begins to fall.
________	________	A spinning wheel held by only one end of its axle will fall down.
________	________	Objects carried by a moving person fall straight down after they are dropped.
________	________	A rock and a feather dropped from the same height above the surface of the moon fall at different rates.
________	________	A monkey hanging in a tree can avoid being hit by a hunter's bullet if he lets go of the limb he is hanging on as soon as the bullet is fired.

- Now turn the page, ponder the picture and the questions on the next page, and then mark T or F in the "Reaction" column of the guide above.

Results

Students are forced to face their misconceptions concerning scientific concepts, actively interact with their textbooks, recognize that they are not the only ones having trouble learning counter-intuitive concepts, and incorporate real-world examples of these concepts.

Are these children in danger of being hit by the box?
What path will the box take as it heads toward the ground?
If you were the pilot, when would you have released the box?

Flatland: **Adding Dimension to the Geometry Classroom**

SOURCE
Esbenshade, Donald H., Jr. "Adding Dimension to *Flatland*: A Novel Approach to Geometry," *Mathematics Teacher* v76 n2 Feb 1983: pp. 120-23.

Brief Description

Geometry students read and discuss Edwin A. Abbott's novel ***Flatland: A Romance of Many Dimensions, with Illustrations by the Author, A. Square***. Sixth edition, revised with introduction by Banesh Hoffmann. (New York: Dover, 1952).

Objective

To extend students' notions of the apparent boundaries of mathematics; to challenge more capable students with an awareness-expanding activity; to give weaker students a change of pace; and to present an interdisciplinary unit in geometry.

Procedure

Sometimes called "science fiction," *Flatland* is described more accurately as a novel in the genre of a "philosophical voyage." A short book, the novel has only 103 pages in the Dover edition of 1952. The first part of the novel describes life in a two-dimensional land where women are straight lines, soldiers and the lowest order of "workmen" are triangles with two equal sides, the middle class are equilateral triangles, the professional men are squares, and so on up the social ladder to the priests who have so many sides that they are indistinguishable from circles. In the second part, the main character travels to no-dimensional, one- dimensional, and three-dimensional lands, and describes the different points of view. The novel can be read on several levels: as geometrical description, social satire, description of religious experience, and as a philosophy of education. In these respects, *Flatland* is similar to Jonathan Swift's *Gulliver's Travels* and Lewis Carroll's *Alice's Adventures in Wonderland*, and *Through the Looking Glass*.

It may not be easy to convince your students that reading a novel in a geometry class will help them understand geometry better. Just think how unbelieving some of them might be were you to ask them to learn their math from a "children's book" like *Through the Looking Glass*, even though Lewis Carroll was a lecturer and tutor in mathematics at Oxford, and he infused his works with mathematical and logical puzzles. *Flatland* can provide your students with alternative ways of seeing and interpreting geometry. It can also demonstrate to them the wide scope of geometry.

One teacher spent almost two weeks on *Flatland*, including time for discussion, a quiz, and a test. This teacher was able to fit the novel into the course without eliminating instruction in any of the basic material. Just as your textbook may contain discussions of geometrical models of the universe, so you can conduct a unit on *Flatland* along with the other speculative material. Your text may even mention *Flatland* in exercises at the end of a chapter; if so, that would be a good time to conduct the discussion of the novel.

You may find that discussion of the first few chapters of the novel will go rather slowly. Your students will probably be quite interested in figuring out how things work in Flatland. Discussion topics include the following: the plot of the book, reasons for its writing, the social context (discussed in the foreword to some editions), the geometric details of the geography of Flatland. The teacher mentioned above who used the novel in class reported that his students responded to the novel with spirited discussions of social, religious, sexual, and educational values.

Tests based on the novel can include questions requiring only the recall of specific information, as well as essay questions that require some analysis, synthesis, and evaluation. Base the essay questions on some of the livelier discussions in which your students engaged.

Results

The teaching of mathematics becomes humanized, and geometric concepts take on human dimensions (or, human realities are perceived through geometric concepts). You have the opportunity to learn better who your students are, how they feel, and how they think. You have the opportunity to reach some students not reachable through traditional instruction, and students benefit from an alternative approach to literature/mathematics.

Humanizing Science

SOURCE

Larson, James H. "The Humanization of Science," *Journal of College Science Teaching* v15 n6 May 1986: pp. 542-43.

Brief Description

Students read James Watson's *The Double Helix: A Personal Account of the Discovery of the Structure of DNA*, edited by Gunther S. Steut (New York: Norton, 1980); students engage in a literary and humanistic analysis of the book, and they discuss "creativity" in science.

Objective

To convey the human aspects of science to students, to express and defend students' personal contentions, and to have the students demonstrate their ability to analyze and critique a literary work.

Procedure

Designed for a college-level General Studies science course, this activity is easily adaptable to many levels and courses because of the readability and appealing style of Watson's book. Have your students write a paper containing the three components described below. Or, engage your class in a discussion of the book using the three-part-paper format as a guide. Or, as each section can stand alone, have them write a paper that incorporates only one or two of the parts described below. In any case, your students will find Watson's book interesting and highly readable. Your students will not think about the scientific enterprise in quite the same way after reading *The Double Helix*.

Part I. Literary and humanistic analysis—the familiar questions

- What is the theme of the book? The author's purpose and motivation for writing it?
- What points of style, including use of metaphor, anecdotes, narrative style, and analogy, are outstanding?
- What is your personal assessment of the author's effectiveness in developing his theme?

Part II. Structured questions

Raise the following questions with your students. They are to answer these questions and support their arguments by reference to passages in *The Double Helix* and other resources.

- Did the portrayal of scientists in the book alter or reinforce any stereotypes that you held previously?
- Do you think the scientists in the book violated codes of ethics or values?
- Should others have shared the Nobel Prize?
- Discuss the use of large-scale replicas of chemical compounds to decipher the structure of DNA as demonstrated in the book.
- Why did this book become a best-seller?

Part III. Creativity

Ask your students to come up with a definition of "creativity" in the sciences, and compare their definition with the notion of creativity in other fields. Good sources for students to consult on this admittedly difficult subject are Alan MacKay, *The Harvest of a Quiet Eye—A Selection of Scientific Quotations* (Bristol: Institute of Physics, 1977); Jacob Bronowski, *Science and Human Values* (revised edition, New York: Harper and Row, 1972); and Jerome Bruner, *On Knowing* (expanded edition, Cambridge, Mass: Belknap Press of Harvard University Press, 1979).

Classroom discussions of creativity and the closely related issues of imagination, invention, discovery, novelty, and uniqueness typically generate considerable argument. Some would say that only God can "create," i.e., make something truly new (*de novo*) out of nothing (*ex nihilo*). If only God can "create," then what do humans do? Where do new ideas come from? How do they arise?

Use a thesaurus or synonym-finder to enlarge your own and your students' vocabulary of words that precisely state what people mean by their sloppy use of the word "create."

Challenge your students (and yourself):

- Think of something genuinely new!
- Think of something that no one else has thought of.
- In your imagination, create something out of nothing, that is, don't just rearrange old ideas and parts, but come up with something *de novo ex nihilo*.

Results/Benefits

Students report that after reading *The Double Helix* science seems less esoteric. They also marvel at Watson's candid and human account of a major scientific discovery.

Other Books

Lewis Thomas. *Lives of a Cell: Notes of a Biology Watcher.* (New York: Viking Press, 1974).

_____. *The Medusa and the Snail: More Notes of a Biology Watcher.* (New York: Viking Press, 1979).

Robert M. Pirsig. *Zen and the Art of Motorcycle Maintenance.* (New York: Bantam, 1981).

C.P. Snow. *The Two Cultures: And a Second Look.* Second Edition. (Cambridge: University Press, 1964).

Wording Science

$$E=MC^2$$

How to Tell What's Important: Guidelines for Vocabulary Selection and Instruction

Brief Description

Presents guidelines to evaluate vocabulary instruction and how to tell which vocabulary words are important.

Objective

To engage students in active learning of scientific vocabulary through a variety of contexts so that they will learn, retain, and then use their newly acquired knowledge of scientific concepts and terms.

Procedures

Effective vocabulary instruction is a necessary part of learning science. Inappropriate or ineffective instruction is not only inimical to the process of learning science but also it may reinforce students' existing misconceptions concerning scientific concepts or their existing negative attitudes towards learning science. What follows are commonsense ways to choose the vocabulary to present to your students, and four guidelines for effective vocabulary instruction.

A. Vocabulary Selection

It is important to use a variety of methods to choose the vocabulary words for direct instruction. Merely relying on vocabulary words indicated in the textbook sends the wrong message to students: "Only highlighted words are important, and all I have to do is look for the sentence in the text where those words are located and copy the sentences." In the textbook of real life, truth is not highlighted, and falsehood is not italicized. Relying only on the words that you think the students need to know also causes problems: Your students may not know words that you think they do, or may mistakenly believe that they understand words that you also incorrectly think they understand.

Upon first implementation of the lesson plans that follow, the vocabulary words are chosen by you. However, as the lesson plans describe, the responsibility for selection is gradually shifted from you alone to you and your students. The ultimate goal is for your

SOURCE

ED 331 022

Konopak, Bonnie C. "Teaching Vocabulary to Improve Science Learning," in *Science Learning: Processes and Applications*, edited by Carol Minnick Santa and Donna E. Alvermann, 1991, chapter 14.

students to be able to monitor their own comprehension, and to realize which words they are having trouble understanding. You and your students may find it helpful to keep the following three learning conditions in mind when choosing the words to be singled out for direct instruction.

- First, some words represent a new label for an already existing concept. An example is the word "indigenous," for which your students probably already have the concept of "native born." Instruction in these new-label/old-concept words may not be necessary for all students.
- Second, some words engender in students a general idea of what a word means, but a technical definition is lacking. An example of such a word is "force." These old-label/new-concept words are harder to learn than new-label/old-concept words.
- Third, words such as "fulcrum" represent new-label/ new-concept words—the hardest words to learn because students must accommodate a new concept and a new label for these words at the same time.

Working together, you and your students can generate a list of vocabulary words that merit attention, and you can get an idea of how much difficulty to expect in their learning those words.

B. Guidelines for Effective Instruction

Once you have chosen the vocabulary words to be learned, then you need to decide which strategies to use. The five lesson plans that follow incorporate all of these guidelines in varying degrees. Use the guidelines to evaluate other strategies that you may wish to use:

1. Vocabulary instruction works best when it helps students relate new concepts to their past experiences.
2. Vocabulary instruction works best when it aids students in developing their own meaning for new words, not just in writing down other people's definitions. This usually requires follow-up activities in which new words are used in contexts other than one-sentence definitions gleaned from the text.
3. Effective vocabulary instruction involves active student participation in the process of learning new vocabulary.
4. The metacognitive goal of vocabulary instruction is to provide students with strategies they can apply independently.

Results

You and your students will be able to choose those words from the textbook which merit direct vocabulary instruction.

Using Graphic Organizers to Teach Vocabulary

Brief Description

Students arrange vocabulary words to show their hierarchical interrelationships.

Objective

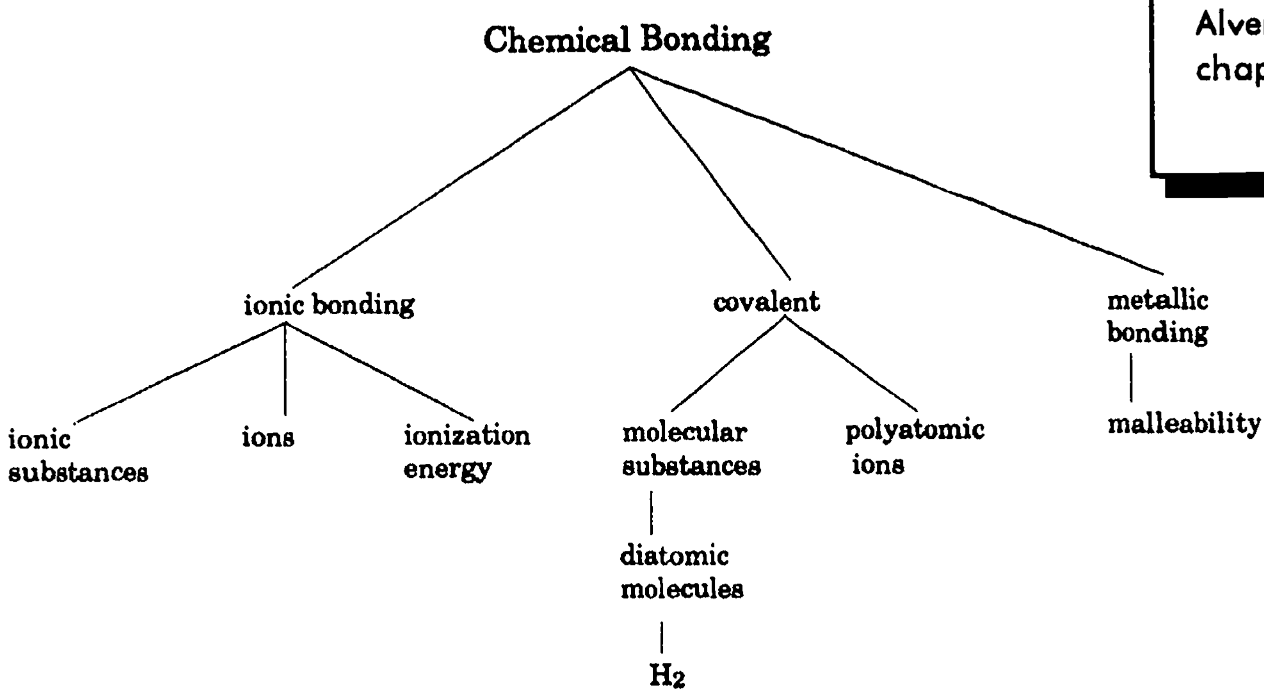
To activate students' prior knowledge relating to the new vocabulary words, and to generate a visual representation of the hierarchical relationship of the new vocabulary.

SOURCE

ED 331 022

Konopak, Bonnie C. "Teaching Vocabulary to Improve Science Learning," in *Science Learning: Processes and Applications*, edited by Carol Minnick Santa and Donna E. Alvermann, 1991, chapter 14.

Sample Graphic Organizer



Procedures

A graphic organizer is a visual representation of the interrelationships among a series of terms. There are six steps in the development and use of graphic organizers.

1. Concept Selection

Concepts chosen from the text should be important, but not so complex that a large graphic organizer would be needed. A good idea in the early stages of use is to demonstrate to your students how a graphic organizer is constructed. At this stage, talk through with your students why a particular concept was chosen. If youwish, you can solicit their input in the choice.

2. Diagram Construction

The terms related to the concept are then arranged in their proper hierarchical order. Again, teacher modeling is important for the students to understand what the organizer is supposed to represent. They will do what students see you doing.

3. Evaluation

Review the resulting diagram to make sure that it is accurate and clearly delineates the interrelationships of the terms. Student input is important because they are the ones who are to use the diagram.

4. Organizer presentation

Particularly if your students have little experience in using graphic organizers, afford them a careful explanation of the graphic organizer's purpose and how it is to be used. Explanation is easier if they have actually watched you design the diagram. Stress that the diagram is designed to help them see the interrelationships of complex terms before they do the reading.

5. Follow-up

Tell your students to keep the diagram and refer to it during and after reading. Encourage them to make changes and add clarifications, or even to alter the structure of the organizer itself. The organizer's usefulness does not end once the students have read the chapter. Redesigning an organizer already presented in class is also an excellent study technique and helpful when reviewing for exams.

6. Independent Practice

In keeping with the guidelines listed in the lesson on "How to Tell What's Important" (pp. 45-47), the students should be involved in the process of designing their own graphic organizers. Starting with a small number of terms and fairly simple interrelationships, students can gain confidence in their ability to devise organizers. Stressing the organizers' use as a study aid helps students incorporate the design and use of graphic organizers into their personal set of learning strategies. One way of encouraging the use of organizers as study guides is to present partially completed organizers for concepts already discussed, and then work with your students to fill in the gaps.

Results

Graphic organizers assist students in learning new vocabulary by presenting a visual representation of the hierarchical relationship of a group of scientific terms. Graphic organizers are also useful as study guides.

Comments

List-Group-Label

> **SOURCE**
> ED 331 022
> Konopak, Bonnie C. "Teaching Vocabulary to Improve Science Learning," in *Science Learning: Processes and Applications*, edited by Carol Minnick Santa and Donna E. Alvermann, 1991, chapter 14.

Brief Description

This activity, like graphic organizers, stresses word relationships. However, because it is a post-reading exercise, List-Group-Label is work that your students themselves do after they have read a text.

Objective

To reinforce word meanings learned through other methods, and to see how other students associate new words.

Procedures

Follow these steps to show your students how it is done:

1. Select a topic from the text that implicates important related terms.
2. On the chalkboard or overhead transparency, write a broad term related to the chosen topic.

Matter

heterogeneous	alloy
homogeneous	mixture
109 elements	gas
compounds	rust
water	solution
oxygen	solid
atoms	iron
substances	liquid
aluminum	

3. Invite your students in a brainstorming fashion to supply related terms that they recall from the text.
4. Have your students then group the terms into categories, and give each category a title.

Same Composition
homogeneous
substances
water
mixtures
alloy

Different Composition
heterogeneous
mixture
alloy

Forms of matter
solid
gas
liquid

Compounds
elements
rust
oxygen
iron
alloy

Elements
atoms
109
oxygen
iron
aluminum

5. Write the categories produced by the students on the board or on the overhead. Hold class discussion focused on the reasons for placing particular terms in particular categories. One question to pose is this: Why is "alloy" found in three of the five lists? What does the word mean? One possible end-product of this activity is a unified series of categories and their related terms, achieved as the result of class discussion.

It is advisable for you to model this activity until your students become aware of what is expected of them. As with any vocabulary exercise, the goal is to have the students become active learners, and practice the procedures independently. A mixture of teacher modeling of procedures, whole-class discussions, small-group work, and individual work will keep the activity from becoming tedious. Your students become involved in a variety of contexts for learning vocabulary.

Results

Students explore newly acquired words and their interrelationships. Based on student responses, you will be able to gauge the extent to which your students grasp the meanings of the vocabulary words.

Possible Sentences

SOURCE

ED 331 022

Konopak, Bonnie C. "Teaching Vocabulary to Improve Science Learning", in *Science Learning: Processes and Applications*, edited by Carol Minnick Santa and Donna E. Alvermann, 1991, chapter 14.

Brief Description

Students make predictions about the relationships among unfamiliar words before reading the text; next, they read the text to determine the accuracy of the prediction; then they use the textbook to refine their initial prediction.

Objective

A combination prediction-and-vocabulary lesson, this activity helps students to determine the meanings and relationships of new vocabulary words.

Procedures

The first time you use this strategy, model it for your students. Once they become familiar with the strategy and understand the steps, gradually shift more of the responsibility for completing the activity to their shoulders.

1. Choose important words from the text.
2. Write a sentence that might possibly appear in the text using at least two words from step 1.

   Homogeneous matter has all the same elements in it.

   A mixture has several different substances in it.

   Compounds are elements put together.

   A solution is heterogeneous when it has different substances in it.
3. Read the text and verify the accuracy of the "possible sentences."
4. Change the sentences to reflect accurately the information presented in the text.

Students may check their own sentences or work in small groups to check each other's sentences or a few "possible sentences" could be written on the board for the class as a whole to revise.

You and your students can work together to generate more sentences to extend the meanings and relationships of the new words. These sentences must also be checked against the text for accuracy. To avoid the very real possibility of reinforcing students' existing misconceptions, incorrect "possible sentences" are to be rooted out from the final compilation of sentences. Whether generated and checked individually, in small groups, or by the class as whole, incorrect sentences must be discarded. It is of the essence of scientific methodology for the scientist to be able to recognize his or her own errors, and then to discard them in favor of perceived new truths, or, at least, in favor of improved hypotheses.

Encourage your students to formulate "possible sentences" on their own, once they have had a chance to practice the strategy with their classmates. Allowing a few minutes of class time prior to reading the text will assist in this transference of the strategy from you to your students.

Results

Students become actively involved in reading their textbook as they evaluate the accuracy of their predictions concerning the meaning of new or unfamiliar vocabulary.

Comments

Feature Analysis (or Semantic Feature Analysis)

SOURCE

ED 331 022

Konopak, Bonnie C. "Teaching Vocabulary to Improve Science Learning," in *Science Learning: Processes and Applications*, edited ' · Carol Minnick Santa, and Donna E. Alvermann, 1991, chapter 14.

Brief Description

Students complete a matrix containing a series of terms and their corresponding features. The matrix is then used to discuss the similarities and differences among related concepts.

Objective

To help students understand the similarities and differences among related words. Used as a post-reading activity, feature analysis offers a systematic procedure for exploring and reinforcing vocabulary concepts.

Procedures

This activity includes the following steps:

1. Category Selection

Choose a category from the text either by yourself or in conjunction with your students. The category must contain at least two similar items. (The source for this lesson plan contains "the classification of matter" as a category.)

2. Listing the Words

Write terms belonging to the category down the left side of what is to become a matrix.

3. Listing the Features

Across the top of the matrix, list the featu es associated with the terms that belong to that category.

4. Recording Feature Possession

Fill in the resulting matrix with symbols indicating which term within the category has the features describing the terms. For some terms, both conditions might apply. Save detailed discussion of issues raised by the matrix until it is nearly (or completely) filled.

5. Filling in the Matrix

Filling in the matrix is best done as a whole-class activity. Ensuing class discussions concerning whether certain features do or do not have the feature indicated (or whether more than one feature applies), are an excellent way to get students involved while at the same time reinforcing their vocabulary.

Students can also use this activity in small groups or individually, once they gain some experience in filling in the matrices.

Classification of Matter

Terms	Features					
	same throughout	different throughout	evenly distributed	unevenly distributed	pure	separated physically
heterogeneous	-	+	-	+	-	+
homogeneous	+	-	+	-	/	/
heterogeneous mixtures	-	+	-	+	-	+
homogeneous mixtures	+	-	+	-	-	+
substances	+	-	+	-	+	-
solutions	+	-	+	-	-	+

Note: + means yes; – means no; / indicates that both conditions apply.

Results

Students understand the similarities and differences among a group of related terms, and they actively participate in completing the matrix by expressing their knowledge and, when challenged, by providing a reason for their decision.

Concept Maps

> **SOURCE**
> ED 331 022
> Konopak, Bonnie C. "Teaching Vocabulary to Improve Science Learning," in *Science Learning: Processes and Applications*, edited by Carol Minnick Santa and Donna E. Alvermann, 1991, chapter 14.

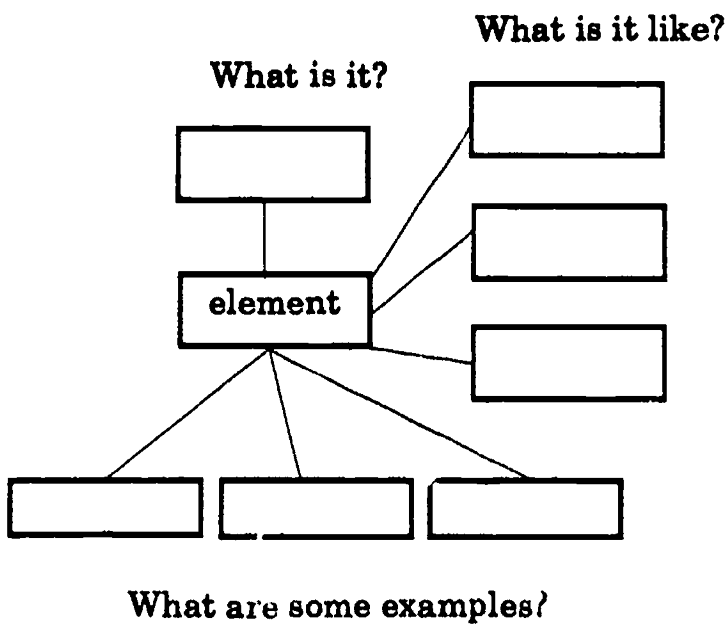
Brief Description

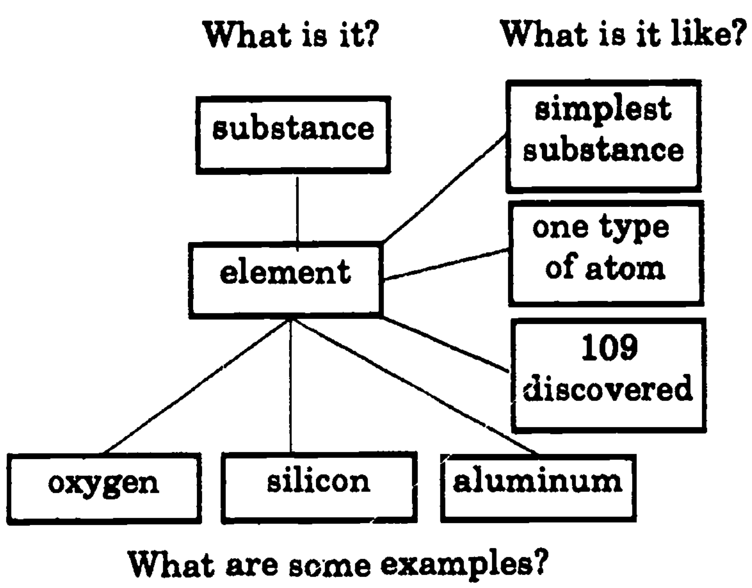
Students independently use clues from the text to develop definitions of vocabulary words.

Objective

Primarily student-centered, this activity assists your students in conceptualizing the components of word definitions.

1. **Choose important vocabulary words. You can help them make these choices first, but the students themselves must learn to make the choices on their own. See the lesson on "How to Tell What's Important" (pp. 45-47).**
2. **Locate the passages in the text in which the words are used in context.**
3. **Fill out the following frame with information from the passage:**





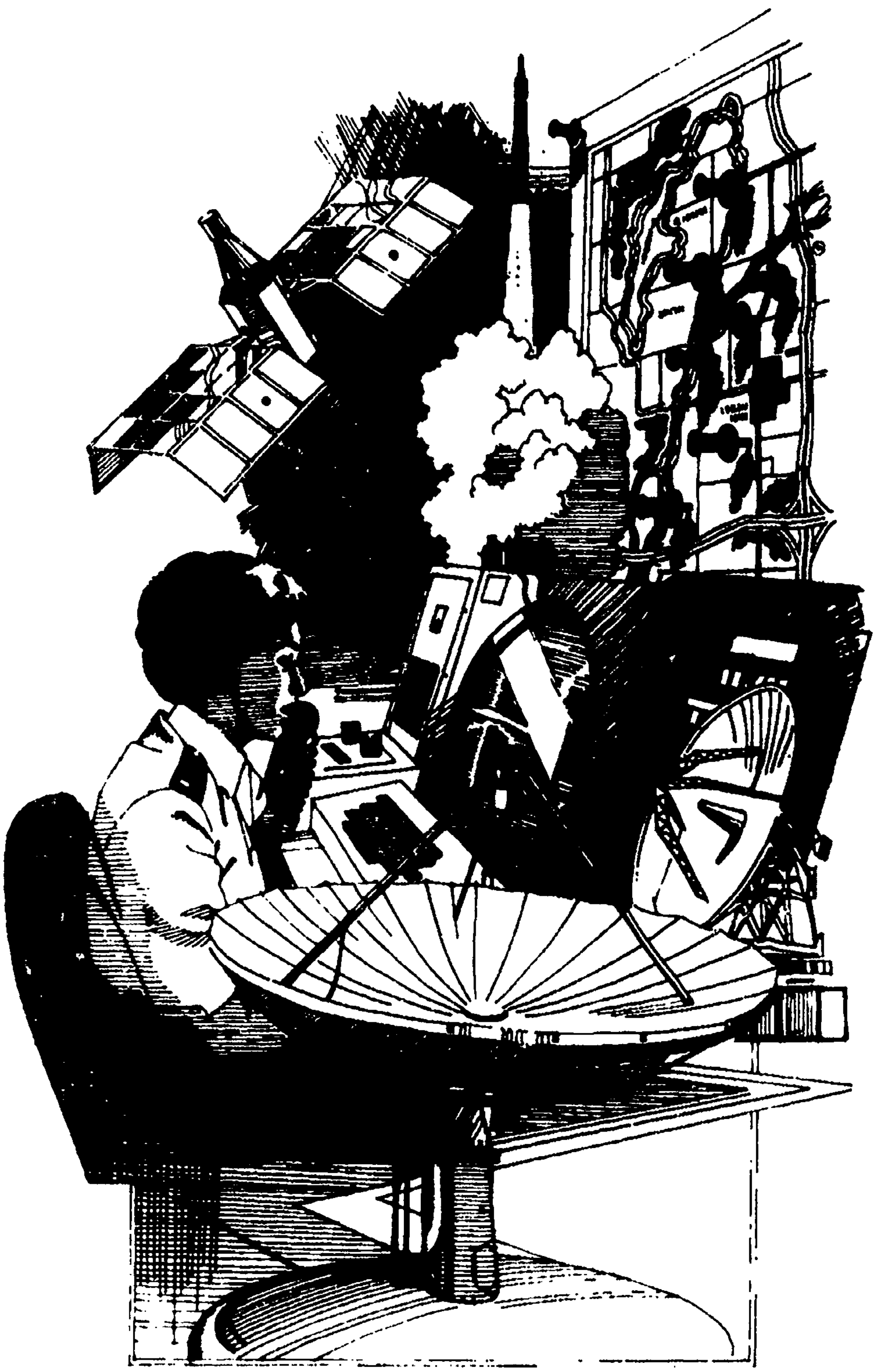
The first few concept maps might be filled out by you while your students observe. Gradually, more of the activity is shifted to the students until, depending on their own interest and ability, they are able to complete the framework themselves.

This strategy helps students to internalize scientific definitions. It also allows them to realize that their occasional inability to define some terms is not their own fault, but is due to unclear writing by textbook authors. When this realization occurs, invite your students to find a better definition from other sources.

Results

Students learn to understand the constituents of a good definition, learn how to evaluate the textbook explanation of vocabulary terms, and learn to evaluate their own comprehension of the vocabulary words. Once students start using this strategy on their own, they will have developed a critical attitude (supportable with specific examples) toward their textbooks. They will no longer have one-book minds, but they will be developing the courage to disagree with the canonical text and the ability to look elsewhere for information when their text fails them.

Short Scientific Writing Assignments



Science Fiction Stories

Brief Description

Students write short (about 500 words) science-fiction stories centering around a chemical, physical, or biological reaction.

Objective

To sharpen communication skills, and to bring out latent scientific and literary talent.

Procedures

This activity is designed to replace a unit exam on material that is simple and usually needs only to be memorized. Instead of reviewing the unit's material, students spend that time writing outlines and fleshing out the plot. The outlines can include the entire storyline and all major characters. Students can make minor changes, but you should approve any major changes to prevent them from veering too far off course.

Give your students a fairly free choice of topics, but insist that they use the correct scientific terms when possible. The result of the reaction can be as fictional as the rest of the story, but the reaction itself must be clearly and accurately spelled out somewhere in the story.

Examples of student-generated topics:

1. The protagonist mixes two compounds and gets an explosion instead of a rather tame color change. The particular chemical reaction is expressed in a chemical equation and is accurate.
2. A bored girl serving detention by cleaning the chemistry lab begins to rummage through the cabinets looking for something interesting to mix together.
3. An "Incredible Hulk" fantasy develops, in which the transformation of the protagonist is brought on by an elixir formed from a real chemical reaction.

Grade the stories on scientific content, originality, sentence structure, and grammar.

SOURCE

Barra, Paul A. "It Was a Dark and Stormy Chemistry Class...," *Science Teacher* v55 n7 Oct 1988: pp. 33-35.

Results

Although stories may be predictable, this assignment can elicit stories that are ingenious in design and interesting to read. Keep this assignment "quick and dirty"—a simple but enjoyable means of assessing knowledge of simple, possibly boring, material.

Comments

Recognizing Interrelationships by Combining Facts into a Paragraph

Brief Description

Students write a paragraph connecting information presented in a list of facts drawn from their texts.

Objective

To capture the interest of students who think science is a dull memorization of facts; to give them experience in recognizing relationships underlying facts; and to help them learn how to support their opinions and conclusions.

Procedure

You and your students select a list of facts from the text.

Choose four or five facts from the selected text and write a paragraph that links the facts together.

First attempts usually consist of a string of "and's," but most students move beyond that groping towards making more appropriate connections.

Students will probably make mistakes in spelling and grammar in the first-draft stage. Refrain from correcting these mistakes until the final draft of the paragraph. It is better to have students try to use terms even when they are unsure of the spelling, rather than to avoid using the term at all for fear of being graded down for a misspelling.

Many students will become actively involved in learning the material. They will spontaneously generate classifications of the facts, and they will generate testable hypotheses. While sometimes wrong, these observations are volunteered and then are subject to examination, testing, and revision. This is scientific methodology at work. Teach your students that "getting it wrong" is second only to "getting it right." In science, when an experiment fails, we then know what *not* to do, and thereby may discover what *to* do. In science, "negative results are valid results."

SOURCE

Strenski, Ellen. "The Write Stuff," *Science Teacher* v51 n5 May 1984: pp. 58-61.

Consider having your students exchange their paragraphs with other students, and make suggestions for revision.

Results

Students write sentences that pull the facts together, and then link sentences together to form a paragraph expressing a relationship that was previously hidden in the facts. As students gather the facts and perceive the relationships, they become actively involved in learning science scientifically.

Comments

Brief Writing Assignments

Brief Description

Writing activities: journals, letters, newspapers, personal narratives, and poetry

Objective

To involve students in writing for varied purposes to help them learn the course content, and to help them express themselves in writing more effectively.

Procedure

Journal Writing

- In the last five minutes of class, record the thrust of the science lesson for that day.
- Keep a log of your field trips.

Letter Writing

- Write to a specific scientific society (such as the Sierra Club, the Department of Forestry, or the Audubon Society) for information.
- Write to a scientist or inventor.

Newspaper Writing

- Write up a classroom experiment as if it were a breakthrough for science.
- Write a biographical sketch about a little-known scientist.

Personal Narratives

- Imagine yourself as a plant, animal, or rock. Tell the story of your history.
- Write a scientific observation of an object or phenomenon. Write your personal reaction to this observation and the subject.

SOURCE

ED 260 410

Steinacker, Debbie, ed., and others. "Writing: Don't Leave It in the English Classroom—Activities to Enhance Teaching in All Areas". South Bay Writing Project, English Department, San Jose State University, San Jose, California.

Poetry Writing

- **Write a limerick about a scientific formula.**
- **Write a scientific formula in the form of a poem.**

Results

These brief writing assignments help students to learn science by stimulating their thinking, and by actively engaging them in modes of thought that do not occur in the typical lecture format.

Comments

Short Writing Assignments in the Mathematics Classroom

Brief Description

A series of short in-class or overnight writing assignments in which students explore their knowledge of a topic by writing what they know in their own language.

Objective

To use writing assignments to expose and identify students' learning problems, and to suggest writing activities to address those problems.

Procedure

Students in mathematics classes at all levels and of all abilities can participate in these writing activities. Grammar and spelling are not the primary concern; in fact, they are of little concern until the latter stages of the writing process. More important is encouraging your students to write about what they know (or think they know) about particular mathematical concepts, theoretical issues, or scientific procedures. In the first section, I describe a variety of activities. In the second section, I discuss what to do with the students' writing when they have completed their essays.

SOURCE

EJ 380 974

Keith, Sandra Z. "Explorative Writing and Learning Mathematics," *Mathematics Teacher* v81 n9 Dec 1988 pp. 714-19.

A. Writing Activities

1. Summaries

   Ask your students to summarize what they know about a particular concept, e.g. "What is your notion of the term 'function'?" or "What is a "radian" and why do we prefer this notion to that of "degree"? Asked after instruction, this request serves as a guide to help your students (and yourself) determine how much they have learned. Asked before instruction, this assignment gives you an idea of how much your students already know (or don't know) about the concept.

2. Visual image translation

   These activities integrate visual and verbal understanding.

   a. Ask your students to describe in writing the graph of a function as if you were explaining it to a friend over the telephone.

   b. Have your students explain how the graphs of $y=x^2$ and $y=1/x^2$ are related.

   c. Divide the class into groups of two. Ask one student to describe the graph of a particular function while the other student attempts to draw the graph without peeking at the graph which the first student is describing.

3. Summarizing tactics for problem-solving

   a. Ask your students to describe in words the procedure to solve a particular problem. No equations allowed!

   b. Have your students compare problem-solving techniques for two related operations (such as permutations and combinations).

4. Giving an algorithm

   Students describe in explicit detail the steps in a problem-solving process.

5. Giving a definition or stating a theorem

   Although this assignment seems straightforward, you will be surprised at the variety of responses you get when your students attempt to write down the complete statement of a particular definition or theorem. Your students will also realize the precision required to state mathematical definitions or theorems.

6. Communicating to a specific audience

   Writing for different audiences is a good way for students to learn any content area material.

   a. Ask your students to rewrite a section of the text that they either did not like, found difficult to read, or did not understand well or easily. Have them write it as they would have liked to have seen it written.

b. Have your students write a summary of a section of the text or of your lecture or of the class' activities, for a friend who missed class.

7. Inventing a problem

Offer your students the beginnings of a word problem: ("You live in a house with 3 sisters, 4 brothers, 2 dogs, and 17 cats..."). Ask your students to spin off a series of problems from that beginning.

B. Responding to student writing

The four techniques described below are ways in which you can respond to the issues raised in your students' writings. Their writings are not designed merely to be marked and then returned. **A basic tenet of writing to learn is that the process of writing needs to be used to help students learn, not only as a way to evaluate what they have already learned.** With this tenet in mind, approach your students' writings as representing one step in the process of instructing them. Use their writing as a springboard to further activities, instruction, learning, and understanding.

1. Discussion

Share examples of individual students' writing with the whole class (preferably anonymously to prevent embarrassment). Discuss with your students positive and negative aspects of the writing samples. Try to understand by verbalizing out loud in the hearing of the class the thought processes that went into the writing of the sample. Teachers who have used this technique notice that their students sometimes have a mysterious ability to interpret fellow students' writing to a mystified teacher, and the teacher's intentions to students who may have missed the point.

2. Peer evaluation

Have your students read and evaluate their fellow students' writing. With your students, develop a set of criteria or a checklist for use during peer revision. Otherwise, most students will have little motivation to evaluate their own or others' writing seriously, and—without some guidelines to follow—they may not know what to look for and correct.

3. Revision

   Following the peer evaluation, encourage your students to revise their writing. "All writing is rewriting." Your students will learn more by actually revising their writing (especially based on comments from their peers) than if they simply read teacher-written comments and then put the assignment away.

4. Anticipation

   An assignment can be given before a topic is introduced. Students draw on their background knowledge to respond to the assignment. As the students discuss their written response, they realize that, in many cases, they already know something about the next topic to be covered in the textbook.

Results

Short writing assignments teach strategies for maximizing understanding; they develop trust and improve participation and collaboration in and out of the classroom. Students sense that they have read and retained the material more easily through using writing to learn.

Comments

Expressive Writing

Brief Description

A series of writing activities designed to evoke expressive language from students in their science classes.

Objective

To use expressive writing to help students learn the course material better, and to have them engage in problem-solving.

Procedure

Two high-school biology teachers decided to study whether using expressive writing would help their students learn better. One teacher taught his usual course the first semester, and the other teacher incorporated the activities described below. In the second semester, the teacher who used expressive writing went back to his old teaching styles, and the other teacher used expressive writing. Results of their study of the effectiveness of using expressive writing appear at the end of this chapter.

I. Reading Logs

Have your students record their thoughts on a sheet of paper as they read. This is not meant to be a note-taking activity, but, rather, a tracking of students' own impressions of, and reactions to, the reading assignment.

An anonymous poll of the students gave this activity mixed reviews. Whereas some of the students complained that they had to "stop reading and right [sic] stuff down," others believed that the logs helped them study for the test.

II. "Neuron Notes"

Take about ten minutes each day so that your students can write in a journal what they learned that day in class. Encourage them to write down any thoughts, even if they think they might be trivial. Assure them that their journal will not be read by the teacher, unless the student is willing.

Many students are unable to overcome the idea of the teacher as an examiner. This assignment teaches them that their intellectual

SOURCE

ED 238 725

Wotring, Anne Miller and Tierney, Robert. "Two Studies of Writing in High School Science. Classroom Research Study No.5." Developed by the Bay Area Writing Project. 1981.

work is done not merely to impress the test-maker and the grade-giver. Most entries of beginning journal writers are regurgitations of what was said in class. Journal writing can be very useful when it is thoughtfully implemented. For more information, see the chapter on journal-writing (pp. 6-7).

III. Practice Essays

This activity, carried out a week before an exam, is designed to provide instruction and practice for students in writing essay exams. Give the students a sample essay question, and have them read the essay question in class. Offer clarification of the question, if necessary, and answer questions. Instruct your students to look over the textbooks and other material, and take some notes on important items they will want to include in their essay.

Have the students compare their notes with each other in small groups or as a class. Allow them to add to, or modify, their lists at will. Reserve the last 20 minutes or so of class time for the students to write their individual responses to the essay question.

Suggest to your students that, when writing the essay, they consider it a first draft. Do not worry too much about spelling punctuation, or grammar.

Invite your students to read their essays aloud for student comment.

IV. Writing for a Specific Audience

Students, so accustomed to writing to and for teachers as examiners and graders, find it difficult to write for other audiences or even for themselves. To help students write for other audiences, have them explain a scientific concept that they have studied to any one of a number of different fictional or non-fictional characters (Miss Piggy, Superman, a grandparent, a kid on a skateboard, a little brother or sister).

Other students find writing for a different audience a refreshing and different way to grapple with, and understand, scientific concepts for themselves.

V. End-of-Class Summaries

Once in a while, ask your students to take the last 15 minutes of class to summarize what they have learned about the topic under discussion. Give them full credit if they do the assignment, regardless of the correctness of the content. You may be surprised at what the students do not know. It will give you a clear indication of whether the course material for that day was understood by the students.

VI. Group Writing

Students form into groups of two or three, and they engage in the normal lab activity. The group writes up one lab report and hands it in. Occasionally, quizzes might be given after the lab to insure that all students are participating and understanding the laboratory work.

Group writing motivates students to engage in serious discussion of the lab and collaborative writing of the report. Grade-conscious students, however, occasionally dominate the groups.

VII. Essay Exams

Although students may complain bitterly at first about having to take an essay exam in a science class, after they practice essay-writing and take their first essay exam, most students change their minds. To show them how to do it, you could write out your own responses to the essay question and then read it aloud to the students after the exam. Your essay can serve as the catalyst for a discussion of the exam, and as a basis for student appeal of their grade on the exam.

Results

Tests were given at the end of the terms to the students in both the science class that incorporated writing and the science class that did not. Students in both groups performed about the same on multiple-choice exams, but students who used expressive writing performed better on recall tests given several weeks after instruction ended.

Comments

Adding Variety through Short Writing Assignments

SOURCE
Lehman, Jeffrey and Jane Harper Yarbrough. "Twenty-five (Scientific) Writing Activities," *Science Teacher* v50 n2 Feb 1983: pp. 27-29.

Brief Description

Short, frequent writing assignments designed to add variety to classwork, and to encourage students to think with inventiveness.

Objective

To give students experience in expanding ideas, synthesizing information, and using their imaginations.

Procedure

1. Extinct No More

Tap your students' knowledge of issues concerning endangered species by having them write a brief account of the rediscovery of an animal once considered extinct. Or, you can have your students write an obituary of an endangered species.

2. Blast Off!

Encourage your students to weigh the risks and rewards of space flight by having them explain in writing why they would or would not like to be a passenger on the Space Shuttle. Or, have them describe an experiment to be conducted on board the Shuttle.

3. For Sale

Inform your students that a tract of land is being sold in your community. Fictitious bidders include the National Park Service, a children's hospital, a shopping-mall developer, an oil drilling company, and the U. S. Armed Forces. Have each student become a lobbyist for one of these, and have them write arguments on behalf of their interests.

4. How Do You Use It?

Assist your students in learning how to use laboratory equipment by having them choose a scientific instrument from your lab, and write directions on how to use it.

5. What's New?

You and your students can write about your experiences on a recent field trip. Send the account to your local newspaper.

6. Little-known Edisons

Your students can learn about the history of inventions by writing about the origin of everyday objects, such as roller skates, safety pins, or ice-cream cones.

7. Exploration Stories

Form "exploration groups" of about five students. Starting with an opening line for a story, pass the story around the group, each student adding a sentence or two to the story.

8. Questions Up Front

You and your students write down as many questions about a new unit of instruction as you can BEFORE the unit begins.

9. What Do You Do?

Have your students write about a science-related profession, explaining why they are interested in it. As a class, choose a few scientific career options of interest, and invite a member of that profession to speak to the class.

10. Choose!

Have your students choose some thing that they could imagine being (an asteroid, a cactus, a volcano), and describe why they would choose to be that thing.

11. Free Association

Write a scientific term on the board. Have your students make a list of words that they associate with that term. Compare the lists to demonstrate to students that they do not all have the same mental picture of the concept. Next, engage in another round of free association, and see what new metaphors, analogies, and images crop up to describe the term on the board.

12. Identification

Have your students picture themselves as part of a scientific phenomenon, and write about the experience. Phenomena include respiration, blood flow, transmission of nerve signals, chemical reactions, heat transfer, lightning, combustion, and propagation of radio waves.

13. Filling in the Gaps

Have your students describe museum exhibits that might have been, but were not, present at a museum that they visited.

14. New Space in Outer Space

Have your students make up a new planet. Have them describe the important features of the landscape, what the climate is like, and what lives there. They might write from the viewpoint of the first visitor to this planet.

15. Design a T-Shirt

Try this during a unit on environmental science or wildlife preservation. Take the design to a local mall where they tailor T-shirts and have the "creations" produced.

16. What Should It Look Like?

Gather illustrations of plants with unusual names. Give students one name, and ask them to describe what it might look like. Give the same name to more than one student so that they can compare their descriptions. Show them the illustration of the plant after they have completed their descriptions.

17. The Practical Environment

Have the students gather maxims on how to conserve natural resources. Have them think up new ways of conservation, recycling, and efficient use of natural resources.

18. Oh, No!

Your students can grapple with issues concerning form and function by writing about how the world would be different if cockroaches were the size of poodles (or other such distortions of scale and size).

19. Want a Pen Pal?

Have your students write a letter to an inhabitant of another planet explaining basic things on Planet Earth, such as what air, water, earth, and fire are.

20. On the Air

Have your students imagine that they are talk-show hosts getting ready to interview a famous scientist. Have them write down some questions that will elicit useful, interesting information from the scientist.

21. You Should Join!

Encourage your students to design a flyer to encourage other students to join the science club.

22. Turning the Tables

Have your students rewrite a section of their science text so that a third-grader could understand it.

23. What's on the Test?

Have your students write easy, average, and hard questions that might appear on their next unit exam. (And warn them: These questions just might appear on the exam.)

.t's Their Turn

Have the students themselves come up with a writing activity for their class.

Results

Students get a chance to use their imaginations; they sharpen their language skills in a science class.

Comments

Writing to Learn Algebra: Equations in Two Variables

SOURCE
Venne, Greg. "High-School Students Write about Math," *English Journal* v78 n1 Jan 1989: pp. 64-66.

Brief Description

Students engage in a variety of brief writing activities that involve solving equations in two variables.

Objective

To help verbally adept non-math students use their talents to learn mathematics; to help the large number of students who usually just sit in class and listen to get involved; to help all students learn to solve equations in two variables by writing about mathematical operations and relations.

Procedures

While collaboration with an English teacher would be beneficial, you can implement in your own classroom the kinds of writing activities described below. After all, the purpose is not to have the students write error-free essays on two-variable equations, but to have them use writing to help them learn how to solve these problems. If the writing that your students produce is not clear, then their understanding of the underlying mathematical concepts is probably not clear either. Your students can learn mathematics by attempting to write clearly about mathematics. Punctuation, grammar, and spelling are of secondary concern.

The three writing activities described here vary in complexity and the amount of time required to implement them.

A. Multiple choice

This activity is not complicated. It serves as an introduction for you and your students to the idea of writing to learn mathematics. This activity will also give you an idea of your students' mathematical knowledge.

Start with simple equations in two variables, such as $x + y = 95$. Let x equal the number of pounds of apples, and y equal the number of pounds of oranges. Write one correct, and two incorrect or incomplete, statements relating these variables. Have your students choose the correct statement and explain in writing why the other statements are wrong. Here are some examples:

1. Don has 95 pounds of fruit. He has apples, bananas, and oranges.
2. Dorothy bought a box of fruit weighing 95 pounds. Each box weighs 95 pounds.
3. Darren lifted a box of fruit weighing 95 pounds. In the box were apples and oranges.

Most of your students will pick the third statement as correct. What is more interesting is why they chose it as correct, and why they ruled out the other two choices. Maybe they chose the correct statement using faulty reasoning, or maybe they just misread the problem statement. Maybe the students who did not choose the correct answer really understand the problem, but they made a simple error. Reading what your students wrote will remove any uncertainty in your mind as to why your students chose the statement they did. Consider asking the students who wrote inarticulate responses to revise them.

B. Expressing equations in writing

The next activity is a very short writing activity that involves having your students translate an equation in two variables into words that accurately describe the equation. Word problems are often difficult for students to understand because they do not understand how to translate the information to mathematical expressions. This activity offers your students a chance to write their own word problems, given an equation. As they attempt to write the sentences that will elaborate the word problem, they will realize just how difficult it is to choose the right words to express the mathematical relationship, and how easy it is to write an unclear or misleading word problem. Ask your students to revise any incorrect statements.

To add variety to the activity, you can vary the amount and kind of information you provide. You can give your students the equation, or the conditions, or neither the conditions nor the equation, so that they write a word problem from scratch. For example, consider the equation $4x + 7 = y$. Let x = Baby's weight, and y = Daddy's weight. Have your students write a sentence or two describing the conditi·· ns of the equation. Some students will opt for the straightforward method: "Four times Baby's weight plus seven pounds is equal to Daddy's weight." Others may write mathematically accurate but potentially misleading statements: "Daddy's weight is seven pounds more than four times Baby's weight." Your students, reading only that statement, might write the equation incorrectly as y + 7 = 4x.

C. Writing the solution for two equations

As a preliminary step to actually solving two equations in two unknowns, give your students the algebraic solution to a problem such as this:

$x - y = 6$

$2x + 3 = 4y$

Ask your students to verbalize in writing the first substitution in the solution to the problem. For example: "The first thing to do is to change x - y = 6 to x = y + 6 by adding y to each side. Then, because the value of x is equal to y + 6, we can substitute y + 6 for x in the second equation. Then solve for the single variable."

Ask your students to include as many details of their thinking process as they can. If they do not spell out their thoughts, ask them to revise taciturn statements such as "You substitute y + 6 for x in the equation." Writing out the first step of the solution in detail lets you and the student know that the student understands at least how to start the solution.

Results

Externalizing the algebraic process by putting it into words gets it "out there" where you and your students can "see and hear" it. This is a step in the self-check of metacognition. A large number of students who just sit there and listen in class may now become actively involved in learning how to solve equations in two variables because you are letting them use words. Some people "do" words better than they "do" math, just as some people "do" sports better than they "do" either words or math. Good teaching is to allow each student to learn the unfamiliar through the familiar, to let each student learn in his or her own best, preferred way. Students can learn mathematics by writing about mathematical operations and relations. Verbally inventive, non-math students have found a way to express themselves in a mathematical context.

Writing Dialogues

SOURCE

Wilkes, John. "Science Writing: Who? What? How?" *English Journal* v67 n4 1978 pp. 56-60.

Brief Description

Students write brief dialogues on scientific issues of general interest between a scientist and an intelligent, but ignorant, friend.

Objective

To give the students a different audience to write for, and to put them into a position in which they need to explain scientific concepts.

Procedures

An important element in the effectiveness of this lesson is that students are writing for an audience other than yourself, an "expert" in the field of science. Students will find that they need to explain what they mean: They can no longer hide behind the assumption that because the audience for their writing knows everything, they can get away with omitting detailed explanations. By writing a dialogue between a scientist and a non-scientist, the student-writer is forced to take both points of view and express both perspectives in writing. Your students will also find that they will need to be persuasive to make their dialogue interesting, for having the "friend" be a mere "yes man" (the way Plato did) will not make for an effective dialogue.

An alternative strategy is to have your students purposefully engage in polemics in their dialogues. Fun to write, polemics have an excellent precedent: Galileo wrote some of the most fiendishly polemical works in the history of science. The writings of Galileo, in particular his *Dialogue Concerning the Two Chief World Systems—Ptolemaic and Copernican* (University of California Press: Berkeley, 1953), are excellent examples of persuasive writing. For the most part, Galileo wrote not in Latin for his learned colleagues but in the Tuscan dialect for non-scientists. Consider providing your students with excerpts from the *Dialogue* as examples. (See p. 36.)

Topics for dialogues are easily found in mass-media accounts of scientific developments, such as articles in *Science News*, *The New York Times*, or the *Wall Street Journal*. Issues of concern to a wide audience lend themselves to the format of a dialogue. The student's role is to bring out the science underlying the issue portrayed in the media report.

Suggestions for the format of the dialogue

1. Keep the dialogues short, 500 to 1,000 words or so.
2. Include about ten speeches for each of the participants in the dialogue. Each speech corresponds to one aspect of the issue under consideration.
3. Give approximately equal time to each of the participants. Do not let the scientist dominate the conversation. Let the intelligent friend be an active participant. Even if the dialogue is polemical, attempt to maintain some balance in the space given to each participant.
4. Use analogies and visual imagery to help the reader understand the issues under discussion. Use humor or clich)s when appropriate.
5. Keep the tone conversational by using simple sentences.

Completed dialogues are both fun and instructive to share with the class. The dialogues could be collected into a book for distribution. Selected dialogues could be performed before the class. Dialogues on timely issues could be submitted to the school newspaper or literary magazine for publication. The purpose of this activity is to give the students a different audience for whom to write. To be able to reach their audience, they will have to learn to write simply and clearly and in plain English.

Results

Students realize that audiences are many. Their teacher is not the only audience for the writing they do in school. They gain experience in logical and persuasive writing, and they have the opportunity to share their writing with others.

The sample dialogue on the following pages is based on an actual conversation I had with one of my "older" students. The material that follows in the dialogue is based on articles in *The New York Times* and *Science News* concerning the discovery by the Cosmic Background Explorer (COBE) satellite of fluctuations in the microwave radiation that fills the universe.

Student: Say, Roger, have you heard about the discovery of wrinkles at the edge of space? The newspaper article said that those wrinkles prove that the Big Bang theory is true, and that scientists now have a profound insight into how time began.

Teacher: Yes, but the claims are overinflated, and they raise several issues: First, the issue of the Big Bang theory itself. Second, the data supporting the Big Bang theory. Third, the claim made in the newspaper about the insight on the beginning of time. Fourth, the issue of how the media reported the discovery.

Student: Let's start with the Big Bang. I understand that the commonly accepted belief (at least among astronomers) concerning the origin of the universe is that about 15 billion years ago, all the matter and energy in the universe was concentrated in an infinitely dense, infinitely hot ball no bigger than a basketball. This ball exploded, hurling out matter in its most primitive, subatomic form. Intense radiation accompanied the explosion. As the universe expanded, things cooled and at some later time, matter condensed into stars.

Teacher: Those are the basic elements of the theory, but scientists tinker with many variations, trying to overcome perceived difficulties in a particular theory. Two auxiliary theories are important to consider when talking about the satellite data. The first is the inflationary model, in which the universe expanded quite rapidly very early, and then settled down to a more sedate rate of expansion. Any unevenness in the distribution of energy and matter in this inflationary stage was exaggerated, setting the stage for the later clumping of matter we see today.

Student: I was wondering how the Big Bang could account for the stars, clusters, and galaxies having formed from such a small, uniform ball of matter and energy.

Teacher: That has been one of the many objections to the theory. Maybe "objections" is too strong a word. The theory cannot explain everything related to the origin of the universe, but it has been able to account for enough to keep the interests of cosmologists. Getting back to the auxiliary theories, the second is the existence of dark matter.

Student: I've heard of that. Some astronomers believe that as much as 90% of the matter in the universe is not located in stars, and it does not radiate light, so that we can only see it by the effects on matter that does radiate.

Teacher: Right. Dark matter is needed to account for the formation of galaxies and other motions observed in the heavens. There isn't enough bright matter in the universe to produce the gravitational attraction needed to account for the observed distribution of matter in the universe.

Student: Let's talk about the actual data. They claimed to have found minute variations in the supposedly uniform microwave radiation representing the remnants of the Big Bang, but these variations are tiny, only thirty-millionths difference from the microwave background. The newspaper article mentioned that the results were based on 70 million measurements at each of three wavelengths.

Teacher: Just because millions of measurements were taken does not mean that the data are more reliable. Errors in any step in the data-gathering process could have introduced errors into the final result; however, the team of scientists working on the data apparently took great precautions to eliminate error. While the deviations are small, and the raw data need vigorous computer processing, it may well be that the results are correct.

Student: What about this "looking back into time" and "insight into how time began" stuff?

Teacher: The newspaper reporter got carried away. The microwave radiation analyzed by the equipment in the satellite takes a certain amount of time to travel from the source to the sattelite. The delay is similar to the delay when you see a baseball player hit a ball but you don't hear the sound until a little bit later. Imagine that you are at a baseball game and that your eyes are closed. You hear the sound of the bat hitting the ball. You know that the actual hit occurred a fraction of a second before you heard it. You are, metaphorically speaking, looking back in time. Once you hear the sound, you know that an event (the hit) took place a fraction of a second ago.

Student: So the light that we see from a star four light years away lets us "look back in time" four years. It tells us what was happening on that star four years ago. Now, the microwaves they are measuring are supposed to arise from processes unleashed during the earliest stages of the evolution of the universe, estimated to be 15 billion years old. If the microwaves have taken 15 billion years to reach us, the information they contain is 15 billion years old, and we can tell what the universe was like 15 billion years ago.

Teacher: This "when time began" phrase is inaccurate. The Big Bang theory says nothing about the beginning of time. It could be that this primordial ball of matter and energy got that way because an earlier universe collapsed in upon itself. There is room, but no necessity, for a deity or deities here; besides, time is relative.

Student: I've had that idea myself. I call it the "accordion theory" of the universe: bang and collapse; pull out, squeeze in; exhale and inhale; out and in, and so on forever—it's the nature of the universe to rise and fall, rise and fall, infinitely.

Teacher: I think the headline-writers got carried away when they indicated that the discovery shed light on the beginning of time.

Student: The people on TV were turning it into a Sunday School lesson, and scientists indicated that the discovery was a "breakthrough" and a "revolution." This hyperbole did not seem warranted to me!

Teacher: Advertisers use "new and improved" to sell more of a product that may not really be that different from the older version. Science writers, and scientists themselves, use "breakthrough" or "revolution" to draw attention to themselves, their stories, and their grant applications.

Error-Filled Essays Demonstrate the Need for Clarity and Accuracy

Brief Description

Students are given an essay that is full of errors of fact and "literacy errors"; they are asked to correct all the errors they can find.

Objective

To improve students' scientific literacy, and to encourage genuine and critical interactive discussion.

Procedure

Present your students with an essay full of errors of fact and literacy similar to the one presented in the box on p. 84. The sample essay was developed largely from mistakes that students have made on exam questions. You can develop your own essay based on your experiences as a teacher. The number and severity of the factual errors can be adjusted to conform to your perceptions of how difficult this activity needs to be for your students. Include both substantial and trivial factual errors.

There are several kinds of "literacy errors" that can be included:

1. inappropriate forms of words
2. inappropriate use of words
3. inappropriate use of generalizations
4. imprecision and lack of clarity
5. irrelevance

Once your students working alone have found all the errors that they can find, engage in a class discussion to compare their results. Class discussion immediately after completion of the identification of the errors is both an efficient method of assessing student performance and an opportunity to engage in a genuine discussion over the use and misuse of language in scientific writing.

SOURCE

Downie, Roger. "'Deliberate Mistakes, Articles, and Scientific Literacy," *Journal of Biological Education* v17 n4 Win 1983: pp. 303-06.

Advanced students can write a critique of a published paper, testing it against their developing standards of scientific writing.

Old and out-dated science texts can be used as samples for discussion for two reasons:

1. What is considered "good science writing" has changed over the years.
2. Science is an ever-progressing field of knowledge in which new discoveries make old truths uncouth.

Results

Fewer students note the "literacy errors" compared to the number that note the factual errors, but perception of literacy errors improves with practice. During the discussion period, students begin to realize that avoidance of literacy errors is as important as avoidance of factual errors. Faulty English leads to misunderstanding and miscommunication. In science writing, above all else we need simplicity and clarity of language as surely as we need facticity and accuracy in reporting data.

Epithelial tissues (error-filled)

Apart from endotheliums, which come from endoderm, epithelial tissues are all derived in the embryo from ectoderm. Epithelia is covering and lining tissue and is therefore often adapted for protective and transport functions. Another major function is secretion: all secretary tissues are basically epithelial.

(Corrected version, assuming vertebrate epithelia)

Apart from endothelia, which come from mesoderm, epithelial tissues may be derived from all three germ layers. Epithelium is covering and lining tissue, and it is therefore often adapted for protective and transport functions. Another major function is secretion, but not all secretory tissues are basically epithelial. For example, connective tissue cells secrete fibrillar and ground-substance components.

Short Writing Assignments to Teach Problem-Solving Methods

Brief Description

Presents a list of short-term writing activities, and an in-class review procedure involving whole-class, individual, and small-group writing activities

Objective

To help students use writing to learn mathematics

Procedures

A. Short-term Writing Assignments

The following assignments are easily adaptable to a variety of teaching styles, grade levels, and class sizes. Some take only a few minutes to complete, whereas others require most of the class period. Students complete their assignments in a notebook. Your responses to the assignments may follow the suggestions for responding to students' journals that appear on pp. 6-7.

1. Explain How

   Perhaps the most straightforward of all the assignments, it is best to start off with a technique in which students talk to themselves on paper as they solve a problem. If your students have trouble in writing down their thoughts, refer them to the writing probes and general writing instructions [in the sidebar on pp. 86]. An example of this technique is to have the students explain in writing each step as they solve an equation in one variable. Suggest to your students that this procedure is equivalent to undoing what has been done to the variable:

$2x + 3 = 17$	Two multiplied by X is added to three. The total equals 17.
subtract 3 from both sides of the equation	This is the first step in undoing what has been done to the variable "X."
$2x = 14$	Two multiplied by X is equal to 14.

SOURCE

ED 300 247

Kenyon, Russel W. "Writing Is Problem Solving." 1988.

General Writing Instructions

Write down everything you are thinking.

Write as if you were explaining to a friend.

What you are writing is not necessarily right or wrong; it is what you are thinking at the time.

Make your writing as understandable to your "friend" as possible. If you are not sure how to spell a word, spell it as best you can, and don't worry. (Look it up later.)

Try to rephrase your thoughts to make them clearer.

Draw diagrams whenever possible.

Discuss why you accepted or rejected ideas initially. Explain how you expanded on the idea(s) finally.

When you have completed writing, re-read your essay, make corrections, and then write down your impressions of what you wrote.

divide both sides of the equation by 2	This is the second step in undoing what has been done to the variable "X".
$x = 7$	This is the solution to the equation.

2. Compare Two Concepts

First have your students define in their own words the meanings of various concepts such as "equation," "line," "point," "linear equation," or "fraction." Their first attempts may involve poorly written paragraphs. After some practice, your students should be able to explain the meaning of terms in one or two sentences. Now that your students have demonstrated that they understand the meaning of individual terms, have them compare two related terms, such as "equation" and "graph," "line" and "plane," or "point" and "line." Again, you may find that they write poorly organized paragraphs. As you respond to their writing, encourage them to be succinct. Temper criticism with praise when appropriate. Do not grade their writing on the basis of grammar and spelling, but on clarity and meaningfulness.

3. Explain Why

This activity requires some additional effort on your part and some experience in writing in the mathematics classroom on the part of your students. Pose an open-ended question to your students, and have them respond in their notebooks. For example, they may have already "Explained How" to add fractions, so now ask them to "Explain Why" fractions are added that way. The open-ended nature of this activity means that there is no definitive answer to the questions. Expect your students to encounter difficulty in dealing with this activity.

Try it yourself beforehand. How would *you* "Explain the Why" of fractions? You will probably resort to the use of analogies. See the essay on pp. 123-127 on the use of analogy in explaining scientific concepts.

4. Outline the Chapter

Your students may never have outlined a math textbook (or any other textbook). Outlining is useful in introducing a new chapter—it makes your students aware of the topics covered in the text, helps them to activate their prior knowledge of the material, and gives them a sense of the structure of the text. Outlines are also useful for the traditional reasons—as guides to learning the material, and reviewing for exams. In class on the chalkboard, go through the process of outlining a chapter for your students the first time. Engage them in a discussion of what they think is, or will be, important in the chapter. The goal is to get them to start writing outlines on their own, and to get them actively involved in reading their text.

5. Test Questions

Turn the tables on your students—have them write the test questions. The students will realize that in order to write good test questions, they have to understand the material, and be able to organize and synthesize information. Ask your students to write questions on all or part of the chapter. The sample questions can then be reviewed by you or your students, and rewritten as needed. Compile the questions into a review test. You may well choose to include some of the student-written questions on the exam.

6. Replace Two-column Proofs with Prose

Have your students write down proofs in prose rather than in the traditional two-column format. Encourage them to write about problems they are having in completing the proof. Writing out their thoughts may help your students overcome mental blocks that proof-writing can set up. Prose-written proofs also give you and your students documentation concerning the students' thought processes.

7. Journal Writing

See pp. 6-7 for a discussion of journal writing. Journal writing can be effective in any content area. Headings for journal entries include these: precise and succinct restatement of what was learned in class, reflection on what was learned, discussion of a difficult concept, applications of what was learned, personal feelings about the material, etc. You may choose to pose a question to your students to which they respond in their journals.

B. Reviewing for an Exam

This activity involves whole-class, small-group, and individual writing activities to prepare for an examination. The activity will take most, if not all, of the class period before the exam.

1. Reflection

Give your students ten minutes to reflect on their own about the unit on which they will be tested. Ask them to

Writing Probes

A. General Probes: ideas to help students form their thoughts as they are writing.

1. What are you thinking?
2. Can you explain further?
3. Explain so that a fifth-grader would understand.
4. Write it again in a different way.
5. Are you sure about that?
6. Check the accuracy of that last step.
7. What does the equation say in plain English?
8. Can you draw a picture of that?

B. When you are stuck

1. Why are you stuck?
2. What information do you need to get unstuck?
3. How can you get that information?
4. What makes this problem difficult?

Writing Probes (continued)

5. What else are you thinking about besides the problem?

C. When you think you are finished

1. Do you have other ideas you have not written about?
2. What were you thinking about when you took a particular step?
3. How can you show that you did this correctly?
4. Can you do this another way?

write whatever they can recall from their text, including methods for solutions, diagrams, difficult concepts, and so on. Ask them to write down the questions they have concerning the material.

2. Clarification

   Take five minutes to engage in a whole-class discussion to insure that your students understand the procedures for the activity.

3. First Draft

   Working individually, the students spend 15 minutes revising their initial reflections on the material. Ask your students to turn their initial reflections into complete sentences that describe the material on which they will be tested.

4. Peer Inquiry Stage

   Have your students form small groups (three or four students per group). The group members take turns reading their work to the group. The members of the group offer at least two positive, concrete comments about each student's work. The procedure is completed when all students have received a set of peer responses. Allow at least ten minutes for this stage.

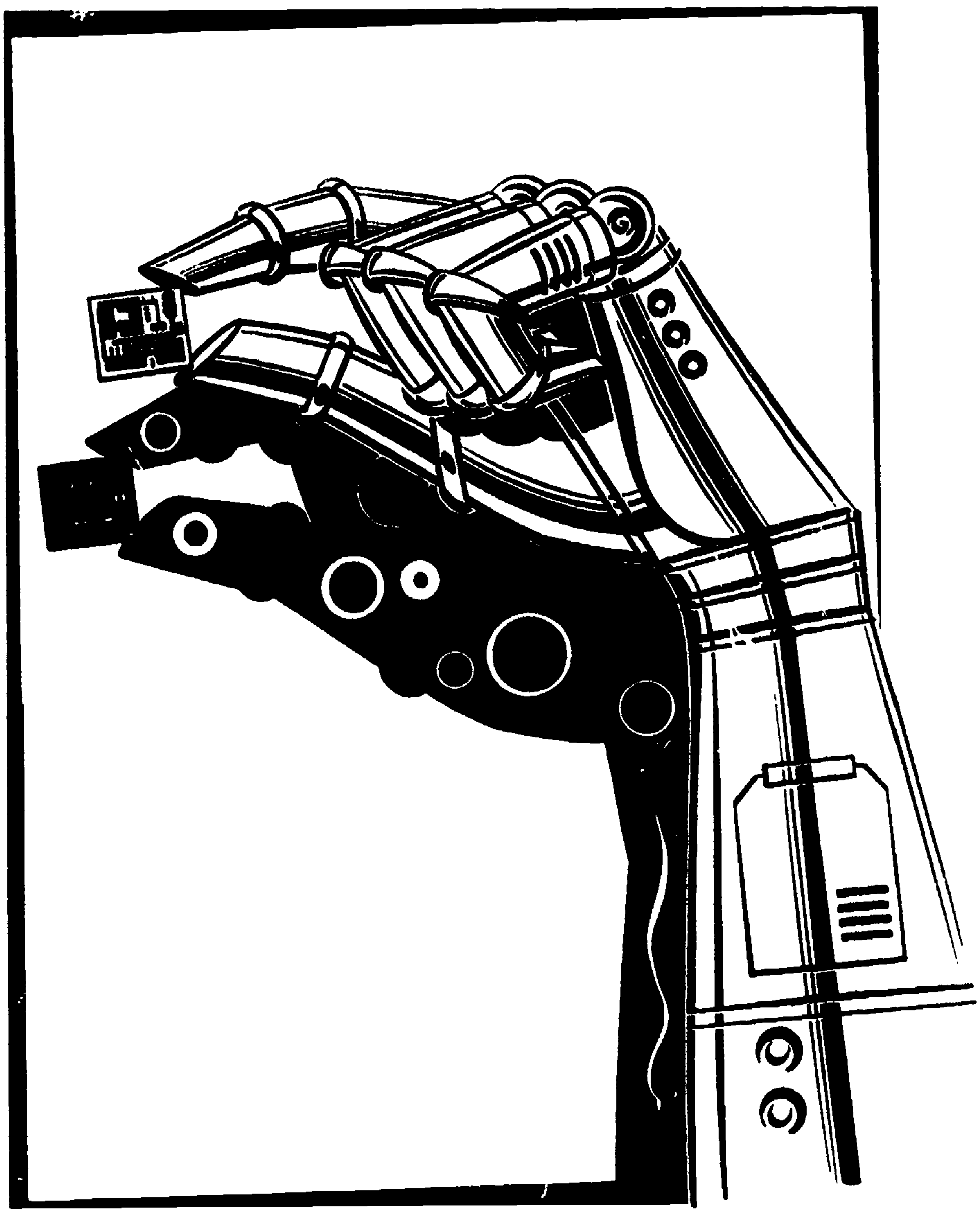
5. Revision

   As a homework assignment, ask students to revise their work by incorporating the suggestions from their peers. This revision will be, in effect, a review for the exam. If you have the time to spend two days reviewing for an exam, use part of the second day to read over your students' papers to determine what material needs, and does not need, to be reviewed in class.

Results

Students play a more active role in the problem-solving process when they use writing in the mathematics or science classroom. They are able to use writing to help them work through difficult material, to study for exams, and to see the subject of mathematics in a broader context through longer writing assignments.

Long Scientific Writing Assignments



Long Scientific Writing Assignments

Interrelating New Concepts with Existing Knowledge

SOURCE

House, Ken. "Improving Student Writing in Biology," *American Biology Teacher* v45 n5 Sep 1983: pp. 267-70.

Brief Description

Students use lab reports, review articles, and book reports to discuss and write about interrelationships of new facts and concepts with previously learned materials.

Objective

To improve student writing and to help students interrelate scientific concepts and processes on essay exams and written assignments.

Procedure

In conjunction with Huntington High School's Writing Center, Huntington, New York, new writing assignments were developed that gave more direction to the students through the use of broad questions that make clear the interrelationships between new and old concepts. These assignments included class discussions, collaborative writing, and frequent writing.

These assignments deal specifically with biological topics, but they can be adapted easily to other natural sciences.

I. Lab Reports

Have your students record their observations during the course of a normal lab activity. Then ask them to gather to discuss their observations and findings with each other and to notice any differences among their results. For example, your students might observe the predator-prey relationship between *Didinia* and *Paramecia* on different slides.

After class discussion, you and your students can generate hypotheses to explain the differences in the observations of the organisms' activities. Build these hypotheses upon your students' store of knowledge, and call on them for revision of their hypotheses on the basis of further observation and rational discourse. After each discussion, have your students summarize their findings and outline a plan of study to test their hypotheses further.

II. Review Papers

Ask your students to write brief reports on review articles selected from popular science journals. The chosen articles typically reflect concepts that appear in more than one unit of study. Class discussion of the articles will clarify some of the fine points in the articles. Next, have students respond in writing to a broad question designed to help them understand the particular concepts presented in the articles. This also helps to integrate and reinforce the material presented in class that overlaps the material in the articles.

III. Book Reports

Your students will enjoy reading popular books (such as *The Andromeda Strain* by Michael Crichton) that emphasize scientific themes. By doing this reading assignment late in the term, your students will be able to bring their new knowledge to bear in analyzing the presentation of scientific information. In frequent class discussions, address the issues raised by the science represented in the books. Focus the written assignment on the students' opinions of the effectiveness of the author in developing his or her theme. Require that your students support their opinion with specific examples from the book and with information they have learned in class.

Results

Your students will improve their writing skills and be able to interrelate the knowledge gained throughout the term. At the end of the term, one student said that she found multiple-choice tests boring because she was always trying to figure out what the teacher wanted, whereas, with essay exams and other thought-provoking writing assignments, she had the chance to express her own thoughts and to work out the answer for herself.

Comments

Teaching Science through Science Fiction

SOURCE

Freedman, Roger A. and W. A. Little. "Physics 13: Teaching Modern Physics through Science Fiction," *American Journal of Physics* v48 n7 Jul 1980: pp. 548-51.

Brief Description

Students read and discuss science fiction short stories and then write their own stories.

Objective

To teach aspects of modern physics, and to develop students' imaginations.

Procedure

The one-quarter seminar course described in the source, "Teaching Modern Physics through Science Fiction," supplements the conventional series of physics courses taken by students of the physical sciences. Although the course was designed for college undergraduates, the ideas are easily adapted to the high-school level. They provide a way for students to be exposed to scientific principles far beyond the reach of everyone but college physics majors.

Each week, have your students read science fiction short stories, and then discuss them in class. Suggest that they read a few stories involving the same topic, and then engage in a discussion about the science behind the fiction. You can then assign a writing task (described below), making adjustments for the abilities of your students and the amount of time you think should be spent on this activity.

Three broad topics which you may adopt as needed, form the subject matter of the course: the structure of time, extraterrestrial life, and astrophysics.

1. Structure of Time

The concepts of special relativity (especially time dilation and space contraction) can be approached through science fiction stories dealing with time travel. One way to approach the science behind the fiction dealing with time travel is to have the students assume that the events in the stories are true, and then challenge them to examine the changes that would have to be made in physics to account for the events in the stories.

One interpretation of quantum mechanics is called the many-worlds interpretation. You can introduce your students to this concept through any of the many stories dealing with parallel universes. The many-worlds interpretation of quantum mechanics need not be the private domain of advanced undergraduate students.

2. Extraterrestrial Life

Discussion of the origin of the solar system, the existence and distribution in space of life outside the solar system, and the physical setting required for the origin of life can easily include important physical, chemical, and biological concepts.

3. Astrophysics

The astrophysical phenomena presented in some science fiction stories are not in accord with accepted scientific knowledge, but imaginative material gives you and your students the opportunity to discuss why the science in the fiction is unscientific. Some of the astrophysical subjects mentioned in science fiction used in the course includes the sun and its effect on the earth, and the other planets, neutron stars, black holes, and tidal forces. Science fiction stories that do get the science right, put the physical phenomena into a human context. The human context, by describing the effects of the phenomena on the literary characters, aids the student in comprehending the effects of physical systems that range in size from quantum-level black holes to galaxies.

Writing Assignments

These two writing assignments will exercise your students' imaginations.

1. Ask them to discuss what would happen if one of the fundamental constants of nature were drastically altered, such as the gravitational constant, Plank's constant, or Avogadro's number. Students have written about the effect on humans of localized changes in "c," the constant representing the speed of light. A good example for the students to consult is George Gamow's *Mister Tompkins in Paperback* (Cambridge: Cambridge University Press, 1967).

2. Ask your students to imagine a new physical principle or phenomenon, and explore its consequences. Offer the students the option of discussing their new principle in the context of a science fiction story. College science students have come up with a variety of ideas, including subatomic intelligent life composed of neutrinos and electrons bound together by the weak interactions and communicating with

Additional Sources

R.A. Heinlein. "All you Zombies," in *The Unpleasant Profession of Jonathan Hoag*. (NY: Berkeley, 1976), p. 138.

David I. Masson "Traveler's Rest," in *Voyagers in Time*, edited by R. Silverbery (NY: Tempo, 1970), p. 168.

The first three chapters of H.G. Wells' *The Time Machine*.

B.S. Dewitt and N. Graham, eds. *The Many-Worlds Interpretation of Quantum Mechanics* (Princeton, NJ: Princeton Univ. 1973).

I.S. Shklovskii and C. Sagan, *Intelligent Life in the Universe* (NY: Holden-Day, 1966), chapter 29.

C. Sagan, ed., *Communication with Extraterrestrial Intelligence (CETI)*, (Cambridge: MIT, 1973).

James Gunn, "The Listeners," *Nebula Award Stories Four*, P. Anderson, ed. (NY: Pocket, 1968).

Additional Sources (continued)

Larry Niven. *Neutron Star* (NY: Ballantine, 1968).

Larry Niven. "Inconstant Moon," in *All the Myriad Ways* (NY: Ballantine, 1971), p. 124

each other via electromagnetic radiation; the effects on inhabitants of a spaceship entering a region of space where ordinarily stable nuclei become unstable; overlapping wave functions of different universes leading to "tunneling" of matter and consciousness between universes; and the effect of a small rotating black hole being placed on the surface of the earth.

Your students need not invoke such esoteric phenomena as those developed by college students. Many of the ideas developed by the college students are similar to scripts of television programs, with more and detailed science added to demonstrate their mastery of college-level material. Many a plot of "Star Trek" and "Star Trek: The Next Generation" television series contains enough "science" to provide a good source of ideas for your students to develop, such as different life forms (the less anthropomorphic the better), "rips in the very fabric of the universe," parallel universes, and interstellar travel. Other television shows ("Twilight Zone," "Dr. Who," and "The Six Million Dollar Man") provide more fodder for digestion of the science in science fiction.

Most of your students predictably will write their papers in the form of a science fiction story, but if you leave open the option of writing a more traditional essay, or propose other genres, such as a scientific report, a news report, or even a "chapter" in a science textbook, there's no telling what you'll get.

Results/Benefits

The response to these writing assignments is usually quite impressive. Students for the first assignment routinely suggest a variety of nontrivial effects caused by modifying fundamental physical constants. The results of the second assignment can be even more striking: You can expect many of the papers to demonstrate a large amount of research into existing physical ideas as well as demonstration of a high degree of original thought. These are not merely flights of fancy. Students tend in a logical fashion to develop physical consequences that are consistent with accepted physical principles.

Writing a Term Paper

Brief Description

Students write a term paper on a scientific question that has as yet no known answer.

Objective

To impress upon students the need for good writing in science, to familiarize them with the mechanics of writing an inventive paper, and to show them the scope in science for the wide-ranging mind.

Procedure

The noteworthy aspect of this activity is in the choice of a topic. It is not unheard of for a term paper on a closed issue to be required in a science class, but this wide-open term paper is to be on a topic that is still a matter of debate in the scientific community. Students will be researching a problem that has no clearly defined solution. In this manner, they will get a glimpse of how scientists actually think and explore ideas.

If your students are not taking, or have not taken, an English course in which the mechanics of a term paper were discussed, then you need to instruct them in the preparation of a term paper. Several sources are available to guide students in the preparation of a term paper. See the end of this lesson for a list of sources.

The mechanics of the term paper are important, but the process of topic selection is emphasized here. Advise your students to start looking for a topic early in the term. They are to select topics according to their own interests, and they are to do some initial research in the library to see if there is enough information for a term paper. The topics can be stated as an objective ("To accumulate evidence that leukemia is caused by a virus") or as a question ("What is the potential for using atomic fusion to generate electrical power?" "Is inter-planetary space travel physically bearable by the human species?").

Give careful consideration to approval of their topics. If a student chooses a topic that proves too large, he or she may find the experience of writing a science term paper overwhelming. On the

SOURCE

Werner, Deborah. "Research on Topics with Unknown Answers," *American Biology Teacher* v41 n1 Jan 1979: pp. 48-49.

other hand, help your students pick a topic that is not so narrow that most of the literature is written for specialists and is thus probably beyond the students' comprehension. Also, help them pick topics for which the varying points of view are readily accessible in available resources.

The science term paper and the English term paper share similar processes: research, notetaking, and outlining. If you take a "writing-is-a-process" approach, the final product will be superior.

Have your students read each others' rough drafts and comment on them. One way for students to get a fair number of different points of view on their rough draft would be for them to form small groups, and have the members of a group edit the drafts of the other group members. Substantive and helpful comments from peers will stimulate the author to clarify the ideas presented. The intention is to avoid the tendency that students have of making merely cosmetic changes to ease a rough draft into a final draft. Encourage them to rethink their language usage seriously, the order of presentation of their ideas, their choice of references, the clarity of their writing, and their intended audience. Hard-hitting attention to rewriting students' rough drafts will improve their papers *and* their concept of their topics. This process demonstrates in a concrete way the mechanics of revision, a process that most student writers use only sparingly, if at all.

The final drafts are to be graded for scientific content and style as well as for the use of the English language. You may wish to ask an English instructor to grade the papers for the non-scientific content, in exchange for your assistance in incorporating science writing assignments into the English classroom.

Consider having the students prepare brief oral presentations of their papers to be given in class.

Results

Students respond positively to choosing a topic that deals with a problem with no generally accepted answer. Knowing that they are not searching the literature for "the right answer" causes students to weigh various approaches, and to take into consideration their own values and notions of what good science is. Also, getting students involved in their fellow students' papers (through group revision and hearing an oral presentation) exposes them to topics and approaches of which they might not otherwise think.

Additional Sources

EJ360673
Benson, Linda K. "How to Pluck an Albatross: The Research Paper without Tears," *English Journal* v76 n7 Nov 1987: pp. 54-56.

EJ332995
Dinitz, Susan and Jean Kiedaisch. "The Research Paper: Teaching Students to be Members of the Academic Community," *Exercise Exchange* v31 n2 Spr 1986: pp. 8-10.

ED260438
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ED295221
Zemelman, Steven and Harvey Daniels. *A Community of Writers: Teaching Writing in the Junior and Senior High School.* Heinemann Educational Books Inc., Portsmouth, New Hampshire, 1988. 286 pp.

Descriptive Writing

SOURCE

Rajan, Raj G. "Descriptive Chemistry in High School Curriculum," *Journal of Chemical Education* v60 n3 Mar 1983: pp. 217.

Brief Description

Students prepare a technical paper on a chemical element.

Objective

To introduce students to descriptive chemistry and to scientific and technical writing.

Procedure

After instructing your students in the Periodic Table, have them pick one of the elements and write an essay about that element. No two students may choose the same element; this way each student in the class will become the class "expert" on that element.

The essay is to include the following five sections:

1. History: Supply the date and description of the circumstances of discovery.
2. Atomic data: list the atomic number, mass, position in the Periodic Table, electronic configuration, metallic property, etc.
3. Occurrence, extraction, and purification: Describe the form in which the element is obtained, geographical location of the ores, and methods of purification.
4. Properties: Describe several physical and chemical properties of the element. Require the students to include a balanced equation describing each chemical property.
5. Uses: Describe four different uses of the element; describe three compounds of the element, and the methods used in preparing the compounds.

Research and writing of the essays takes about four to five weeks, depending on your students' previous experience in doing library research. An effective grading procedure for this assignment is basically a checklist against which to tally the students' presentation of the correct number of uses, compounds, formulas, etc. With this grading procedure, the student keeps looking until he or she finds the correct number of uses, compounds, etc. The students' grade depends on the quality of the presentation of the information, on the clarity and conciseness of the writing, and on the correct use of the English language.

Results/Benefits

Students come to "adopt" their elements, and they soon become the class "expert" whose advice and information are sought by other students during the normal course of instruction. When this "adoption" occurs, and the student is consulted about his or her element, another important goal of writing across the curriculum is achieved: The student achieves the feeling of "intellectual ownership," and enjoys actual use of his or her knowledge beyond the immediate requirements of an essay or an exam.

Comments

Long Scientific Writing Assignments

Explaining Scientific Concepts Using Metaphor

SOURCE

Sunstein, Bonnie and Philip M. Anderson. "Metaphor, Science, and the Spectator Role: An Approach for Non-Scientists," *Teaching English in the Two-Year College* v16 n1 Feb 1989: pp. 9-16.

Brief Description

Students read essays chosen for the use of metaphor written by noted science writers. Students then write their own essays using metaphors to explain a scientific concept to a lay audience.

Objective

To structure students' thinking through carefully chosen reading and writing strategies; to guide students through the exploration of a scientific topic; to encourage a cognitive shift from writer to reader as students develop a sense for their audience; to produce a shift from simile to metaphor by moving students (using James Britton's terminology) from the "participant role" to the "spectator role."

Procedure

Have your students read essays by noted science writers. A good collection is Nancy R. Comely's *Fields of Writing: Readings across the Disciplines* (New York: St. Martin's, 1984). Encourage your students to keep a journal in which they record their observations on the essays. Require your students to include discussions of the topic of the essay, the audience, purpose, voice, style, form (use of rhetorical methods), research, and use of metaphor. Your students are to *evaluate* the essays, not merely take notes.

Topic selection and rough draft

Ask your students to investigate and write about an unfamiliar topic. The selection and initial exploration of the topic involve the students' existing knowledge, in line with the observation that "writers write about what they know." Three examples of topics are these: the human nervous system as automobile traffic, tonsils as soldiers providing the body with a first line of defense, and the body's cooling system as air conditioning.

Encourage your students to read several primary and secondary sources as they research their topics, while keeping in mind that they need to develop a metaphor for their topic. Students' rough drafts typically have a "research paper" look with an occasional analogy thrown in.

Structured Revision

Encourage your students to draw on their readings of the model essays in order to refocus their draft essay and turn it into literate discourse. The writing process includes the following steps:

1. Peer revision, in which the writer's classmates comment on the effectiveness of the metaphors used in the draft.
2. Further research to flesh out the extended metaphor.
3. The "verb pass," in which verbs associated with the non-scientific element of the metaphor are used in the description of the scientific element. For example, the student working on the topic of the nervous system as "traffic" replaced "carry" with "race" and "travel" so that the verbs in her essay clearly elaborated/extended the central metaphor. This student also replaced "is made up of" with "jammed" and "crowded."

Results

Not all students achieve the "spectator role" in their essays, but even when they do not achieve special rhetorical success, they often gain a greater understanding of the scientific concepts they write about. The student who wrote about the body's cooling system as an air conditioner did not reach the same metaphoric heights as the other students, but she did improve her writing and did think through the several drafts of her essay. Those students who succeed in thinking and writing metaphorically achieve a high level of insight into the scientific concepts on which they write.

Evaluation

A good way to evaluate students' essays is to have the students read and assess each other's work. Since your students are now familiar with reading and evaluating science writing, have them exchange papers with one another, and evaluate their fellow students' essays using procedures similar to those used to evaluate essays written by scientists.

Comments

Long-term Writing Assignments in the Mathematics Classroom

SOURCE

ED 300 247

Kenyon, Russel W. "Writing IS Problem Solving." 1988.

Brief Description

Presents a list of long-term writing assignments designed for a variety of reading audiences and using a variety of rhetorical forms.

Objective

To help students understand that mathematics is more than just plodding through their textbook, chapter by chapter.

Procedure

These assignments require from a few days to a few weeks to complete. If your school does not have a writing center or some other place where students can get help to improve their writing, then the quality of the papers you receive may not be to your liking. If no outside assistance is available, perhaps you can enlist an English teacher willing to incorporate some of these suggested writing assignments into his or her course.

Suggestions for long-term writing assignments include the following:

- Write a paper about a career in mathematics.
- Review a book or paper on mathematics or computers.
- Write about the use of mathematics in particular sectors of the economy, such as insurance or space exploration or agriculture or predicting the national economy.
- Report on a famous mathematician.
- Report on math anxiety.
- Write about how mathematics is used statistically to measure intelligence, reading skills, mathematical abilities, and other aptitudes.

- Write about the history of some part of mathematics, such as algebra.
- Write about new developments in computer technology.
- Write a letter to a friend or fellow student describing your feelings, which can range from love to hate, towards the study of mathematics.
- Write a paper presenting a solution to a longer mathematics problem. Use no mathematics in presenting the solution.
- Report on the origins of a particular measurement (the length of a day, longitude or latitude) or measurement of standards (the meter, physical constants such as the speed of light, or the gram).
- Write a letter from the point of view of a career professional (lawyer, dentist, engineer, stockbroker) describing why mathematics is important in your job.

Results

Students are able to use writing to help them work through difficult material, and to see the subject of mathematics in a broader context through longer writing assignments.

Comments

Science and Imagination

Writing Poetry

Brief Description

Students write in a poetic form called "cinquain" (pronounced *sin-cane*) on topics including earth sciences, astronomy, and meteorology.

Objective

To give students a deeper appreciation of scientific subjects by evoking original ideas that go beyond the textbook.

Procedures

The basic form of the cinquain is as follows:

one word to name a topic

two more words that describe it

three words about what is happening

four words to describe how you feel about it

one word that to you means the same as the first

An example of cinquain using meteorology:

Snow

gentle, cold

glistens, floats, drifts

dazzels me in the moonlight

soft

Grading is perhaps best done anonymously by the class. Find a way to publish—on the bulletin board, in a class newsletter, in the school newspaper—the best poems.

Results

Some of the best poems are written by students who are low achievers in science.

SOURCE

Yelverton, Barbara and Dorothy Grange. "Crystallizing the Cinquain," *Science Teacher* v50 n1 Jan 1983: pp. 38-39.

Turning Images into Poetry

SOURCE

Blake, William E. "Science and Creative Writing: An Ad(d)verse Relationship?" *Science Teacher* v50 n9 Dec 1983: pp. 30-33.

Brief Description

Students gather visual images along with traditional fossils during a field trip. These images are then combined with other students' images to form a poem.

Objective

To get students to use their quantitative and their imaginative abilities to broaden a traditional scientific experiment—a field trip.

Procedures

Encourage your students to construct "imaginary cameras" and ask them to "take" at least one roll of film of things they think are beautiful as they proceed through the more traditional tasks of gathering fossils and studying flora and fauna. They will need to take notes on their imaginary shots to be able to remember them.

At the end of the trip, have the students review their imaginary photos, and pick the best one. Have them write down a few words that describe that imaginary photograph.

Gather the best images of each student, and then begin to form the images into a poem. There are a variety of ways to combine the images into a poem:

You could gather the images and write the poem yourself.

You could involve the students in the poetry writing by having them help you combine the images.

Students could, by themselves or in small groups, come up with poems on their own.

The particular way the poem gets written depends on the interest of the students in the activity, the quality and the quantity of the images, and the students' prior experience in writing poetry.

Results

This activity encourages students' imaginative and qualitative thinking. It enriches the learning process by demonstrating that imagination and science are not separate. The vivid imagery and economy of language characteristic of good poetry provides students with a record of their field trip that will probably stay with them longer than the purely quantitative information they gathered in the field.

Observation

Field trips are an important part of science education, but this poetry-writing activity can work just as well with observations made closer to home on the school grounds. Science and technology are at work everywhere in school, and imagery appropriate for this activity can be found all around. Also, having students observe, instead of just look at, the science and technology that surrounds them, will help them to understand scientific methodology better. They will realize that science does not come only from books—it is all around them.

Comments

Poetry Writing

SOURCE
ED 313 716
King, Robert.
"Poetry and Science in the Classroom," *Insights into Open Education* v22 n5 Jan-Feb 1990.

Brief Description

Presents a series of poetry-writing assignments capable of being fitted into the teacher's own practice of teaching and learning about science.

Objective

To demonstrate to students that poets and scientists are bound together in their attempts to observe closely, to discover and to define connections, and to offer their results for empathic identification.

Procedures

Poetry and science can be seen, and taught, either as ways of making meaning, or as mindless replication of existing knowledge. In the first case, science is presented as a process of gathering information to form generalizations which are then tested; and writing is used by students to turn their ideas and experiences into meaning. In the second case, science is rote memorization that is assessed using mindless multiple-choice questions; and writing poetry is reduced to squeezing hackneyed notions into rigid frameworks required by the particular metric scheme or rhyme pattern.

The following ideas for poetry-writing assignments energetically embrace the notion that science and poetry can be taugnt as ways of making meaning, rather than ways of regurgitating textbook information or producing lifeless words in coffins of form.

A. Poems of Observation

- List the sensory qualities of an object, and then use vivid sensory words to write a poem to describe that object. Suggested sensory qualities include the smell of a flower, the visual impact of snow falling, the sound of a thunderstorm, and the feel and smell of an herb plant.
- Observe a scene and write a poem. Then write a poem including things not discussed in the first poem. The intent is

to focus on the elements of the scene that were not "observed" while writing the first poem. Scenes might be a rainstorm, then its effects on fledglings in a nest; or a lightning strike, then its effect on whatever (or whomever) it hit.

- Write a poem, or just a few lines, about a scene. Later, go back to that scene and write about how the scene has changed since you wrote the first poem. Scenes might be a rainstorm, then the flooding afterward; or a blizzard, then the efforts to dig out from under all the snow.

- Observe (or imagine) how a variety of animals move. Start by listing verbs that describe the motions of each animal, and then make the verbs alliterate with the names of the animals. Write a poem on how a group of animals moves, or the variety of one animal's motions. Animals with distinctive ways of moving include cheetahs, grizzly bears, snakes, humming birds, and slugs.

- Choose a color in a scene, and write a poem about that color and those things in the scene with that color. Colors include the blue in the sky, the reddish-orange color of the sunset, the black (or grey) color of asphalt, and the green or yellow or red or orange or brown or other color of leaves.

- Pick something around you that is very small. Just what "small" means in this context is up to you. Write a poem as detailed as possible about small things, such as a grain of sand, the seed of a plant, an electron, a water molecule, a strand of DNA, or a single gene.

B. Poems of Connection

- Connections of time: Pick something that changes (whether a lot or a little) over time, such as the earth, a plant, an animal, a cell, or an idea. The first stanza could be about the object's beginning; the second, about its present circumstance; and the third, about its future; or, you could reverse the order.

- Connections of cycle: choose a phenomenon involving developmental stages (such as of plants and animals) and write a poem describing the processes of life as vividly as possible. For each stage of the development, try to write several lines or a stanza.

- Connections of metaphor: Choose a metaphor for some scientific concept, and write a poem. Metaphors include atoms as small solar systems, the human nervous system as automobile traffic, and tonsils as soldiers defending against invading germs.

- Connections of scale: Write a poem in which you shift back and forth from details of something very near you to something very far away. A good choice would be to write a poem using the weather (rain, hail, snow storm, tornado) as your subject. Emphasize the difference in scale from the very close to the very far away.

C. Poems of Empathic Identification

Avoid the tendency to anthropomorphize in writing these poems. Really try to imagine yourself as the object, rather than as a human pretending to be the object. Get inside the object; become one with it; explore all your senses, now, as the object.

- Choose some common object and write a poem as if you were that object. Imagine what it feels like to be that object: avoid including or ascribing human attributes to the object. Objects might be a red blood cell, a tree, a vacuum cleaner, or a computer keyboard.
- Imagine yourself to be an animal, and write a poem concerning what it feels like to be that animal, such as a flamingo, a cockroach, a flea, a newborn baby turtle racing to the sea to avoid being eaten by a hungry seagull, a tadpole, a cat, or a dog.
- Choose some process that is not directly observable (heat flow, electricity, magnetism). Write a poem as if you were a part of that process.
- "Identify your world" by choosing a vantage point and becoming an observer. Write a poem about that world, being as detailed as possible. Be a cell describing its world, or an ant describing its world, or a planet describing its solar system and its galaxy.

Results

Poetry and science are not so different as your students might think. After writing a few poems, they will begin to realize that scientists and poets are akin in their attempts to observe, to discover connections, and to invite empathy. Students will realize that science need not be an accumulation of dry facts to be memorized, and that poetry need not be a string of words forced into predetermined and rigid forms.

Drilling for Oil

Brief Description

Teams of students examine geological survey maps to decide where, and whether, to drill for oil.

Objective

In dealing with a variety of ambiguous data, the students learn to cooperate, to weigh conflicting information conscientiously, and to argue—in writing—their position on a problem for which there is no known correct answer, and many possible incorrect answers.

Procedure

Assemble geological survey maps and prepare a hypothetical budget for each group of students to include in their evaluation of the feasibility of drilling for oil.

Instructions for Students

- Form small groups (about four in each group) to examine the geological survey maps and consider the budget. You must decide whether drilling would be profitable for your company.

- Consider breaking the job into smaller parts and assigning these parts to people in your group according to their particular interests or strengths. Your group must decide how to weight the various factors, including demand for oil, cost of drilling, availability of oil in the geological region under study, the rock strata in which the oil might be located, etc.

- Allow several days for group meetings. Role-play the "chair of the board" and respond to students' questions concerning their reports. Have each group decide upon their own format for their written reports. If a group has trouble getting started, you can recommend a format.

- You may find that some groups work very well together, whereas others may need more advice and suggestions on how to tackle this project. One student group came up with an unusual approach to gathering data: When a member of one group wandered from group to group, and the instructor asked

SOURCE

ED 233 383

Thaiss, Christopher J. *Learning Better, Learning More: In the Home and across the Curriculum. The Talking and Writing Series, K-12: Successful Classroom Practices*, 1983.

what he was doing, the student replied that he was serving his group as an industrial spy.

Results/Benefits

Students develop their writing and speaking skills in the context of understanding and communicating with their peers in a structured learning environment. Applied geological science becomes the center of attention, and students use writing to demonstrate that they can argue their case. The students may not remember the factual details of the assignment for long, but they do remember HOW they learned what they learned. Students recognize that using writing to learn science is an effective way of learning, and that the ability to express oneself orally and in writing is as important in science as it is in the English class.

Evaluation

The reports should be assessed for the thoroughness, accuracy, clarity, and strength of reasoning. Consider having rival groups assess the others' reports. A class discussion in which rival groups are pitted against each other should make for a lively discussion. Imagine that these several research teams are trying to sell the chair of the board on drilling for oil according to their research findings. Millions of dollars—and the teams' jobs—hang in the balance!

Comments

Student-Development Narrations for Existing Audio-Visual Materials

> **SOURCE**
> Leeper, Faye. "Integrating Biology and English," *American Biology Teacher* v46 n5 May 1984 : pp. 280-81,288.

Brief Description

An interdisciplinary project in which students write, edit, and record narratives to accompany a series of filmstrips, or other audio-visual material, on scientific topics.

Objective

To demonstrate to students the interrelatedness of the material that they learn in English class with the material that they learn in science class.

Procedure

This activity can be used in a science class, an English class, or both. Select a filmstrip, film, or video, with a script that you consider to be faulty or inappropriate. You and your class may wish to rewrite the narration either for a different audience (for example, making the subject clear to younger students), or you may attempt to improve the existing narration for yourselves.

Break the class into small groups, and have each group work on a different script. Have the students outline their narration, conduct research in the library to update and verify the content of their narration, and then script their narration frame by frame.

Once the script for the narration is completed, the students need to consider how many different narrators to use, and whether to incorporate audio effects (such as background music or sound effects) into the narration. The final version is then recorded.

Evaluate the narrative for scientific accuracy, evidence of adequate research, and proper use of the English language. You can also evaluate for interest, appeal to audience, clarity, and other aspects of production.

Results

Your students may at first be skeptical that they can succeed, but as they begin to work, their initial insecurity disappears and is replaced by high motivation to do well. Students end up with something concrete to show for their efforts, and something that can be seen and heard by their fellow students. Writers write to be read; this activity results in a type of publication that is gratifying to its authors and beneficial to its users.

Comments

Using Scientific Methodology to Teach Consumer Values

Brief Description

Using the magazine *Consumer Reports* as an example, students plan and carry out an experiment to rate consumer products.

Objective

To enliven the science class, to encourage consumer awareness, and to demonstrate the way science works outside of class.

Procedure

Paper towels are a consumer product that can be tested cheaply, effectively, simply, and easily. The factors to be considered when choosing the type of product to be tested include these: the cost of experimental objects, absence of recent product-testing results in "Consumer Reports," capacity of the product to have its characteristics tested by simple means, and availability of several brands of the product so that clear-cut differences will appear among the brands tested.

Have your students design procedures to determine the best product. Refer them to *Consumer Reports* for examples of the characteristics that are typically tested. To avoid plagiarism, pick a product that has not been tested recently. In consultation with each other and with you, the students come up with simple procedures to test the various characteristics of the product. Choosing the product and establishing the procedures to be used can be done by you alone, by your students, or by the class as a whole.

Perhaps the first few times you try this activity, it would be better for you to pick the product and establish the procedures. However, students will soon tire of the activity if all they do is follow directions. Once your students become comfortable with the activity, shift the responsibility for conceiving and developing the activity to them.

Your students may find that the procedures developed to test the product either do not work or are not really applicable to this

SOURCE

Seese, John W. "Don't Throw in the Towel—Test It!" *Science Teacher* v51 n4 Apr 1984: pp. 28-29.

product. In that case, as in real-world science, new procedures will have to be devised. When this happens, you may wish to point out to your students that scientists have similar problems: If something does not work, new procedures need to be developed.

Students then write up the results in typical lab report format, except that the final conclusion is in the form of a detailed narrative describing the results of the testing and any recommendations for the consumer based on the results.

In developing procedures to test paper towels, some students researched how paper was made. Others wrote to manufacturers for information on the products. While this kind of involvement is not necessarily required, students can become involved with the experiment to the point that they look for information beyond their classroom, textbook, and teacher.

Results

Students become better informed consumers, and they see practical applications of their science skills.

Comments

Science and Imagination

Writing a Laboratory Report

Brief Description

Students generate problems or questions to investigate, develop hypotheses, brainstorm ways to test the hypotheses, perform the experiment, and then write a report.

Objective

To teach scientific methodology to students by showing them how to define and analyze a problem, how to formulate conclusions, and how to write up their results.

Procedures

This activity is designed to replace "cookbook" lab manuals, fill-in-the-blank worksheets, and other boring materials that prevent students from participating actively in the scientific process. Banishing these materials does not mean, however, that you want to leave the students on their own. For the first few times that students engage in scientific activity, they need you to walk through the steps with them. As your students become familiar with the steps, they will require less direct assistance from you.

Have your students form small groups (usually three to a group) as they become able to complete the guidelines on their own. Even after your students are able to follow the procedures on their own, you may still wish to engage in whole-class discussion concerning the purpose and problems section of the guidelines. Based on your own experience, you may have noticed that certain parts of some laboratory experiments are more problematic than others. Consider discussing the problematic parts as a class, using the students' combined knowledge and experience to try to work through the difficult part of the lab. Such occasional variety in the implementation of the laboratory exercise also helps to keep the activity interesting.

SOURCE

ED 331 022

Santa, Carol Minnick and Lynn T. Havens. "Learning through Writing," in *Science Learning: Processes and Applications*, edited by Carol Minnick Santa and Donna E. Alvermann, 1991, chapter 13.

A. Laboratory Guidelines

The following lab guidelines are designed for use by you and your students in developing and implementing a laboratory exercise. The guidelines serve as a framework for notes taken during the various stages of the activity. Your students will write up their reports based on the notes taken while using the guidelines.

Laboratory Guidelines

- 1. Purpose: Why are you doing this lab?
- 2. Problem: What problem are you investigating?
- 3. Hypothesis: What outcome do you expect? Make an educated guess based on what you already know.
- 4. Materials: What hardware do you need for the procedure?
- 5. Procedure: What steps will you take, and in what order?
- 6. Data or results: Record any data or observations resulting from the procedure.
- 7. Analysis or conclusion: Did your results resolve the problem? Refer to data or results to support or invalidate your hypothesis.
- 8. Class conclusion: Compare your results with those of your fellow students. Note any discrepancies, and consider modifying your conclusions.

B. Report Writing

Your students can now turn their notes on the lab exercise (based on the guidelines) into a written report. Not every lab need be written up. The report contains the classic four sections: purpose, materials and procedure, results, and conclusions. The students can take material from steps 1, 2, and 3 of the guidelines to formulate the purpose section; from steps 4 and 5 for materials and procedure section; from step 6 for results section; and from steps 7 and 8 for their conclusion.

Evaluation of the written reports can be done by the students themselves. Have your students form groups of three. Your students then take turns reading their reports to the other members of the group who comment on the quality of the report. Knowing that their fellow students will be reading and evaluating the reports offers the students experience in writing for a knowledgeable peer, rather than for an omniscient reader (yourself). Having the students evaluate each other's reports has the additional benefits of saving you time in marking papers, and developing in your students the ability to read critically.

Introduce your students to peer evaluation through a demonstration. For example, you and two students can, in front of the class, read sample reports out loud. You and the students can then offer their comments on the clarity of the reports, whether the reports provide enough information, whether the data is presented in a clear manner, whether the conclusion follows from the data, and so on. You might also stress that being critical does not mean being negative. During the demonstration, offer positive comments as well as recommendations for improving the report.

However, having your students evaluate each other's reports can degenerate into a perfunctory activity. Some students may cease to offer their peers any substantive comments; others may fail to act upon the comments that they do receive from their peers. Either way, peer evaluation is not a panacea. One way to keep it useful is to develop a checklist for lab reports. You and your students can come up with a list of attributes that a well-written lab report should contain. The checklist can then be used in the peer-evaluation groups.

Results

Students become familiar with scientific methodology because they actually perform the steps, instead of "doing what the lab manual says to do." Students gain experience in writing for an audience other than the teacher.

Comments

Collaborative Writing of the Dreaded "Word Problem"

SOURCE
"Sharing Teaching Ideas," *Mathematics Teacher* v83 n7 Oct 1990: pp. 542-47.

Brief Description

Students form small groups and write their own word problems.

Objective

To give students experience in collaborative writing and solving problems, and to assist them in learning the techniques of problem-solving.

Procedure

Dealing with Dread

Word problems pose a challenge for most students. The difficulty usually lies in comprehending the meaning of the problem and translating it into appropriate mathematical terminology, not in actually solving the equations. The goal of this activity is to help your students understand word problems by reversing the normal problem-solving process. Instead of learning how to solve problems that someone else wrote, your students themselves will write problems that someone else will solve. These "someone elses," however, will be their fellow students. Peer pressure is a powerful stimulator to write clear and intelligent problems. Your students will see how hard it can be to write a word problem that is easily understandable.

Organize Them into Small Groups

Form your students into small groups of three or four. Have each group select a leader, and identify which member will be responsible for what duties. The specific duties will vary depending on the resources available to you and your students. Assuming that the groups have a computer available for their use, they can designate one member as responsible for generating graphics for the word problems. Groups may designate other members as being responsible for generating topics, for working on making the language clear and concise, and for working out the solution to the problem.

Divide the Labor

One teacher who used this approach set the whole activity in the context of an editorial group working under daily deadlines. One group member was the editor-in-chief, another was the language editor, a third was responsible for providing a detailed solution to the problem, and the last was responsible for the graphics. The requirements and daily deadlines were spelled out in detail for the students, including how many problems to write, and what proportion of the problems had to deal with percentages, geometry, fractions, and so on. Use this approach, if you like, or tailor the implementation of the activity to the needs, desires, and abilities of your students.

Supply Guidelines

Details—such as how many problems each group is supposed to write—depend on how much time and effort you want your students to put into this activity. Provide some guidelines concerning the types of problems written. You need not be as specific as the teacher mentioned above, but to avoid having your students write a lot of easy problems on the same topic, you need to specify that each group write some easy, some moderate, and some difficult problems using fractions, percentages, whole-number operations, and other procedures. Topics can be specified as well, and whole-class brainstorming for topics is a good way to start.

Appropriate Language

Working together in their groups, your students should be able to generate several problems and solutions in a short period of time. What will take more time is actually writing out the problem, agreeing on the appropriateness of the language, figuring out the correct solution, and then making sure that the level of difficulty and mathematical concepts included in the problem are within the guidelines.

As your students work together, you will see them propose problems in which the language is vague or misleading. If the other members of the group do not immediately recognize that the language is faulty, they will do so as soon as they try to agree on a solution. The group then needs to revise the problem and its solution until all agree on the appropriateness of its statement, and each member can solve the problem independently of the others.

How to Evaluate

Have your students write the problems on index cards with the problem statement on the front and the solution on the back. Collect the cards as they are completed, and enter them into a class problem file. One way to evaluate a group's work is to have another group, or the class as a whole, evaluate the problems. Criteria for evaluation would need to be developed and announced ahead of time, such as clarity of language, appropriate level of difficulty, effectiveness of graphics (if any), comprehensibility and correctness of the solution. Or, you could evaluate the performance of the group yourself. Or, both.

Recycle the Results

An excellent motivation for the students is for you to use some of the student-generated problems in your quizzes and exams. Your students will not only want to make sure that they can solve the problems that their own group generates but also they will want to make sure that the problems of other groups are comprehensible and solvable. The primary goal, though, is to help your students learn how to solve word problems by actually writing problems themselves.

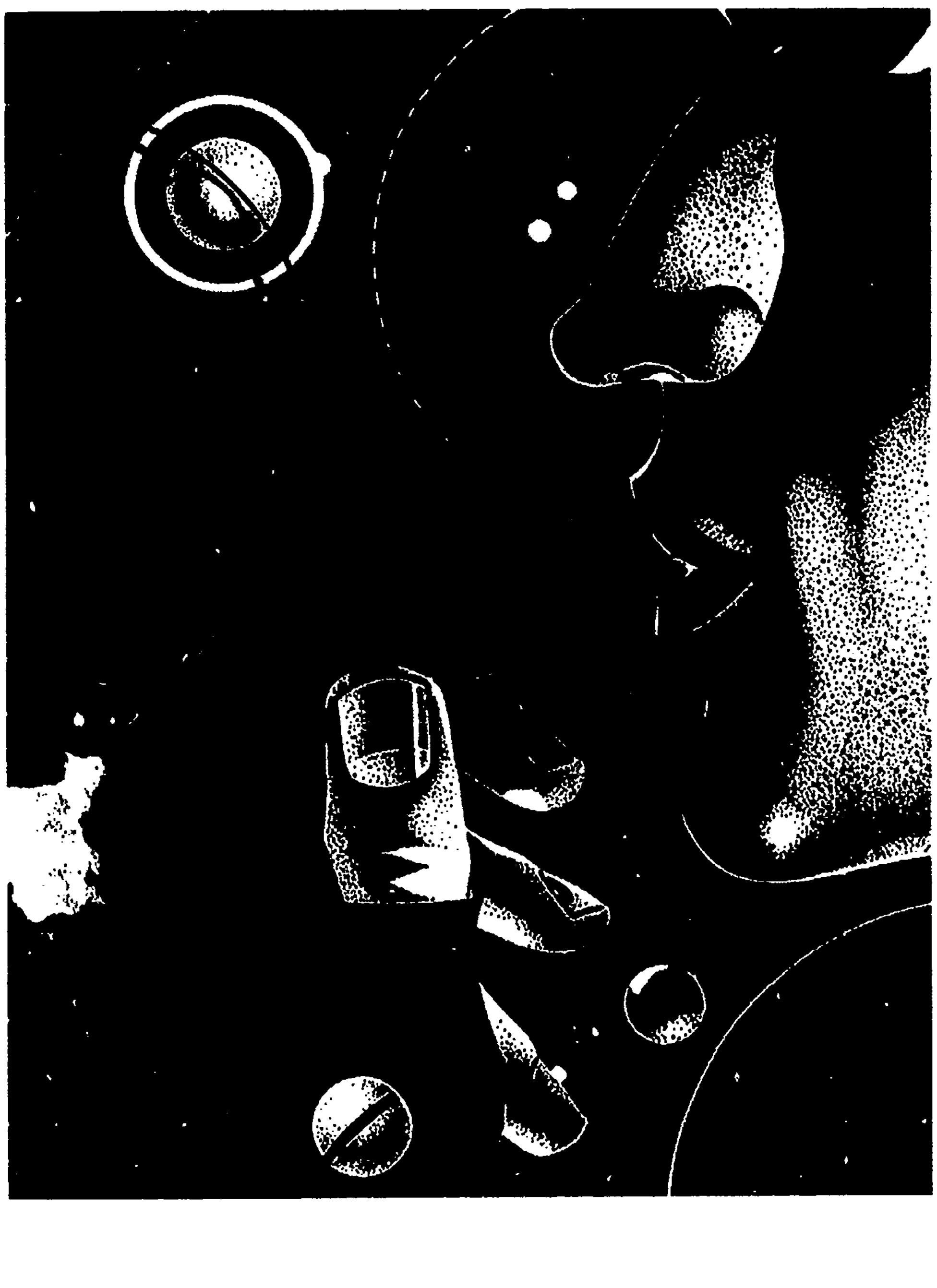
Your students may wish to extend this activity. They can write problems for students in lower-level math classes. They can exchange problems with students in other schools via computer modems.

Problem-writing—and good math students can write some ferocious problems—makes a great activity for the Math Club.

Results

Collaborative writing of word problems works for students at any level. Students improve their ability to communicate their mathematical understanding. Students see mathematics from the "inside out," as generators rather than mimickers. Students have the opportunity to clarify and reflect on their thinking. This technique is also useful as an evaluation tool.

Analogical Reasoning: From Science and Math to Words and Ideas, and Back Again



Analogical Reasoning: From Science and Math to Words and Ideas, and Back Again

Analogical reasoning—the ability to think that "this" is *like* "that"—is an important way in which students can learn difficult mathematical and scientific concepts. Analogies help us all to relate what we already know to what we are just now learning or do not yet understand well. Saying that the atom is *like* a miniature solar system with electrons orbiting a positively charged nucleus, for example, is an example of an often-used analogy. Drawing this likeness is effective, assuming that the learner knows what a solar system is.

Nevertheless, analogy has definite limitations that you as a teacher need to be aware of. Students may take the analogy too literally, thereby negating its value when the analogy instills in the mind an incorrect formulation of a scientific or mathematical principle. Students may believe that atoms ARE miniature solar systems, rather than that they are LIKE miniature solar systems. Analogies can be oversimplifications or incorrect or they can be pushed too far, also negating their instructional value. To make an analogy, analogies are like rubber bands: Stretch them too far, and they break.

The role of **analogy-making** in the development of twentieth-century atomic physics and quantum mechanics mirrors the power and limitation of **analogy-making** in the classroom. The first thinkers to propose an analogical atomic theory were the ancient Stoics, and in the nineteenth century atomic theories abounded, but it was not until the late 1890s that physicists realized that atoms must have an underlying structure.

One of the phenomena that eluded explanation was how atoms could produce spectral lines. Balmer developed an equation that could account for the lines, but there was no real understanding of how the lines were produced. **J.J. Thomson**, working with cathode rays, "discovered" the electron near the turn of the century by measuring the charge-to-mass ratio of what he assumed were little charged particles. Thomson's discovery ushered in a slue of conceptual models to describe atomic structure. His own model of the atom placed a very large number of electrons (on the order of 1,000) in a uniform distribution of positive charge. He likened the atom to a plum pudding. Thompson's readers who had never eaten a plum pudding missed the analogy, of course, as would many non-British students today. Other models developed in the early years of the twentieth century included one that likened the atom to the planet Saturn, with the electrons orbiting in rings around the central core of positive charge. These models had their limitations, as their developers themselves acknowledged. Tinkering with these natural and confected analogies to the atom went on for some years in an attempt to make the models fit spectral data.

The discovery of radioactivity also stimulated a great deal of research into atomic structure. A few months after Wilhelm Konrad Roentgen discovered X-rays in 1895, Henri Becquerel reported that uranium salts continuously emit radiation capable of penetrating black paper and exposing a photographic plate. How could a small amount of uranium emit this continuous stream of radiation? Scientists took up the study of radioactivity immediately.

Ernest Rutherford used two radioactive rays, called "alpha" and "beta" for simplicity's sake, as a probe into the structure of matter. Rutherford aimed a stream of alpha rays at a thin metal foil, expecting that most of the rays would pass through. Most of the rays did pass straight through or were deflected by only a small amount, a few of the rays were reflected through large angles, and some even bounced straight back. Using Rutherford's own analogy, it was like firing an artillery shell at tissue paper and having it ricochet back at you. In 1912, Rutherford developed a model for the atom that incorporated the results of his experiments on scattering: Atoms consist of a small, massive nucleus of positive charge surrounded by an equal number of electrons. Most of the atom is empty space, so when an alpha ray passes through, most times it does not hit anything, and so it passes through matter undeflected. Once in a great while, however, the rays will hit the nucleus and bounce back.

Rutherford's model accounted for the data he obtained by scattering alpha particles off of metal foils, but it also had problems: How could the electrons overcome the attraction for the positively charged nucleus? How can such a large amount of positive charge be packed into so small a space?

Niels Bohr, a student of Rutherford who went on to become an internationally known physicist, published a trilogy of papers in 1913 in which he put Rutherford's model on a firmer mathematical and conceptual foundation. In Bohr's model, electrons occupy "stationary states" around the nucleus. He solved the problem of stability by fiat: Electrons in stationary states, he proclaimed, do not lose energy and spiral into the nucleus, as classical electrodynamics requires. Bohr "quantized" Rutherford's model by explaining spectral lines as transitions between stationary states: The difference in the energy levels of the initial and final stationary states is emitted as radiation, the wavelength of which corresponds to the energy difference. The radiation is emitted not as a continuous wave but in little packets of energy called *quanta*. Bohr's grand analogy also explained the periodic table of the elements in a straightforward way.

Bohr used both classical mechanics and quantum ideas in developing his model. The results of calculations using classical mechanics, however, began to diverge from the results obtained using quantum theory at the atomic level. Bohr found that to specify certain parameters in the model, he had to match the results obtained by using quantum theory to the results obtained by using classical mechanics, in the range where the two theories were applicable.

The practice of using classical mechanics to be able to get results from quantum theory was characteristic of the period from 1913 to the mid 1920s. The procedure bore much fruit. A large number of phenomena were subsumed under quantum theory by using classical mechanics as a crutch. Bohr called this procedure the "correspondence principle," for classical mechanics can be used in the region where the results correspond to the results obtained from purely quantum theoretical calculations.

Bohr's model was accepted quickly by scientists, but the cost in terms of **"visualizability"** (the ability to form analogies) of the atom and its processes turned out to be high. One issue that perplexed physicists was what happens as the electrons "jump" from one energy level to another? Bohr wrestled with that and similar problems for some time. During the 1920s, his model, successful as it was for one-electron atoms, ran into difficulty.

Werner Heisenberg, among other young physicists, purposefully abandoned any attempts to visualize what was going on in the atom. In 1925, Heisenberg developed "matrix mechanics," a formulation of quantum theory, on the basis that all that matters are those quantities that can be observed—a behavioristic version of physical theory, one might say. Other matters—such as what was "really" going on in the atom—were banished. There could be no analogies to atomic physics in terms of classical phenomena, Heisenberg concluded, because classical physics cannot describe the insides of the atom. Other physicists, however, while accepting Heisenberg's formulation of quantum mechanics, did not accept his point that there is no way to visualize what goes on in the atom. (Analogy and visualizability also played a major role in Heisenberg's later, seminal contributions to nuclear physics and elementary particle physics, but that's another subject.)

Erwin Schroedinger developed another formulation of quantum mechanics in 1927. Schroedinger's "wave mechanics" is mathematically equivalent to Heisenberg's "matrix mechanics," but the former differs from the latter in its greater ability to suggest analogies to what goes on in the atom. One interpretation is that the mathematical equation representing the "wave function" of the electron describes the statistical probability of finding the electron in its orbit around the nucleus: The electron is likely to be found at those points in space where the wave function has a large amplitude, but it is unlikely to be found at those points in space where the amplitude of the wave function is small.

In 1930, yet a third formulation of quantum mechanics was put forth elegantly by **P. A. M. Dirac**. His book, *Principles of Quantum Mechanics* (4th, revised edition; Oxford: Clarendon Press, 1981), soon became the bible for physicists.

Historians of science argue over how these German physicists used the term *Anschaulichkeit* (visualizability). For the purposes of this essay, "visualizability" and "analogy" can be closely related. If you could visualize what an electron looks like or how it behaves, then you could draw an analogy between the quantum and classical phenomena.

An example of the extent to which physicists were trying to regain the power of analogy to describe the indescribable is the introduction of the concept of "spin." To explain anomalous splitting of spectral lines without resorting to "non-mechanical forces" (*unmechanischer Zwang*), physicists proposed adding "spin" to the properties of electrons. But a "spinning" electron cannot be visualized in a purely classical sense as a rotating top because a point on the electron could move faster than the speed of light. Physicists settled for the barely analogous concept of spin rather than give up visualizability completely.

In 1924, **Louis de Broglie**, using analogy, proposed that just as light has particle-like properties, matter has wave-like properties. Physicists had been loath to accept the notion put forth by **Albert Einstein** in 1905, that light exhibits particle-like properties and can be thought of as traveling in localized bundles of waves. The wave theory of light was so well entrenched that even as great a physicist as Niels Bohr had strongly resisted the "light quantum" hypothesis for years. Experimental evidence, however, began to mount, indicating that electrons could form a diffraction pattern, just as light does. Evidence also mounted that electromagnetic radiation exhibits particle-like aspects. In fact, **G.P. Thomson**, son of J.J. Thomson, conducted an experiment showing that electrons can diffract just as waves do. Father and son won Nobel prizes for their work. Physicists found themselves forced to accept that electrons and light act like both waves and particles, thus the word "wavicles" was coined. This wave-particle duality was not an easy concept to swallow.

Redefining visualizability, using wave-particle duality, Bohr promulgated the "Principle of Complementarity," which arguably has become the standard interpretation of quantum mechanics.

Referring to the location of his Institute of Physics in Denmark, Bohr's interpretation is also known as the "Copenhagen Interpretation." He asserted that quantum theory cannot unite causality and space-time descriptions as in classical mechanics. The laws of physics must be phrased in ordinary language to be understandable, although ordinary language is incapable of expressing events in the atomic domain. Quantum theory can express these events accurately in mathematical form, but they must be translated into ordinary language to be expressible.

The answer to this dilemma is that the wave and particle aspects of energy and matter are both complementary and mutually exclusive: One experiment demonstrated that the wave nature of light cannot also account for its particle-like behavior. Experiments demonstrating wave nature, and others demonstrating particle nature, are both required for a complete description of atomic phenomena. Quantum phenomena are thus visualizable only in a restricted sense. We need analogous concepts to express our grasp of wavicles—a term that **Dr. Seuss** might have invented—but no analogous concept conceived thus far seems valid in the atomic domain. Therefore, whatever analogies or means of visualizing atomic phenomena we have devised to date are necessarily incomplete.

So, then, are atoms like little solar systems, or not? The answer depends on the level of abstraction at which you wish to phrase the answer. To a student who knows little science, the solar-system analogy is a good place to start, keeping in mind that, like any analogy, it has its limitations. For more advanced students, the analogy begins to break down because, whereas gravity is an exclusively attractive force, particles charged alike repel each other, and unlike particles attract each other. Students still more advanced need to grapple with the Copenhagen Interpretation, Bohr's approach to visualizing the "orbit" of the electrons in the atom, or what happens when electrons "jump" from one orbit to another.

The history of the development of atomic models and the development of quantum mechanics show that analogy has played an important role in the thinking of scientists. If for no other reason than its habitual usefulness, analogy will continue to be used to train budding scientists. What we are able to describe accurately to degrees of mathematical precision through the left-hemispheric application of our brains, we may be able to glance—visualize—less precisely but in a fraction of the time with a right-hemispheric application of our brains. **This quick-and-dirty visualization is the beginning of analogy.** Even for those students who plan never to make a career of science, analogy is a way for them to relate formidable scientific concepts to similar concepts that they already understand. The history of science demonstrates that analogies come and go: They are useful for a time, but then they disappear into history books. Then it is time for the next generation of scientists to forumlate their own analogies in the quest to understand nature.

Thinking analogically—juxtaposing two universes of discourse so that the one illuminates the other—comes naturally to some people, but not to everyone. Like other cognitive skills, analogical thinking is a learned practice, and because it is learned, it can be taught. I recommend the book *Bridging: A Teacher's Guide to Metaphorical Thinking*, by Sharon Pugh, Jean Hicks, Marcia Davis, and Tonya Venstra (copublished by NCTE and ERIC/RCS), as an excellent way to teach yourself how to teach your students to think analogically. This guide to metaphorical thinking is more about literature and social sciences than it is about physical sciences or math, but the process of analogical thinking is essentially the same in any discipline.

The uses of analogical thinking in science teaching are practically limitless. I have talked about analogies to the atom, here, but you yourself can elaborate any number of other analogies, and you can stimulate your students to do likewise. Analogies work in all the sciences, and it has often been the analogies, not the scientific facts and realities, about which people have fought. The analogical statement in biological evolution, for example, that "man came from monkey," is a bit of metaphorical hyperbole that no Neo-Darwinian would affirm, and yet that is the battlefield in the war of the creationists *versus* the evolutionists. What if someone could come up with some really insightful, novel analogies for human origins that allowed us to circumvent this metaphorical impasse? How helpful that would be!

Annotated Bibliography of Related Resources in the ERIC Database

Annotated Bibliography of Related Resources in the ERIC Database

Documents cited in this section provide additional ideas and activities for teaching reading and writing across the high school science and math curriculum. The ED numbers for sources in *Resources in Education* are included to enable you to go directly to microfiche collections, or to order from the ERIC Document Reproduction Service (EDRS).

Abraham, Katherine. "Reading and Mathematics: The Twain Shall Meet." 1983. 15 p. [ED 315 734]

In today's mathematics classroom there is much concern about the students' lack of success. Mathematics teachers can successfully incorporate reading into their classrooms by (1) promoting in-class reading activities (2) teaching vocabulary (3) emphasizing mathematical symbols (4) ensuring understanding of mathematical sentences. Reading and mathematics are inextricably intertwined. Taught together, they can advance the student to higher levels of success.

Applebee, Arthur N., and others. *A Study of Writing in the Secondary School*. Final Report. National Council of Teachers of English, Urbana, Illinois. 1980. 242 p. [ED 197 347]

Provides discussion of a study detailing the instructional situations within which students are learning to write. Data reported from the study include a national survey of teaching practices and many classroom observations in ninth- and eleventh-grade content-area classrooms (English, mathematics, foreign language, science, social science, and business education). Following the first two chapters, which offer an overview of the study and its design, results from the various parts of the study are woven together in three chapters focusing on the major research topics: the types of writing that students are asked to do, teachers' purposes in making these assignments, and the interaction of purposes with the writing instruction provided. The sixth chapter brings the major findings together, highlighting the results in outline form. The final chapter places the results in the context of the more general question of what is needed to improve writing instruction in the secondary school. In service of the same goal, an appendix provides a bibliography of materials that offer practical, classroom-oriented suggestions for incorporating writing into a variety of different subject areas. Other appendices provide further details about results and instrumentation.

Berkheimer, Glenn D., and others. *Matter and Molecules Teacher's Guide: Science Book*. Occasional Paper No. 121. East Lansing Institute for Research on Teaching, College of Education, Michigan State University. 1988. 148 p. [ED 300 274; for activity book, see SE 050 125]

Based on the premise that science was developed for the purpose of describing and explaining natural phenomena. This means that an important part of teaching science consists of giving students the chance to practice their own describing and explaning. This unit was specifically designed to help middle-school students acquire an adequate understanding of kinetic molecular theory. It is organized into nine lesson clusters with an accompanying workbook. Each cluster contains goals and objectives, conceptual explanations and contrasts. This teacher's guide contains comments that accompany the text; lists of transparencies, charts, posters and videotapes; transparency masters; a list of materials by lesson; and an introduction to writing descriptions and explanations for the teacher.

Briggs, James, and others. "Survey: Writing in the Content Area." 1981. Paper presented at the Annual Meeting of the Wisconsin Council of Teachers of English, 1981. 21 p. [ED 207 062]

As a follow-up to the Central Wisconsin Writing Project, a writing survey was prepared to (1) introduce the concept of writing across the curriculum to high-school faculty in the district, (2) determine the district's need for inservice in writing across the curriculum, (3) establish the validity of the data, (4) collect information about writing expectations in high-school courses other than English, and (5) use the information as a basis for designing inservice strategies to meet the needs of non-English teachers. The survey was administered during October 1980 to departments of social studies, science, business education, driver education, physical education, home economics, industrial arts, and agriculture. The results indicated that 62% of the teachers did not connect the learning of course concepts to the ability to explain them in writing. Seventy-six percent felt that all written work should be read and evaluated by the teacher, but while 50% indicated that writing ability had some effect on grade, no more than 10% said that it had a major role in grading. Over 50% said that little or no teaching time was spent on activities to

improve writing, and most teachers had their students taking notes on a daily basis. No other type of written assignment received much attention other than short answers on worksheets.

Dupuis, Mary M., ed. *Reading in the Content Areas: Research for Teachers*. Newark, Delaware: International Reading Association. 1984. 88 p. [ED 236 544]

Intended for both elementary and secondary school teachers, this book is a reference source for the most recent research in content area reading instruction. The seven sections of the book cover the academic disciplines of English, foreign language, mathematics, music, physical education, science, and social studies. Each section opens with a summary of research that shows the major concerns and features of reading within that content area, then discusses the skills emphasized in the area and specific teaching methods for use with each. An appendix is a list of texts in content-area reading. Mary M. Dupuis and Linda H. Merchant, editors, *Reading across the Curriculum: A Research Report for Teachers* (ERIC/RCS, 1992), is a second, revised, and enlarged edition that includes new chapters on health education, business education, home economics, and vocational education.

Farren, Sean N. "Reading Assignments across the Curriculum—A Research Report." Paper presented at the Annual Meeting of the International Reading Association, 1983. 26 p. [ED 233 308]

Examined classroom practices in English, social studies, and science classrooms, seeking information on the purposes for which teachers assign reading within their specific disciplines, the reading activities that might be associated with these assignments, and the assistance or guidance that teachers might give their students to help them carry out the assignments. The results of the questionnaire completed by first-year secondary-school teachers indicated that reading assignments that required students to review the content of lessons, or to elaborate on that content, accounted for more than 50% of all reading assignments. Answering questions, orally or in writing, accounted for almost half the activities in the classroom. Assistance with lexical items, or vocabulary, was the most reported prereading activity—more direct assistance for dealing with ideas of text was reported much less frequently. In terms of cross-disciplinary comparisons, it is discouraging that the general-science teachers seldom reported assigning readings beyond the immediate lesson in a discipline that should be encouraging curiosity. It is also discouraging that questions requiring only literal understanding of a reading passage accounted for most of those asked, and that the level of explanation of the aims for the social-studies reading assignments was low. The results highlight the need for teachers to monitor constantly their classroom practice in light of the aims and objectives they set for themselves.

Gambell, Trevor J. "What High School Teachers Have to Say about Student Writing and Language across the Curriculum," *English Journal*, v73 n5 p42-44 Sep 1984.

Describes the difficulties that students have in language use in the areas of math, social studies, science, and English, as reported by high-school teachers in Saskatoon and rural Saskatchewan.

Hightshue, Deborah, and others. "Writing in Junior and Senior High Schools," *Phi Delta Kappan*, v69 n10 p725-28 Jun 1988.

Secondary teachers returning from Cummins Engine Foundation Writing Project seminars (Indiana) shared their ideas about integrating writing skills with various academic subjects. This article provides helpful hints to teachers of business, electronics, English, foreign languages, home economics, mathematics, science, social studies, and vocational education. An inset recommends practice essay exams.

Grimaldi, Candace M. "Can Improvement of Retention of the Science Content Area Be Had by the Addition of Study Skills?" M.A. Thesis, Kean College of New Jersey. 1987. 40 p. [ED 281 169]

Explored whether instruction involving an emphasis on study skills could help seventh-grade students retain material encountered in science classes. Subjects were 32 students from two intact science classes in a predominately white, middle-class school in New Jersey. To help them in organizing the content, the experimental group received an advance organizer as an overall summary of a textbook chapter they were studying. They were introduced to the chapter; were told to look at headings, pictures, and diagrams; pronounced and defined vocabulary terms; noted names of people and places relevant to the chapter. Each day, a review of the previous lesson was conducted before the new lesson was begun. The control group was taught without the use of any learning aid. All students were tested at the end of each chapter. Results indicated a significant difference between the means of the samples in favor of the experimental treatments. The findings suggest that study skills can help students retain science material content. (Appendices contain pre-test and post-test raw scores of the samples, and samples of pre-tests and post-tests used in the study.)

Healy, Mary K. *Using Student Writing Response Groups in the Classroom*. Berkeley, California: Curriculum Publication No. 12. Publications Department, Bay Area Writing Project. 1980. 38 p. [ED 184 122]

One of a series of teacher-written curriculum publications launched by the Bay Area Writing Project, each focusing on a different aspect of the teaching of composition. Provides step-by-step directions to develop small writing-response groups in any junior high or high school classroom, whether English, science, or social studies. The steps described include preparing for small-group response sessions, establishing response groups, using transcribed examples of small-group response, evaluating response group work, and coping with problems that may occur in small group work.

Hill, Ida J. "AP Calculus for Schools without AP Calculus Teachers." 1984. 7 p. [ED 248 129]

To meet the need for advanced placement (AP) calculus instruction in Virginia schools faced with a teacher shortage and small enrollments, the Virginia Department of Education--in cooperation with schools and television stations—was developing a high-technology advanced placement credit course. The course had eight components: (1) teleconferences/workshops to inform and initiate interaction with course developers, (2) a program handbook providing specific lesson information for students, (3) twenty linear television lessons on important calculus topics, (4) five interactive video programs using microcomputers and videocassettes, (5) independent computer diskette programs, (6) a teacher's guide to accompany the television programs, (7) a textbook and four ancillary manuals, (8) a non-credit in-service course for teachers, offered during the summer. Using the handbook as the main assignment reference, the student reports at a scheduled hour for independent study; assistance is provided by an identified teacher, if necessary. Periodic tests are administered; final evaluation is the Advanced Placement Calculus test of the College Board. Summative research for evaluating the project was being conducted.

Horton, Phillip B., and others. "The Effect of Writing Assignments on Achievement in College General Chemistry," *Journal of Research in Science Teaching*, v22 n6 p535-41 Sep 1985.

Students in a treatment group turned in written summaries of eight lectures, which were returned with chemistry and writing mistakes noted. Although achievement gains were found, results may have been due to the processes involved in organizing/writing the summaries or to the additional time required to complete the assignments.

Johnson, Lory Nels, ed. *Guides for Teaching Secondary Students to Read in Subject Areas*. Des Moines, Iowa: Iowa State Department of Public Instruction. 1980. 43 p. [ED 195 971]

Intended to help secondary school teachers with content-area reading instruction. Sections of the book contain step-by-step guidelines for successful reading experiences in business education, driver education, English, home economics, mathematics, music, science, and social studies. The booklet also contains a glossary of reading terms and appended information on the cloze procedure and the maze technique, the Fry Readability Formula, mapping, patterns of writing, designing structured overviews, constructing study guides, and content-area vocabulary development.

Kessler, Carolyn, and others. "Empowering Migrant Children: Talking, Writing, Learning." Paper presented at the World Congress of Applied Linguistics, 1987. 34 p. [ED 295 777]

This ethnographic study of 22 bilingual Mexican-American fifth-grade students in rural Texas examines which pedagogical techniques reduced students' risk of failure. Classroom instruction was based on the Cummins' model of community intervention in which storytelling, dialogue-journal writing, and bilingual dialogue between teacher and students figure significantly. Twenty-one books, written and compiled by the students in one year, achieved the following goals: They (1) conveyed the importance of writing, (2) developed fluency, (3) showed students that errors are integral to the learning process, (4) provided genuine communicative exchanges, (5) provided a daily reading lesson, (6) addressed individual needs, (7) developed a positive self-image, and (8) generated a sense of success. Pre- and post-test scores on the initial reading inventory revealed an achievement gain of three years during this one-year program. Students' statements of their future plans suggested that their self-esteem as bilingual students, and their goal orientation, had improved. Examples of the children's writing and drawing are appended.

Kresse, Elaine L. C. "Reading for Story Problem Comprehension." Paper presented at the Annual Meeting of the Plains Regional Conference of the International Reading Association, 1985. 5 p. [ED 273 923]

Students who have the necessary computational skills can solve word problems in mathematics only if they can comprehend the language of the problem. To teach reading comprehension of mathematical word problems best, teachers need to consider the following steps: (1) Prepare for teaching a problem by analyzing the ways the problem can be solved correctly, and identifying the words in the problem which suggest that process. (2) Give the students guided practice in solving a sample word problem by letting them see, step by step, how the problem can be solved. (3) Involve students in problem-solving by asking them to supply some of the answers; then gradually release them from direct instruction until they can solve the problems completely on their own. A sample word problem illustrating these three steps is included.

Langer, Judith A. *Writing to Study and Learn*. Stanford University, California School of Education. [1986] 58 p. [ED 297 316]

Two studies examined the effects of writing on subject learning. For the first study, 322 ninth- and eleventh-grade students read passages from high-school social studies and science texts and engaged in six writing-to-study conditions. Students who wrote essays scored lower on immediate topic knowledge post-tests, while the students who used study methods other than essay writing had the greatest gains on the immediate post-test, but also the greatest falling off at the 4th-week post-test. The second study focused on the relationship between what writers do during different writing tasks and recall. Ninth- and eleventh-graders (N=110) read two passages from the first study and engaged in four writing-to-study tasks. Findings indicated that the writing conditions led to greater recall of content than the non-writing condition, and that the more the content was manipulated during writing, the better it was recalled. Together, both studies indicate that tasks such as question-answering and notetaking involve a superficial manipulation of content, and they lead to extensive but short-lived learning, while the analytic writing tasks involve a greater depth of processing, and they lead to longer-term learning of a smaller band of information.

Lapp, Diane, and others. *Content Area Reading and Learning: Instructional Strategies*. Englewood Cliffs, New Jersey: Prentice Hall. 1989. 426 p. [ED 304 673]

Offers strategies to help educators become increasingly effective in teaching various areas in content-area reading and learning. Includes the following chapters: "Content Area Reading: A Historical Perspective" (E. Dishner and M. Olson); "Content Area Reading: Current State of the Art" (T. Bean and J. Readence); "The Role of Reading in Content Area Instruction" (D. Schallert and N. Roser); "Understanding the Readability of Content Area Texts" (G. Klare); "Comprehension and Instruction in Learning from a Text" (H. Singer and S. Simonsen); "The Students: Who Are They and How Do I Reach Them?" (N. Marshall); "Instructional Strategies for Developing Student Interest in Content Area Subjects" (M. Haggard); "Context for Secondary Reading Programs: Students as Beneficiaries" (C. Smith); "Banish Fears and Sorrows in Beginning Secondary Teachers: Some Suggestions for Teaching Learning-disabled and Gifted Students" (B. Wong); "Bilingual Students: Reading and Learning" (E. Thonis); "The Content Area Teacher's Instructional Role: A Cognitive Mediational View" (L. Roehler and G. Duffy); "Real-World Literacy Demands: How They've Changed and What Teachers Can Do" (L. Mikulecky); "Teaching Secondary Science through Reading, Writing, Studying, and Problem Solving" (C. Santa and others); "The Role of Reading Instruction in the Social Studies Classroom" (B. Hayes and C. Peters); "Teaching the Reading of Literature" (R. Probst); "The Role of Reading Instruction in Mathematics" (J. Curry); "Reading and Writing in the Content Areas of Physical and Health Education" (L. Gentile and M. McMillan); "Teaching Content Area Vocabulary" (M. Graves and others); "Study Techniques That Ensure Content Area Reading Success" (D. Ogle); "Using Conceptual Mapping as an Effective Strategy in Content Area Instruction" (D. Lapp and J. Flood); "Using Questioning Strategies to Promote Students' Active Comprehension of Content Area Material" (H. Anthony and T. Raphael); "The Significance of Prior Knowledge in the Learning of New Content-Specific Instruction" (P. Anders and C. Lloyd); "Ways of Activating Prior Knowledge for Content Area Reading" (A. Berger); "Thinking, Writing, and Reading: Making Connections" (A. Glatthorn); "Literacy, Learning, and Student Decision Making" (R. Tierney and J. O'Flavahan); "Using Computers Effectively in Content Area Classes" (C. Mathison and L. Lungren); "Text and Context in Content Area Reading" (R. Vacca and others); "A Cooperative Learning Approach to Content Areas: Jigsaw Teaching" (R. Slavin); "Assessment Instruments and Techniques Used by the Content Area Teacher" (R. Farr and others); "A Look inside an Effective Content Area Program: Trends" (D. Alvermann); and "Theory Becomes Practice: One Program" (J. Barton and R. Calfee).

McMillen, Liz. "Science and Math Professors Are Assigning Writing Drills to Focus Students' Thinking," *Chronicle of Higher Education*, v31 n19 p19-21 Jan 22 1986.

Math and science instruction now often includes more brief, informal writing exercises, sometimes completed in class, as a means of helping college students think more clearly. While writing skills are not emphasized, student writing often improves as a by-product.

Mumme, Judith; Shepherd, Nancy. "Implementing the Standards. Communication in Mathematics," *Arithmetic Teacher*, v38 n1 p18-22 Sep 1990.

Discussed the importance of teaching students to communicate mathematically. Examined ways to develop this skill. Includes activities and open-ended questions are included. Emphasized the use of physical materials, cooperative groups, listening skills, and writing.

Myers, John W. *Writing to Learn across the Curriculum*. Fastback 209. Bloomington, Indiana: Phi Delta Kappa Educational Foundation. 1984. 38 p. [ED 248 532]

Intended for use by secondary-school teachers in all subject areas, this booklet provides research-based information designed to make writing a learning process. Following brief discussions of the writing-to-learn concept, the importance of writing in all curricular areas, and steps in developing a writing-across-the-curriculum program, provides writing ideas and suggestions for the following subject areas: language arts, social studies, science, mathematics, industrial arts, business and vocational studies, art and music, and home economics. Among the ctivities discussed are these: (1) writing journals (2) writing in response to films (3) preparing oral histories (4) writing limericks (5) creating logic problems (6) preparing written interviews (7) setting up a research and development report (8) writing in response to music or art (9) career investigations (10) writing business letters.

Nordberg, Beverly. "Let's Not 'Write a Report.'" Paper presented at the Annual Meeting of the National Council of Teachers of English Spring Conference, 1984. 20 p. [ED 244 279]

In the traditional classroom, written reports assigned to students are generally returned as poorly written, reworded collections of facts taken from single sources. Cross-curriculum writing is a way of circumventing this and encouraging learning and thought development by the student. Writing is usually considered a communication skill, but recent research is establishing a link between the writing process and the use of cognitive skills that aid in thinking, like distinguishing relevant material and arranging data and assertions in patterns. In part, this notion derives from England's Bullock Report, which surveyed student work and isolated two important dimensions of writing—a sense of audience and function. In the United States, the Third National Assessment of Educational Progress found that students were unable to interpret what they read past a superficial level, and had serious problems with various writing tasks. The teaching implications of these findings are varied and wide, and extend from pre-writing—or examining a wide variety of resources—to breaking down composition into manageable steps, to selecting a real or imaginary audience to foster confidence. In subject areas like social studies, methods of inquiry can be stressed, while in science, writing as a tool for organizing and evaluating a body of knowledge can be emphasized.

Randall, Alice F. "Scientific Writing beyond the Textbook." Paper presented at the Annual Meeting of the College Reading Association, 1977. 25 p. [ED 154 345]

In contrast to the rigid forms of scientific textbooks and research reports, the examples of scientific writing discussed in this paper demonstrate a regard for human values within science, and they provide a rationale for introducing students to a variety of scientific writing as part of their educational experience. States that not all scientific thought or writing is technical or difficult to understand, and that the wide range of purposes, structures, and styles in scientific writing is something that high-school and college students should learn to appreciate. Suggests that by reading beyond the science textbook, students will discover that scientists are not a race apart, unconcerned about the effects of their work on others, but that they wield their enormous power only at the will of society, and that conscientious scientists strive to communicate.

Shaw, Joan Guelig. "Mathematics Students Have a Right to Write," *Arithmetic Teacher*, v30 n9 p16-18 May 1983.

Promotes incorporation of writing into mathematics classes, with numerous suggestions on using writing to help students recall procedures, develop story problems, and plan computer programs.

Singer, Harry; Donlan, Dan. *Reading and Learning from Text*. Lawrence Erlbaum Associates, Inc., Publishers, 365 Broadway, Hillsdale, New Jersey 07642 ($24.95). 1985. 543 p. [ED 270 717]

Appropriate for teachers of any grade who want to teach their students how to read and learn from text, this book explains how to develop and use strategies that will enable all students to read and learn in the content areas without stigmatizing them. The book is divided into four parts. The first part explains the changing role of the school and the need for teachers and schools to shift from directing instruction toward college-bound students to teaching subject-matter to all students. The second part describes single-text strategies that meet the wide range of individual differences in reading and learning from text, and presents methods of teaching students to discuss in groups and to report to the class in a variety of ways, including in writing. The third part starts with an explication of a blueprint for instruction used in both single- and multiple-text strategies focusing on how the teacher phases out and the students phase in any strategy in reading and learning from text, and concludes with an explanation and application of multiple text strategies in a phase-out/phase-in sequence in the content areas of English, social studies, science, and mathematics. The final part of the book focuses on the complementary role of the reading and learning-from-text specialist as a member of the faculty.

Strain, Lucille B. "Developing Interpretive Comprehension Skills in Mathematics and Science." Paper presented at the Annual Meeting of the World Congress on Reading, 1984. 23 p. [ED 253 854]

Helping students develop proficiency in the use of interpretive comprehension skills such as are required for reading mathematics and science materials becomes both a means for continuation of technological progress and a dimension of the kind of literacy needed for living and working successfully. The development of these skills must be sought in two major ways: as an integral part of the development process of reading throughout the elementary years, and as an objective of instruction in mathematics and science courses during the high-school years. Several specific skills of interpretive comprehension should be the focus of instruction as students read mathematics and science materials: (1) prediction of outcomes, (2) drawing conclusions, (3) making generalizations, (4) perceiving relationships, (5) identifying implied sequences of events and ideas, (6) selecting implied cause-effect relationships, (7) summarizing information. Among strategies for improving reading comprehension are questioning and the structured overview, which requires readers to focus on relationships between prior knowledge and current information and involves a diagram conveying major concepts in a unit of learning.

Yates, Joanne M. *Research Implications for Writing in the Content Areas. What Research Says to the Teacher*, second edition. West Haven, CT: National Education Association Professional Library. 1987. 35 p. [ED 299 591]

The ideas of John Dewey and his fellow progressives have resurfaced in a movement called "writing across the curriculum." Interdisciplinary studies are now being seen as a way to break down the artificial boundaries between subject areas. Research has confirmed that language learning and experience are at the heart of education. The implications are that instruction should be based on the personal and linguistic growth of the child rather than on the mastery of facts or concepts in particular disciplines, and subject areas should be used to provide students with the new experiences they need to broaden their knowledge. Researchers and educators propose a teaching philosophy and approach based on the concept of "learning by doing," which would mean much more talking, writing, and reading in the classroom. A number of ways for teachers to promote more language activities to help students learn include (1) organizing course content around central ideas or themes to give language assignments direction, focus, and purpose; (2) using the writing process to give teachers a more active role in their students' learning; and (3) utilizing journals, reading notes, or learning logs to provide students with the opportunity to describe and explore their own experiences. Teachers can use these and other ideas to integrate new techniques and current information into their teaching methods.

Young, Roberta. "How to Teach Writing without Knowing the Meaning of AWK." Paper presented at the Annual Meeting of the Texas Joint Council of Teachers of English, 1985. 7 p. [ED 254 853]

A Texas high school initiated a writing-across-the-curriculum program in which an English instructor first taught the writing process to 10 colleagues from social studies and science. The first session brought out concerns, questions, and frustrations, and laid the foundation for trust and understanding in the working relationship. Actual training began with the second session, which included setting goals, considering more extensive use of essay questions to promote one type of writing, examining the writing process, and practicing pre-writing activities. The third session concentrated on writing as a thinking and learning tool, and the fourth allowed small-group collaboration on specific areas as well as departmental efforts and sharing across the discipline lines. Lessons demonstrated practical procedures for the writing process, the use of writing as a learning tool, writing designed as an integral step in accomplishing existing course objectives, and increased potential for motivation, challenge, and student participation in learning. The ultimate goal is to have writing as an integral part of every discipline, district-wide. Initiators of the program have learned the following: (1) An appointed task force has the advantage of a small, select group, but the disadvantage of limited involvement through departments. (2) Release days for the participants are a definite advantage. (3) Teachers must actually perform the writing activities themselves, from pre-writing through evaluation. (4) The basic sequencing, from essays to thinking/learning/comprehending, is sound.

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