

the weave allowed light to peek through (i.e., the stars), and a hole cut in the top of the basket by a god let light in during the day.

Contrary to what many think, it was not explorer Christopher Columbus who first suggested that the Earth is “round.” Although the very early Greeks thought the Earth was a flat disc floating on water, Pythagorus proposed a spherical Earth about 540 BC.

About 250 BC, Eratosthenes made a good estimate of the Earth’s circumference. He used the observation that, in a deep well some 787 km south, the midsummer noon sun shone directly downwards, whereas in his town on the same day, the angle of the sun was about 7.2°. Over 100 years later, Posidonius made another good estimate based on the angles that the star Canopus made, with the horizon, at two different locations.

Toward the end of his life, Columbus (1451-1506) came to believe that the Earth was pear-shaped. This conclusion followed observations, during the third of his four voyages to the New World, of corresponding changes in the movement of the North Star and the temperature he experienced, with changing latitude. He further believed that the Garden of Eden was located in the pear’s stalk.

It was not until 1958 that the satellite Vanguard I provided photographic evidence that the Earth is an oblate spheroid (i.e., not quite round). The spinning of the earth gives it a slight bulge near the equator. The circumference around the poles is slightly less (just 43 km) than the circumference at the equator.

Strategies for Teaching Science Content Reading

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Abstract

Many students have difficulty in science because they are passive readers, readers who receive information without understanding. Passive readers begin reading assignments without thinking about the subject. Their counterparts, known as active readers, interact with text to construct meaning. They make predictions, ask questions, generate questions, and vigorously seek answers. For active readers, reading is a means of actively pursuing knowledge. Active readers engage in metacognition, which is an awareness of how they think. Active readers use both pre-reading and during-reading strategies to enhance their comprehension. The following article identifies attributes of passive and active readers, discusses the role of metacognition in reading, and provides pre-reading strategies and during-reading strategies that will help students’ transition from passive reading to active reading.

Introduction

I am always telling my students they do not learn science from textbooks. Neither do they learn science from lectures. They do not learn science from hands-on activities, study guides, worksheets, or tests. I tell my students to place their hands on their heads. That is where they learn science. Science is not learned merely by observing, reading, doing, memorizing, or reciting. Science is learned by thinking. It is learned by processing information and constructing models and theories that can be tested. When my students perform a lab, they are asking questions, making predictions, analyzing their data, and forming conclusions. When I am actively teaching my students, I do not merely recite information. I get in their faces and ask “Why? How? What if? Why not?” I seek total engagement of my students. Teaching and learning is two-way dialogue that forces students to think, to respond, and to defend their responses.

Science students need to be as aggressive reading their textbooks as I am with them when I am teaching. They cannot merely wait for the information to diffuse over to them, because it won't happen that way. In a figurative sense, they need to attack the text. They need to ask questions and actively pursue the answers. They need to ask “Why? How? What if? Why not?” They must pursue answers to their questions and, in turn, not be satisfied with the answers. Answers to questions should lead to more questions. I emphasize to them that questions are more important than answers. An educated mind is not built upon a foundation of static knowledge. Instead, it is continuously under construction through the gifts of curiosity and wonderment.

It has been my observation over the past four decades that many students have difficulty learning science because they tend to be passive readers. Passive reading is a style of reading that one might use when reading for pleasure, such as in the case of a light novel or a magazine article. However, to successfully read science text material, one must be an active reader. Table 1 compares the traits of active readers with those of passive readers (Rosas, 2003).

Background

I presently teach two classes of high school students, aged 15 to 17 years, who failed physics and chemistry during the regular academic year. The goal assigned to me by my supervisors was to give them an opportunity to master those concepts that eluded them the first time. A goal I assigned myself was to use the science curriculum as a platform from which I can teach my students those skills that will make them successful not only in science, but also in other academic disciplines. One of these skills is how to read science text material.

Table 1
A Comparison of the Traits of Active and Passive Readers

<p style="text-align: center;">An active reader (self-monitors, adjusts, and reflects)</p>	<p style="text-align: center;">A passive reader (simply receives information without understanding)</p>
<p><i>Pre-Reading</i></p> <ol style="list-style-type: none"> 1. Builds up background knowledge before beginning to read. 2. Knows the purpose for reading. 3. Asks what the text will be about 4. Previews the pictures, title, heading, boldface quotes, etc. 5. Makes predictions. 6. Breaks text into manageable chunks. <p><i>During Reading</i></p> <ol style="list-style-type: none"> 1. Gives complete attention to the reading task. 2. Keeps the purpose in mind. 3. Self-monitors comprehension. 4. Stops to use a fix-up strategy when comprehension is low. 5. Rereads for understanding. 6. Connects with text--compares learning with what he/she already knows. Has opinions about the reading. 7. Asks what author is trying to say. 8. Continues predicting. 9. Generates questions and seeks answers. 	<p><i>Pre-Reading</i></p> <ol style="list-style-type: none"> 1. Starts reading without thinking about the subject. 2. Does not know why he/she is reading. 3. Is not curious about the text. 4. Does not preview text materials. 5. Does not make predictions. 6. Is overwhelmed by amount of text to be read. <p><i>During Reading</i></p> <ol style="list-style-type: none"> 1. Is easily distracted. 2. Does not know why he/she is reading. 3. Does not monitor comprehension. 4. Does not know if he/she understands. 5. Does not reread the material. 6. Does not, or cannot, make connections and does not have an opinion about what was read. 7. Doesn't care what author is saying. 8. Does not make predictions. 9. Does not ask questions.

Metacognition is an awareness of how one thinks. It is not sufficient that one recites an answer to a problem, but rather one must be able to explain how the answer was determined. One engages in metacognition when one can describe the steps that were undertaken to solve the problem. Another example of metacognition is using criteria to make a choice. Metacognition, then, is the process of thinking about one's own thoughts. It differs from other types of thinking in that its source is tied to one's own internal mental representations of a reality, rather than information that appears from one's immediate reality. In a broader sense, it involves the conscious awareness and control of one's learning (Hacker, 1996).

In the context of reading skills, metacognition refers to thinking about what one is reading (Hacker, 1996). One study found that "metacognition during reading is dependent upon four variables: texts, tasks, strategies, and learner characteristics"

(Collins, 1994). In other words, there are four factors that can influence comprehension: 1) text variables, 2) task-related variables, 3) reading strategies, and 4) learner characteristics.

Text variables. These are features of the text that influence comprehension. Examples are the arrangement of ideas, vocabulary, syntax, clarity of the author's intentions, and the connections made by the reader to prior knowledge. It has been shown that readers can optimize learning by becoming aware of text structures and the resultant effect they have on learning (Collins, 1994). It was also noted that if there are ambiguities or confusion in text passages, good readers will adjust their reading rate and may return to an inconsistent passage several times to compare what they know with what is written.

Task-related variables. Good readers and poor readers differ in their knowledge and ability to control task variables. Derivation of meaning from text is a task that requires the reader to understand that the purpose of the reading is to construct meaning. Another task is being able to monitor one's performance. Good readers have means of assessing how they are performing (Collins, 1994).

Reading strategies. Good readers use comprehension strategies such as forming a mental image, rereading, adjusting the rate of reading, searching the text to identify unknown words, and predicting meaning that lies ahead (Collins, 1994). Research also shows that good readers have a repertoire of strategies, and the selection of a strategy is influenced by the type of text material they are trying to comprehend (Armbruster, cited in Collins, 1994). Such strategies can be taught as study strategies. Examples include underlining, outlining, note-taking, summarizing, and self-questioning.

Learner characteristics. The final variable is the awareness of the reader of his own learning characteristics, such as background knowledge, skills, and deficiencies that could influence his comprehension. Good readers tend to connect text information to previous knowledge. Poor readers show little tendency to make connections. Students can be taught to work with these four variables--text, task, strategies, and reader characteristics--to improve their metacognition skills as a part of the goal of becoming self-directed learners (Collins, 1994).

Reading Strategies

The purpose of this project was to focus on the teaching of comprehension strategies. My literature review identified a variety of strategies that are grouped into two categories, although there is some overlap between the categories. Pre-reading strategies are intended to encourage students to think about what they already know about a topic, to direct their reading to the purpose of the text, and to inspire their

interest and curiosity in the topic (Educational Research Service [ERS], 1999). During-reading strategies are intended to help students monitor their comprehension (ERS, 1999).

The following describes many of these strategies. While quite a few of those found were not specific to science text reading, I made some changes to exemplify how they might be adapted for use in a science classroom. Also, when a teacher is introducing any such strategies, it must be remembered that a good teaching technique is to model the strategy to the class. As in the case of most types of learning, student observation of the proper modeling of a reading strategy will result in enhanced student facility in using it.

Pre-Reading Strategies

Activating Prior Knowledge

One group of pre-reading strategies focuses on activating prior knowledge (ERS, 1999).

Quick Talk. This is a strategy that is based upon the premise that when we talk about things we know and the things we learn, our knowledge can be reinforced (Billmeyer & Barton, 1998). This is particularly effective with the verbal/linguistic learners. Ask students to pair up, and then follow a script similar to: “Turn to your partner and tell him or her what you know about You have 30 seconds. Go!” Once 30 seconds have passed, regain their attention and then say: “Alright, switch roles and tell your partner what you know. You have 30 seconds. Go!”

Variations to Quick Talk include Quick Write and Quick Draw. The titles are self-explanatory.

K-W-L Chart. K-W-L involves using a chart to record what students ***Know*** about a topic, what they ***Want*** to know, and what they ***Learned***.

K-W-L Chart

What do I <i>know</i> ?	What do I <i>want</i> to know?	What did I <i>learn</i> ?

The following steps will help to ensure success with this strategy:

1. Use an example of the chart, on an overhead transparency or chart paper, to model its use for students. To fill in the “What do I know?” column the first time, it is best to talk aloud about things that came to your mind when your students were reading a previous piece. That way, they too are able to add their prior knowledge to yours when filling in the chart. Remember to write as you talk.
2. Share the goals students had for their reading when you completed the last section. For example, “I was hoping that the author wanted to discuss”
3. Share, solicit, and record what was learned from that previous reading. Give students their own blank chart so they can use it for a future assignment.

Anticipation/Prediction Guide. This activates prior knowledge and, at the same time, creates anticipation regarding new information or concepts (Billmeyer & Barton, 1998). An example follows.

Anticipation Guide: Applied Genetics

Directions: For each statement, place a check in either the *agree* or *disagree* column. Be prepared to support and defend your opinions with specific examples. After reading the text, check those statements with which the author would agree and compare your opinions with those of the author.

Agree	Disagree	Author	Statement
			Genetic engineering represents a threat to humans.
			Humans have been cloned.
			Hybrid vigor usually results from crossing animals having different physical traits.
			Sheep are cloned by selective breeding.
			Insulin can be produced by genetic engineering.
			Genetically altered corn will cause genetic defects in humans.

Students will have some basic beliefs that may be challenged by the statements. They will focus on the reading because they have a need to find evidence that supports their preconceived positions on certain controversial topics. Suggestions for constructing an anticipation guide include:

1. Choose the important concept(s) for students to gain through reading.
2. Determine ways these concepts might support or challenge students’ beliefs. Then, create four to six statements that support or challenge those beliefs. Be careful to write statements that can be easily understood.

3. After students have responded to the statements, discuss each statement with the entire class. Knowing that this will be part of the process inspires close reading, as students work to find material to defend their side of the issue or topic.

Analyzing Text Features

A second group of pre-reading strategies is collectively referred to as analyzing text features (Billmeyer & Barton, 1998).

Surveying a Text. This strategy provides students with simple survey questions regarding their class text, and the teacher should “take the students through” these questions prior to inviting them to read the text. Completing the survey helps students to understand more content and to gain a sense of power from that knowledge. The following example is from Billmeyer and Barton (1998).

Textbook Survey

As you look through the text for this class, briefly answer the following questions in the space provided.

Author(s)

- Who wrote the book?
- What information do you find about the author?
- Did the author write a section specifically to the student?
- Is there a preface that gives details about how and/or why the book was written?

Organization

- How is the book organized?
- What does the table of contents reveal about the organization?
- Is the organization historical, chronological, factual, or other?
- Does the book have chapters and/or units?

Timelines

- When was the text written?
- Will the age of the book and its information be a problem in this class?
- Will you need to refer to other sources for more recent information?

Book Contents

- Does the book have an index?
- Does the book have a glossary?
- Does the book have a bibliography?
- Does the book have an appendix or appendices?

Graphic Aids

- How are the illustrations used in this book?
- Does the book contain any graphs, charts, tables, maps, etc.? How are they used?

- Are vocabulary words highlighted in some way?
- Are study questions highlighted or emphasized throughout the text?

Textbook Scavenger Hunt. Students receive a list of key items to be found in their textbook. They must locate the items, note the page on which the items were found, and write down the method they used to find the information.

Unlike a standard scavenger hunt, the items should be chosen on the basis of how well they will clarify the way the text is put together. Items might include:

- Table of Contents
- Glossary
- Important tables, graphs, charts, and/or formulae
- Lists of specific terms
- Important text features (e.g., color-coded text, bulleted lists, italic print, and bold lettering)
- Contents and organization of the index/indices
- Primary sources for the text. (Billmeyer & Barton, 1998)

Vocabulary Development

A third group of pre-reading strategies is based on vocabulary development. (Billmeyer & Barton, 1998).

Student VOC Strategy. This works well in helping students analyze word meanings from context. It also allows for a more sensory approach to learning the vocabulary, addressing various learning styles with one exercise.

Vocabulary Word: (Insert here)

1. Write the sentence in which this word appears in the text.
2. Based upon how it is used in the text, predict what the word means.
3. Consult an “expert” (e.g., a friend, teacher, or text resource) for the actual definition.

Expert: (name/title)

Expert’s definition:

4. Show your understanding of the word by using it in a sentence of your own.
5. Choose one of the following ways to help you remember the word’s meaning:
 - Draw a picture of what the word means to you.

- Select and perform a miming action that the word reminds you of.
- Connect the word with something similar that you've heard (e.g., a story, news report, or song). Write down the association or connection you have made.

6. Explain why you chose this way to represent what the word means to you.

Word Sort. The Word Sort is a relatively simple, yet highly effective, method for building student vocabulary. The idea behind this strategy is to help students build semantic connections between terms as they learn new material. It has the added benefit of providing the teacher with information about the prior knowledge students bring to a topic.

First, students copy vocabulary terms onto note cards, one word per card. (The terms should include both new and known words.) Then, either individually or in groups, students sort the words into categories. The sorting may be closed (the teacher provides the categories) or open (students choose their own categories and identify their own labels for each category).

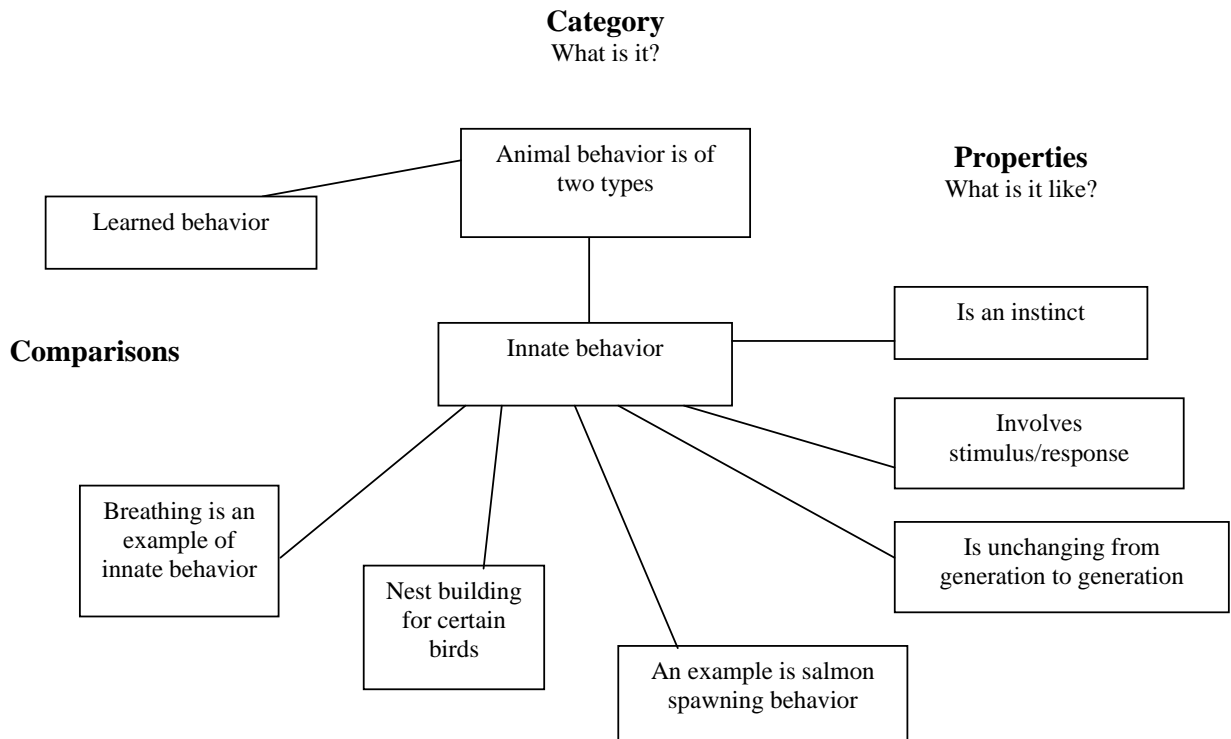
Once sorting has finished, students should discuss the reasoning behind the choices they made. In many instances, it is this phase of the strategy that results in the most learning for both students and teacher alike. A variation on this exercise may include a multiple intelligence approach whereby students, for example, act out the categories, draw a representation of the commonalties between the words in a category, or create a graph illustrating the relationships between the groups.

Graphic Organisers

The fourth group of pre-reading strategies involves the use of graphic organizers (Billmeyer & Barton, 1998).

Concept Definition Mapping. This develops vocabulary by providing an illustration (a “map”) of the attributes of key concepts. By completing a map of the word or concept, students are looking at it from several perspectives. This strategy is particularly effective for those students with strong visual, spatial, or mathematical/logical intelligences, but it also provides all students with an understanding of the semantic relationships between words. The following steps (Billmeyer & Barton, 1998) may be useful:

1. Using an overhead transparency, display an example of a concept definition map, such as the one below for animal behaviour.



2. Discuss the questions that a definition should answer:

- What is it? What broader category does it fit into?
- What is it like? What are the qualities that make it different from other things in the same category?
- What are some examples of it?
- Model how to use the map using a familiar vocabulary term.

3. Using another familiar word, have students provide the appropriate attributes to complete another map.

4. Have students work in pairs to complete a map for a concept in the current unit. Encourage personal, as well as text, examples.

5. When they have finished mapping, ask students to refer to their maps to write a complete definition of the concept.

6. Have students refine their maps as they continue with the unit.

Venn Diagram. This is the simplest and most widely used graphic organizer. While it is used for narratives, it is extremely useful for contextual reading as well. It is used for the second story thinking skill of comparing/contrasting (Costa, 2000).

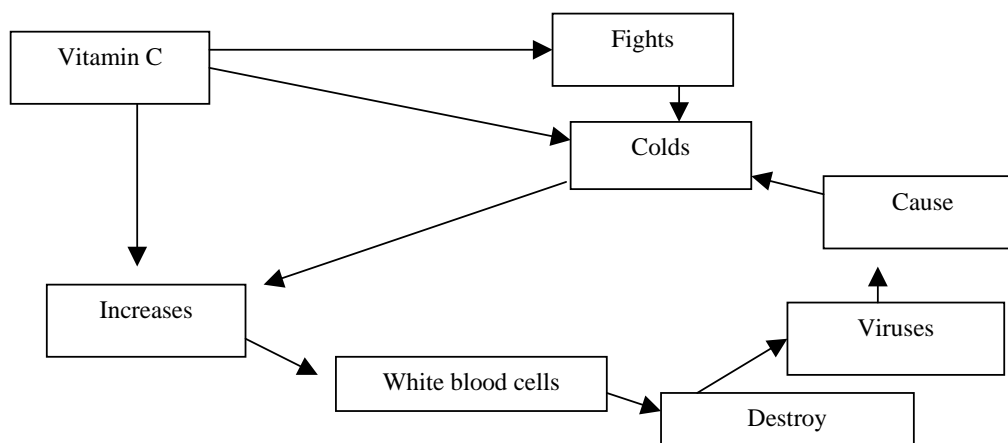
1. Draw two interconnecting circles, labeling each circle with the side of the argument or concept it represents.
2. Before reading a given selection, present and discuss the diagram with students. Make note of the two things they will need to compare.
3. Using students' prior knowledge, complete the diagram as a class, filling in the outer portions of each circle with characteristics unique to that circle while writing common characteristics in the overlapping area of the circles.

The purpose of this lesson is to inspire interest, connect to prior knowledge, establish a purpose for reading, and help students categorize information. Students should create their own diagram to use as they read, and this can set a stage for post-reading conversation among groups of students.

During-Reading Strategies

The Network Model

A network (effectively a Concept Definition Map under a different name) is a collection of terms, concepts, or propositions that are interconnected, possibly in a complex way, to show relationships. Networks are based upon the premise that connections need to be made in order for learning to occur (Grow, 1996). Consider the following example of the action of Vitamin C.



The Schema Theory

A schema is a generalized mental model used to organize memory, focus attention, interpret experience, and codify actions (Grow, 1996). Unlike templates, schemas are self-revising processes. Schemas are:

- Abstract (contain summary information)
- Structured (represent relationships)
- Dynamic (change, interact)
- In response to situations (e.g., the schema for starting a car when you insert the key)
- Shape perceptions (e.g., in the dark it is easy to mistake a bush for a bear)
- Provide context and vocabulary for interpretation of reading material
- Organize, experience, and modify themselves to accommodate new experiences (Anderson & Pearson, 1984)

Click or Clunk Strategy

This strategy is especially useful in contextual reading. Students should ask themselves if the reading “clicks” for them or if it goes “clunk.” If it clunks, they should ask what they can do to make sense of it. The purpose of this activity is to have the students slow their impulsivity and take some time to check for understanding. “This is a delightfully simple yet effective way of getting readers to stop their reading and rethink rather than continuing to read without comprehension. It is most likely adopted by students if the teacher repeatedly demonstrates how he or she uses it and students use it collectively” (Weaver, cited in ERS, 1999, p. 42).

Reciprocal Teaching

The reciprocal teaching strategy encourages students and teachers to take turns asking each other questions about the text. It should occur as students and teachers read a passage of text (Palinscar & Brown, 1984).

The strategy has two phases. The first is instruction in the use of four comprehension-monitoring techniques: summarization, question generation, clarification, and prediction (ERS, 1999). At first, the teacher takes responsibility for the instruction. In the second phase, the students begin to ask questions, request clarification of material they don’t understand, make predictions about what will happen next, and summarize what they have read (Rosenshine & Meister, cited in ERS, 1999). In science reading, which I endeavor to teach, reciprocal teaching can be enhanced by an intervention called Paragraph Patterns (ERS, 1999). Students have a tendency to speed read through science text. In an effort to manage their

impulsivity, the teacher requires that the students identify, and write down, the main idea of each paragraph read. Content comprehension scores have been shown to double after the intervention, with students also becoming more skilled at identifying the main idea of passages (ERS, 1999).

SQ3R

Probably one of the most frequently described strategies, SQ3R involves skills such as summarizing, self-questioning, and text look-back. The five steps (Call, 1991) are:

1. *Survey*: Skim a chapter for general understanding before reading it. Pay particular attention to titles, boldface print, pictures, and diagrams.
2. *Question*: Ask a question about each of the chapter's boldface headings.
3. *Read*: Read the section under each heading and try to locate the answer.
4. *Recite*: As you read each section, paraphrase (write in your own words) the main ideas, and supporting detail, in it and check these against the passage.
5. *Review*: Review your reading by recalling the main points of each section before reading it again. Recall as much supporting information as possible.

Scan & Run

Frequently seen in use by students in social studies classes, this strategy is quite useful for science text comprehension. It helps students plan and monitor their comprehension before, during, and after reading contextual materials.

Before reading, students use four SCAN cues while previewing chapter text:

S = Survey headings and turn them into questions. (Students will answer these questions during reading.)

C = Capture the captions and visuals. (Read the captions and look at the visual clues to try to understand what each means.)

A = Attack boldface words. (Read boldface words and figure out what they mean.)

N = Note and read the chapter questions. (Must be kept in mind while reading the chapter.)

While reading the chapter, students use the three RUN cues:

R = Read and adjust speed (depending upon the difficulty of the section).

U = Use word identification skills such as sounding it out, looking for other word clues in the sentence, or, for unknown words, breaking them into parts.

N = Notice, check parts you don't understand, and reread.

After reading, students extend their understanding of the text by answering questions at the end of the section and discussing the text (ERS, 1999).

Directed Reading-Thinking Activity

The purpose of this activity is to make predictions about the material to be read, and then refine these predictions while reading, as follows (McIntosh & Bear, 1994):

1. *Predict*: Students reflect on what they think will be covered in the text. Students might use clues such as the title, prior knowledge of the subject, introductory remarks by the teacher, or section titles. Students record their predictions on charts they create.
2. *Read*: Students then read a few paragraphs, or pages, of the text.
3. *Confirm*: Students compare the predictions they made with what was actually presented in the text. (Steps 1-3 are repeated until the text is completed.)
4. *Resolution*: Students summarize and evaluate the text.

Visual Representation

This has been a popular strategy over recent years. Visual depictions are intended to keep students focused on content and to clarify the learning task (ERS, 1999).

Examples of visual representations include time lines, web diagrams, pro/con charts, If/then flow charts, Venn diagrams, schema builders, network models, conceptual mind maps, and causal chains.

Final Thoughts

Consider this likely scenario. The lab has been completed and there is now some time to engage students in a quieter activity, such as reading the textbook. After doing a hands-on activity, they are not always eager to read. Nonetheless, having the skills to read a content-matter textbook is of paramount importance to them. My

students are always reminded that reading is not an act in, and of, itself. Rather, reading science material is “thinking with text” (Vacca & Burkey, 1992). A textbook is not merely a printed collection of the thoughts of the author. It is an opportunity to personally interact with the author and the author’s ideas.

Teaching any of the reading skills described in this article requires some quantum of teacher preparation time, direct instruction, and modeling. For students at the grade levels I teach, it is not sufficient merely to write the steps on the board and expect them to actually read the assigned text material following the written format. It cannot be assumed that my students automatically engage in metacognition while appearing to be reading the assigned material. There must be a means of developing individual accountability. For that reason, I prepare written study guides (worksheets) that insure my students will follow the proper steps in using both pre-reading and during-reading strategies.

I always keep a copy of this article nearby when I am teaching. It serves as a guide for engaging my students in a plethora of activities for using the textbook. Each strategy can be taught as written, or it can be adapted to meet the current needs of one’s students.

It must be kept in mind that as specialized subject teachers, we have a tremendous gift not only in the quality of knowledge we possess, but also in our ability to share our knowledge with others. We need to make it a priority to continuously seek new and better ways of refining our craft.

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Demonstration

While the activities in this section of *SER* have been designated demonstrations, they might easily be structured as hands-on student learning experiences. Although some sample lesson sequences may be included, the notes provided both here and in the following *Student Experiments* section are meant to act primarily as stimuli for classroom activities and to provide teachers with background information, so please modify any sample pedagogy as you see fit.

Drop the Matchbox

Needed. Full box of matches.

Exploration. Invite a student to hold a box of matches about 12 cm above the table and to then drop the box so that it lands on its end and remains upright. Try as he will, the box will always bounce off the table surface and fall over. Students will find this task even more frustrating after you assure them that it is possible!

Concept introduction. As the box falls, it gains kinetic energy (energy of motion). Upon collision with the table, some of this kinetic energy is transferred to heat and sound energy, but the rebounding matchbox still has quite a deal of kinetic energy, enough to cause it to rise from the tabletop (i.e., to bounce) and topple over. To achieve the feat, we need to further reduce the kinetic energy of the box after collision.

Without allowing students to see you do it, push the drawer of the matchbox about 2 cm upwards. Your hand will hide this as you hold the box above the table. This time, when the box hits the table, the drawer slides back into the box. During this process, and as a result of friction, a large amount of the kinetic energy of the box, if not all of it, will be transferred to heat energy. After experimenting with the height of the drop, and how far the drawer is pulled out, you will be able to get the box to remain standing on its end--no bounce at all.

"Obstacles are those frightful things you see when you take your eyes off your goal." *Henry Ford (1863-1947)*