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Connections Between Science, Reading, and Math

Too many administrators, teachers, and students believe that science should be a separate subject from math and reading. After all, most of the requirements of the *No Child Left Behind* legislation relies upon student test scores in math and reading, so why should science shoulder its way into what is already a tight curriculum?

To *do* science the way scientists do, rather than simply *knowing* science facts, students need to use reading and math skills and make connections between the natural world and their experiences in it. Science, when properly taught, can actually *increase* student test scores in reading. A four-year study of minority and non-English speaking students using inquiry-based science activities in elementary classrooms showed strong gains in test scores in reading and writing for those students who participated in the program. The preliminary results showed that the longer the students were in the program, the higher their test scores (Klentschy, 2001).

A 2003 survey of adult literacy levels in the United States found that 34 percent of American adults score at basic or below-basic levels for document literacy, and 55 percent of American adults score at basic or below-basic levels for quantitative literacy (U.S. Department of Education, 2003).

According to the *National Assessment of Adult Literacy*, document literacy is "the knowledge and skills needed to perform document tasks, (i.e., to search, comprehend, and use noncontinuous texts in various formats)." Quantitative literacy is "the knowledge and skills required to perform quantitative tasks, (i.e., to identify and perform computations, either alone or sequentially, using numbers embedded in printed materials)" (U.S. Department of Education, 2003). "Quantitative literacy" incorporates many of the math standards described by the National Council of Teachers of Mathematics. It is a simple step to understand how using science text and textbooks, reading lab instructions, computing and graphing numbers, and analyzing data fit into the definitions of document and quantitative literacy skills.

For elementary school teachers who teach all subjects, developing science lessons that build on current math content helps students understand how math is used in other careers. Simple graphing, counting, and calculating activities can be included in most science investigations. Students can practice calculating with fractions and decimals, measuring in standard and metric units, and creating tables and graphs. In addition, when students communicate their results to their peers, they are using mathematical terms to demonstrate relationships while explaining their mathematical reasoning. This covers some mathematical standards specified by many states and assessed on tests for math proficiency.

For middle school teachers who may not teach math classes, collaborating with a mathematics teacher can provide an enjoyable professional experience along with helping to reinforce their students' math skills. Ask the math teacher about the content taught in that particular grade and in which areas on the math assessment test students need the most practice. Enlist these teachers to help identify which concepts will be easiest to include in inquiry investigations. Incorporate these concepts into curriculum at nearly the same time of year they are being taught in math class. Not only will students be amazed that they're learning the same thing in *two different classes* (a revolutionary idea to the average middle school student), but they will see the immediate use of learning such computational skills.

In both cases, the students benefit by learning more about the interrelationships between subject areas and basic knowledge. Incorporating data analysis into most science activities in the classroom not only more closely models what real scientists do every day, but also helps students practice the math skills needed for reaching proficiency on standardized tests.

Using science textbooks or science news articles "requires the same critical thinking, analysis, and active engagement as performing hands-on science activities" (Barton & Jordan, 2001, p. iv). Incorporating their use in instruction can help students practice those reading skills they need to understand expository (informational) text—the *document literacy* skills that are different from the ones needed to understand literature. Pointing out and discussing graphical features of science textbooks or news articles (e.g., headings, subheadings, charts, graphs, and tables) help students become better at quantitative and document literacy skills. Many state-standards assessment tests in reading include selections that resemble news articles or textbook readings. Showing students how reading comprehension skills are required to learn science content knowledge helps them understand that reading is an essential life skill. Directly instructing students in how to read informational documents with graphic features helps better prepare them to demonstrate these skills in a testing situation.

Science Vocabulary Strategies

Vocabulary is integrally linked with background knowledge. Once students have built some background knowledge, teachers must move on to teaching words and concepts explicitly. "Systematic vocabulary instruction is one of the most important instructional interventions that teachers can use, particularly with low-achieving students" (Marzano, Pickering, & Pollock, 2001). In addition to building background knowledge, explicit vocabulary instruction increases reading comprehension, helps students communicate more effectively, improves the range and specificity of student writing, enables students to communicate more effectively, and helps students develop a deeper understanding of concepts (Allen, 1999).

The science discipline has a unique vocabulary, and therefore, teachers must build vocabulary instruction into their planning. "Teaching words well entails helping students make connections between their prior knowledge and the vocabulary to be encountered in the text and providing them with multiple opportunities to clarify and extend their knowledge of words and concepts during the course of study" (Vacca & Vacca, 1999, p. 319). With so much vocabulary in science, where do teachers begin? It is important to focus on specific words that are related to what students will be learning. While teachers cannot teach all the content words students need to know, they must strategically pick a few that are essential for understanding major concepts in a unit.

Looking up words and writing their definitions does not help students learn vocabulary. Instead, teachers must provide a variety of opportunities for students to interact with words. Janet Allen (1999) advises that words be used in a *meaningful context* between 10 and 15 times. The latest research also advises that students should create pictures and other graphic representations of words, be able to compare and contrast words, classify them, and create metaphors and analogies (Marzano, Pickering, & Pollock, 2001).

Word Walls

Word walls can be seen in classrooms from the primary level to high schools. For the purposes of this book, the focus will be the use of content word walls that help develop academic vocabulary. Some word walls are arranged in alphabetical order while others are arranged by topic. However, it is not enough to just have words posted in the classroom. Rather, word walls must be made interactive. As a teacher introduces the content of a unit, key vocabulary words are carefully chosen and gradually added to the walls (Allen, 1999). The words are posted and visible throughout a given unit, and students should refer to them often to use them in their discussions and writings. The words should also be displayed on cards so students can easily manipulate them and make connections among the words. For instance, students could:

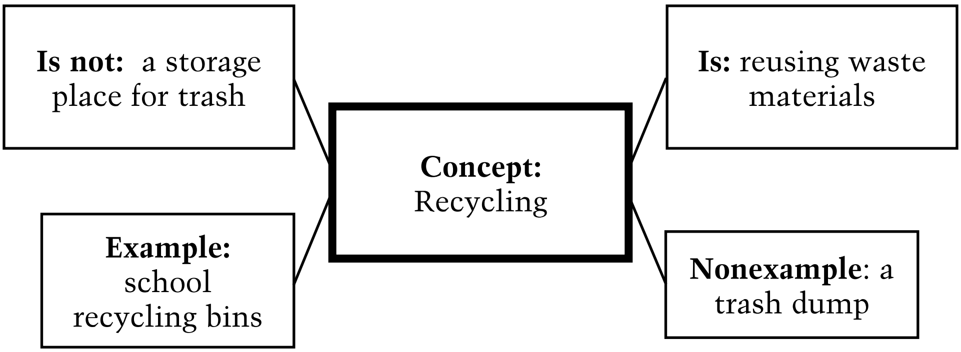
- sort and classify them in various ways
- regroup words when they look for causes and effects
- look for ways to compare and contrast words
- find synonyms and/or antonyms
- examine positive and negative connotations
- use them in journal entries
- create picture dictionaries
- identify the "most important" words and give their reasons
- explain a word's importance to a unit of study

When words are used in warm-up exercises or at the end of lessons, teachers also have an excellent informal assessment tool.

Words in Context (Word Meaning)

This technique helps students explore key concept words. A graphic organizer (Figure 2.1) was designed by Janet Allen (1999) to enable students to develop deeper understanding of important concepts. When students study the environment, they must understand the relationships between organisms and the environment. At the beginning of a unit of study, a teacher could discuss recycling by creating an overhead of the graphic organizer and writing *recycling* in the central box. An example is in Figure 2.1. With the teacher leading the discussion, students could look at the word in a sentence or create a definition for it to be placed in the top box. As the students talk about what it is and what it is not, the teacher would fill in the squares on each side of the word. Students would then discuss specific examples from their current unit of study and be able to give examples from both their previous studies as well as connect the concept to their own lives. The graphic organizer can be revisited throughout the unit, and as students make connections and find additional examples, they would add that information to the organizer.

Figure 2.1: Words in Context



Adapted from vocabulary word map by Raymond Jones at http://www.readingquest.org.

Another graphic organizer has similar components to Figure 2.1, but might be a little easier and can be used very effectively with English language and special education students because it incorporates the use of pictures. Research says that nonlinguistic representations are very effective in helping students think about what they are learning and remember the information (Marzano, Pickering, & Pollock, 2001). With the graphic organizer pictured in Figure 2.2, students combine both linguistic and nonlinguistic tools to learn a concept. They need to find synonyms and antonyms for a word. They also must use the word in a meaningful way and draw a picture of it. This organizer can be created by students individually and used as an assessment tool.

What Is Inquiry?

Defining Inquiry

The *National Science Education Standards* defines scientific inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (NRC, 1996, p 23).

For many teachers, inquiry means all hands-on activities, no textbooks, and few or no directions from the teacher. The students decide on what to do and what to measure. It can also mean students milling around the room, chaos, messes to clean up, and very little learning taking place. If teachers are not adequately prepared to teach inquiry-based lessons, they could easily end up with these results.

There are five essential features of inquiry outlined in *Inquiry and the National Science Education Standards* (NRC, 2000).

1. **Learner engages in scientifically oriented questions.**

   Teachers and students often ask "why" questions: *Why do clouds form*? *Why do plants need sunlight*? *Why does Earth have an electromagnetic field around it*? *Why are some elements radioactive*? In the science classroom, these questions can be changed into "how" questions that lend themselves to scientific inquiry: *How do clouds form*? *How does sunlight affect plants*? Students are engaging in inquiry when they can form testable questions.

2. **Learner gives priority to evidence in responding to questions.**

   Science uses evidence from observations as the basis for explanations about how the natural world works. To make observations, scientists take measurements in natural settings, or in laboratories. The accuracy of the evidence collected is verified by checking measurements, repeating the observations, or gathering different kinds of data related to the same phenomenon. Evidence collected is then subject to questioning and further investigations. When students are engaged in collecting information from their observations, they are learning that all science knowledge is based on similar observations, not simply someone's opinion or "gut feeling."

3. **Learner formulates explanations from evidence.**

   Scientific explanations are based on reason. They provide causes for effects and use the evidence collected to support their conclusions. Instead of simply repeating responses from reading selections in textbooks, students use their observations to develop answers to questions. Students use these explanations to help relate what they already know to what they are learning.

4. **Learner connects explanations to scientific knowledge.**

   Scientific explanations are evaluated for how they best fit the evidence. Explanations can be heavily revised or even discarded as new evidence is uncovered. Student explanations should be consistent with current scientific knowledge. As noted in the *National Science Education Standards*, "explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not science" (NRC, 1996).

5. **Learner communicates and justifies explanations.**

   Scientists communicate their explanations and evidence with one another through scientific journals. An important component of these communications is their clear descriptions of questions, procedures, and evidence so that others can attempt to reproduce their results. Alternative explanations are also included. Other scientists can review their work and bring up new questions.

By providing time for students to share their explanations, others can ask questions, examine the evidence, identify errors, and point out alternative explanations or conclusions that are not justified by the evidence—just as real scientists do. This helps students identify contradictions between their results and their beliefs, and increases the likelihood that they will retain the scientific explanations learned from their activities.