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Ideas for enhancing primary and high school science education

Did you Know?

The term “mad as a hatter” originated from the observation, during the 19th century, that hat makers often suffered from involuntary shaking of the body, with many also undergoing a change in personality. The cause of these health problems turned out to be mercury poisoning. Mercury was used in the processing of the felt used to make hats, and it accumulates in the brain, liver, and kidneys and slowly poisons the body. Such poisoning was subsequently prevented when a new way was found to process felt.

Science Story

The stories in this regular section of *SER* may be used to enrich lessons and make them more interesting.

Shape of the Earth

Early civilizations held a variety of beliefs about the shape of the Earth. Babylonians considered the Earth and all other things, such as the moon, sun, stars, sky, and water, to be inside a hollow mountain, with the Earth floating on a sea.

Hindus pictured Earth as being inside an upside-down bowl. The bowl was carried by elephants standing on the back of a turtle, and the turtle stood on a snake. Egyptians thought of the Earth as being part of their god, Keb. Their god of air held the stars, the jewels of a goddess, in the sky.

Cherokee people believed the Earth to be a four-cornered island, formed by mud rising from under the waters. The sun disappeared beneath the island each night. Polynesians viewed the Earth as being in a woven grass basket with a lid. At night, 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

An active reader (self-monitors, adjusts, and reflects)	**A passive reader** (simply receives information without understanding)
Pre-Reading	***Pre-Reading***
1. Builds up background knowledge before beginning to read.	1. Starts reading without thinking about the subject.
2. Knows the purpose for reading.	2. Does not know why he/she is reading.
3. Asks what the text will be about	3. Is not curious about the text.
4. Previews the pictures, title, heading, boldface quotes, etc.	4. Does not preview text materials.
5. Makes predictions.	5. Does not make predictions.
6. Breaks text into manageable chunks.	6. Is overwhelmed by amount of text to be read.
During Reading	***During Reading***
1. Gives complete attention to the reading task.	1. Is easily distracted.
2. Keeps the purpose in mind.	2. Does not know why he/she is reading.
3. Self-monitors comprehension.	3. Does not monitor comprehension.
4. Stops to use a fix-up strategy when comprehension is low.	4. Does not know if he/she understands.
5. Rereads for understanding.	5. Does not reread the material.
6. Connects with text--compares learning with what he/she already knows. Has opinions about the reading.	6. Does not, or cannot, make connections and does not have an opinion about what was read.
7. Asks what author is trying to say.	7. Doesn't care what author is saying.
8. Continues predicting.	8. Does not make predictions.
9. Generates questions and seeks answers.	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 ***K****now* about a topic, what they ***W****ant* to know, and what they ***L****earned*.

K-W-L Chart

What do I *know*?	What do I *want* to know?	What did I *learn*?

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).

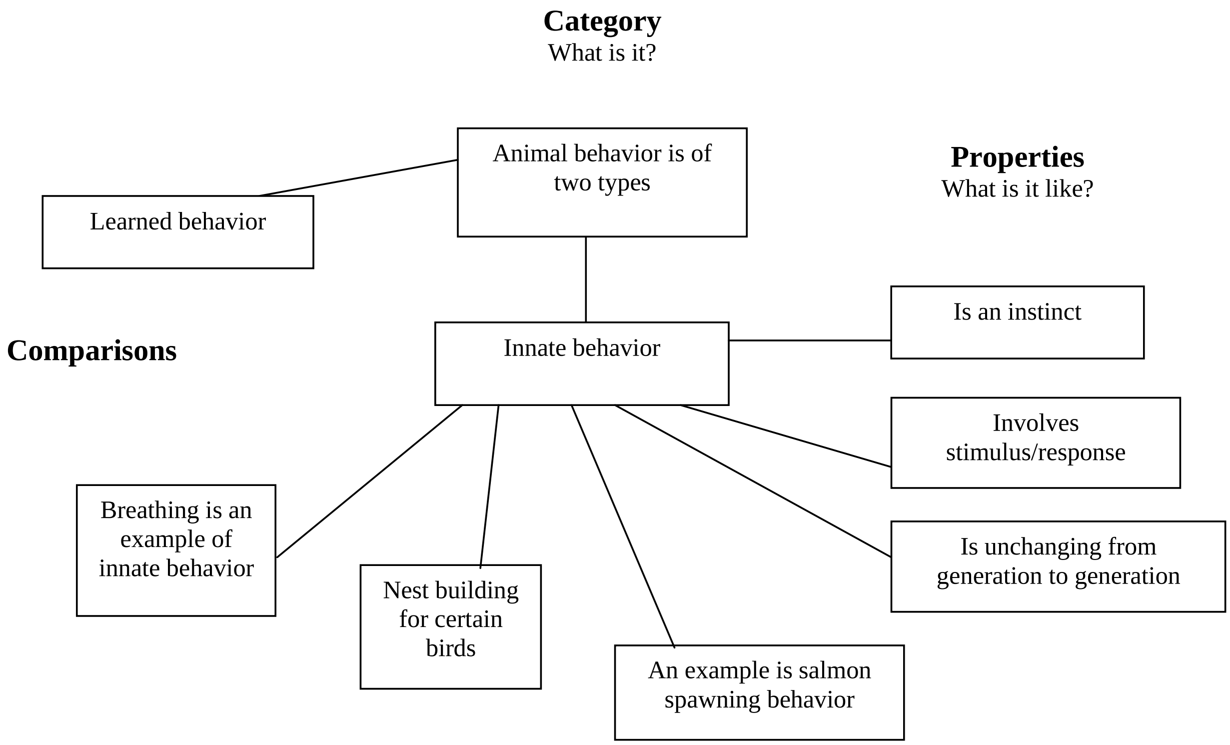
Once sorting has finished, students should discuss the reasoning behind the choices they made. In many instances, it is this phase of the strategy that results in the most learning for both students and teacher alike. A variation on this exercise may include a multiple intelligence approach whereby students, 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.

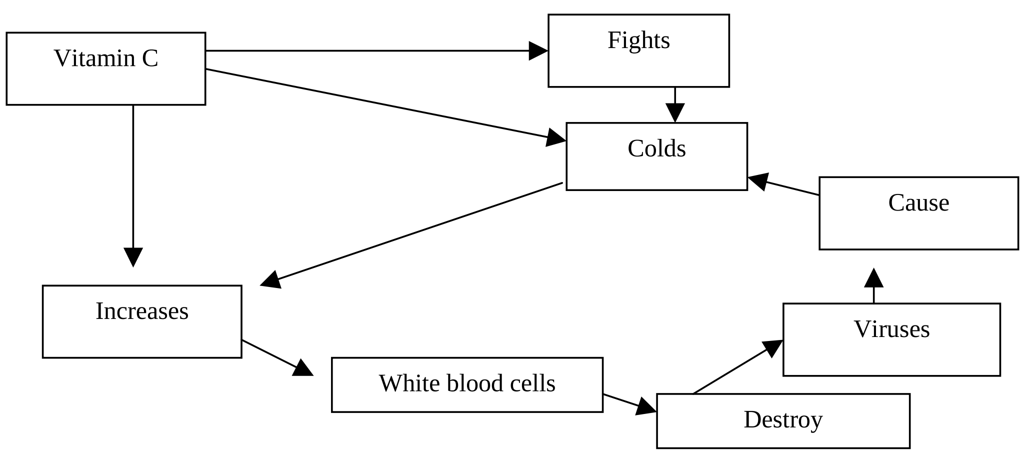
3. Using students' prior knowledge, complete the diagram as a class, filling in the outer portions of each circle with characteristics unique to that circle while writing common characteristics in the overlapping area of the circles.

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)*

Student Experiment

Reminder: Appropriate risk assessment, supervision, and guidance are necessary.

Expansion of Air

Needed. Empty glass bottle or flask, glass tubing (about 30 cm long) through a one-hole stopper that fits the bottle (and with a short section only protruding on one side), solution of food colouring in water, and spray bottle containing water. Thicker-walled glass tubing, with a smaller inside diameter, works best.

Invitation. Invite students, working in groups, to design an experiment to investigate what happens to air when it is heated or cooled (e.g., does it expand or contract?).

Exploration. Discuss the student designs, and provide for suitable ones (if any), that can be conducted with accessible resources, to be pursued. Invite other students to design an experiment using the supplied materials. *Caution:* Students must not press down on the glass tubing with a hand, as the hand may be cut if the glass broke. Guide students towards the following procedure:

1. Dip the short end of the glass tubing a short distance (1 cm, say) into the coloured water, and close the other end off with a finger.

2. Remove the tube from the water, hold it horizontal, take your finger off the end of the tube, and slide the water droplet in the tube until it is a little past the stopper on the longer side of the tube. Close off the end again with your finger.

3. Place the stopper in the neck of the bottle and fit it tightly using your free hand. Remove your finger from the end of the tube, and the coloured water droplet should sit still in the tube a little above the stopper.

4. Hold the bottle by wrapping both hands around it. What happens to the waterdrop? (Try to avoid losing the waterdrop at the top of the tube.) Can you explain the behaviour of the waterdrop?

5. Use the spray bottle to spray a very light mist of water over the outside of the bottle. Wave the bottle gently in the air, or blow on it. What happens to the waterdrop? Why?

Concept introduction. When the bottle is held in the hands, heat energy from the hands heats the air inside. This causes the air particles to move more quickly and push the waterdrop up. In other words, the air expands. Spraying the bottle with water and allowing this water to evaporate will cool the air inside the bottle, causing the air particles to slow down and the air to contract.

All gases, and most liquids and solids, expand when heated and contract when cooled. Exceptions include water expanding as it changes to ice (i.e., cools), a stretched rubber band contracting when heated, and zirconium tungstate (a ceramic) shrinking when heated.

Concept application. Ask students to identify where these principles are used in everyday life. Examples include using hot water to remove a tight-fitting metal lid from a glass jar, leaving gaps between the ends of railway lines to prevent them buckling, and hanging electrical power lines loosely between the poles, as tight lines would contract and perhaps break in cold weather.

Invite students to explain why, when an egg is placed in hot tap water, one or more streams of bubbles rise from the egg. Students might even try this at home prior to their eggs being prepared for breakfast. The hot water causes the air inside the egg to expand and escape through microscopic holes in the shell. If boiling water is used, the air will expand quicker than it can escape through the holes, and the shell will crack. To prepare boiled eggs without cracking the shells, place the eggs in room temperature water and heat slowly.

Pasta Power

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Abstract

A prominent theme permeating national science education reform reports such as the *National Science Education Standards* (National Research Council [NRC], 1996) and *Project 2061: Science for All Americans* (Rutherford & Alhgren, 1990) recommends the incorporation of cooperative learning in the science classroom. Although this pedagogical approach is designed to facilitate and enhance science teaching and learning, various complexities often surround a collaborative environment. The implementation of group-building activities is designed to help teachers provide appropriate structure to group activities, structures which promote equity and fairness in the classroom. This paper discusses a team-building activity that addresses the *National Science Education Standards* for Content Standard E: Science and Technology and serves as a practical, feasible, and engaging activity shaped to encourage the development of cooperative skills.

Introduction

During the past decade, cooperative learning has emerged as a leading pedagogical approach that facilitates science classroom learning experiences. Cooperative learning refers to the use of small groups and teamwork to achieve a variety of academic and social gains in the classroom. Although the roots of cooperative learning can be traced to the 19th century (Johnson & Johnson, 1994), the 1970s noted an onset of a movement toward research on cooperative learning.

Cooperative learning practitioners acquire theoretical support from many educational philosophies and theories (Slavin, 1987), but a significant source of motivation is rooted in social psychology (Deutsch, 1949). Several research reports have revealed the positive effects of student cooperative learning experiences. These effects include higher self-esteem, greater comprehension of content knowledge, higher academic test scores, improved positive social skills, higher student achievement, and reduced stereotypes of individuals of other ethnic groups or races (Johnson, Johnson, & Holubec, 1993; Marzano, Gaddy, & Dean, 2000; Slavin, 1991; Stahl & Van Sickle, 1992). Science education researchers have also conducted studies on the effects of cooperative group problem solving (Heller, Keith, & Anderson, 1992; Heller & Hollabaugh, 1992; Lumpe & Staver, 1995). These researchers discovered that students working in mixed ability groups were able to solve problems at a much higher level than those same students working alone. In addition, the students who worked in collaborative groups were able to develop more coherent conceptual understanding of science topics than those students who worked independently.

Not surprisingly, several science education reform reports call for the inclusion of collaborative learning experiences. For example, cooperative learning is a prominent theme found in the chapter on Science Teaching Standards in the *National Science Education Standards* (National Research Council [NRC], 1996). These standards reveal that:

> working collaboratively with others not only enhances the understanding of science, it also fosters the practice of many of the skills, attitudes, and values that characterize science. Effective teachers design many of the activities for learning science to require group work, not simply as an exercise, but as essential to the inquiry. The teacher's role is to structure the groups and to teach students the skills that are needed to work together. (p. 50)

However, in spite of these positive findings, a cooperative learning environment is very complex, and students can often have difficulty working in groups. For example, teachers may feel frustrated with group work as they inadvertently rush to "cover" the content without investing the necessary time to provide new groups of students with opportunities to practice working together as a team. One common question that many teachers pose is: “How do I get a new group of students to communicate, share information, and work effectively as a team?” Proponents of cooperative learning have applied the term *group building* to refer to a process used to help a new group develop and transition into a highly functioning learning team (Kagan, 1992). Hence, the initial collaborative exercise for a new group should include a meaningful theme to capture the attention of each student. For that reason, the first group experience may often be the most important one, as success here often predicts the teams’ chance for long term success (Vermette, 1998).

The Activity

Pasta Power, the tower building activity described here, provides a non-threatening, group-building opportunity for students to work together and practice communication skills in a setting sure to engage your class. This activity is a wonderful experience when a new group of students form, or during the first week of school. In addition, the use of spaghetti as a building material is inexpensive and offers a motivating and challenging team building experience. Furthermore, this activity is designed to follow the 5Es Learning Cycle Model (Bybee & Landes, 1990). This instructional model has been chosen because of its relevancy to inquiry in science education. The model can be used to design a science lesson that is based upon cognitive psychology, constructivist learning theory, and best practices in science teaching. The cycle consists of the following cognitive stages of learning: engage, explore, explain, elaborate, and evaluate. Rodger Bybee (1997), in his book *Achieving Scientific Literacy-From Purposes To Practices*, declares: “Using this approach, students redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment. Learners interpret objects and phenomena, and internalize those interpretations in terms of their current conceptual understanding" (p. 176). Although the 5Es Model is used to guide the various phases of this cooperative learning activity, the implementation of cooperative learning can be used with other models of instruction as well.

Pasta Power is appropriate for students in Grades 5-9, and may last approximately two, 50-minute class periods. Several standards are addressed in this activity, including the *National Science Education Standards* (NRC, 1996) for Content Standard E - Science and Technology**:** 1**)** Design a solution or product, 2) Implement a proposed design, and 3) Evaluate completed technological designs or products. This activity also addresses the following standard, for problem solving, of the *National Council of Teachers of Mathematics* (2000): Apply and adapt a variety of appropriate strategies to solve problems.

Preparation

The materials required for this lesson are easy to obtain. Each group of 4 students should have a bundle of 40 sticks of spaghetti and 10 pieces of elbow macaroni. The materials needed for the whole class include two or three mass/weight sets, cardboard or hard stock paper, two rolls of masking tape, and an optional digital camera.

Prior to participating in the tower building experience, each student should be assigned a managerial role, which will help with classroom management issues. Each student in a group may be randomly assigned a number, ranging from 1-4 and corresponding with a particular managerial role, by choosing numbers out of a hat. Table 1 highlights the roles and responsibilities for each student. It is important to clearly define and discuss these roles so that each student understands what is expected of them.

Table 1
Student Managerial Roles

Student number	Role	Responsibility
1	Runner	Gathers and returns group materials.
2	Recorder	Records sketches and drawings for the group. Keeps notes about group progress.
3	Spokesperson	Seeks out the teacher regarding group questions. Responsible for speaking for the group.
4	Timekeeper	Keeps the team on task by paying attention to time.

In addition to discussing the managerial roles, this is also a good time to overview the Cooperative Skills Rubric (Figure 1) and notify students that these skills will be evaluated during the activity. Once the student roles are determined, and cooperative skills have been discussed, the class is ready to begin the activity.

Engagement

Set the tone by reading the following scenario to the class:

> A popular architectural team has hired you to work with a group of architects. Your challenge is to work with your design team to develop a spaghetti model of

a tower. However, your resources are limited. Your team challenge is to construct a freestanding tower that will support the greatest weight for 15 s. Your building materials comprise 40 sticks of spaghetti, 10 pieces of elbow macaroni, and 65 cm of masking tape. Your model must also adhere to the following guidelines: 1) the height of the tower should be at least as high as the length of a spaghetti stick (24 cm) and 2) the top and bottom of the tower must be large enough to enclose a 15-cm square.

(*Please note:* The tower must be freestanding. Oftentimes, students want to tape the tower to a desk or table. The towers are permitted to be higher than 24 cm and the spaghetti and elbow macaroni may be broken or cut apart.)

Exploration

Ask the *runner* of each group to collect the materials at a Resource Center. Encourage the students to communicate to other members of their team and design possible sketches of their tower ideas before they begin the construction of their models. Also, ask the students to inspect the building materials before beginning. Any materials that the students feel are not of high quality, or suitable (e.g., a broken piece of spaghetti), should be replaced. Remind students that they are working with limited resources and should not be wasteful of the supplies. As a safety note, you may want to remind the students not to eat the spaghetti or elbow macaroni.

As the students are working, it is important that you circulate around the room, facilitating discussions, making observations, and providing assistance during the activity. This phase of the activity is a great opportunity for you to assess student cooperative skills. Figure 1 contains a Cooperative Skills Rubric.

Cooperative Skills Rubric

Criterion	**Points**					
	0	**1**	**2**	**3**	**4**	**5**
On task	Never	Rarely	Occasionally	Usually	Frequently	Always
Shows respect	Never	Rarely	Occasionally	Usually	Frequently	Always
Everyone contributing	Never	Rarely	Occasionally	Usually	Frequently	Always
Overall group productivity	-	Much time spent without purpose	Off-track frequently	Barely accomplished the job	Did well once ideas were clear	Highly productive

Figure 1. A cooperative skills rubric.

Explanation

This phase is student-directed. Each group should present their tower design to the rest of the class. The *spokesperson* should address the following:

1) Describe and explain the process your architectural team experienced while making the towers, and
2) Discuss any problems that were encountered and what was done to fix them.

Extension

Finally, we arrive at what is perhaps the most exciting part of the activity; testing the towers. Establish a Testing Center that is visible to all students. Have each group bring their model to the Testing Center. Each tower should be tested to see how much weight (if any) it can hold. One approach to applying weight to the tower is to place a piece of cardboard or hard-stock paper (large enough to cover the top surface area of the tower) on top of the tower. Then, proceed by slowing adding small weights on this surface. Another approach, that may be a bit simpler, is to stack small books or magazines on the top of tower. In order to obtain a fair assessment of the tower quality, the tower should be able to support an added weight for at least 15 s, before more weight is added. Also, it is important to add the same amount of mass at each increment. For example, you may choose to add weight in 50-g increments every 15 s. Or, if using non-standard units, three magazines or booklets can be added every 15 s. Do not be surprised if many of the towers collapse during this phase. However, it is likely that some of the towers are so well built that they hold a great amount of weight.

It is critical to discuss with the students that their assessment is based upon their cooperative skills, and not the tower that holds the greatest mass. After the testing period, the students should return to their desks and address the following reflection questions. These responses can be recorded in student science journals, or turned in as a homework assignment. Possible reflection questions include:

- Why did your tower collapse? What could your team have done to prevent the problems that your tower encountered?
- If your tower did not collapse, what do you think caused it to hold weight?
- What other types of building materials would you like to use?
- What changes (if any) should be made in your design?
- Think about all the towers you observed today. What aspect(s) of the tower designs created stable towers?
- Discuss your experiences. What did you do to contribute to the team?
- What is one thing that your team did today that encouraged you to work on task?

- What problems (if any) did your group experience?

Although the overall purpose of this activity is to promote and practice cooperative skills in an engaging team-building activity, it is inevitable that some students may feel frustrated and unsuccessful if their tower collapses. Since the students have now had time to reflect upon their design and observe other team designs, they are well prepared to revisit their tower and create new towers based upon their observations and learning experiences.

Evaluation

Since the overall goal of this activity is to provide a team-building experience so students can practice collaborative skills, the Cooperative Skills Rubric of Figure 1 can be used to assess these skills. You may also want to provide the rubric to the students and ask them to self-assess their skills and the skills of their teammates. The first three categories on the rubric, *On Task*, *Shows Respect*, and *Everyone Contributing*, are intended to be individual ratings. However, the fourth category, *Overall Group Productivity*, is intended to be a group score. An additional cooperative skills category may be *Praises/Supports Other Team Members*.

An important component to this evaluation phase is the post-activity discourse between the teacher and each group regarding their cooperative skills assessment. It is important to communicate both strengths and weaknesses with the students, as this will foster growth and improvement for future collaborative exercises. If you choose to have students conduct self and peer assessments, a comparison and discussion of their evaluations with your assessment of their skills is also important for their learning and growing process.

Further Extension Ideas

This activity can easily be integrated with other content areas, such as economics, physics, or writing. Here are some ideas for additional extensions.

Economics. You may wish to add an economic component to their construction challenge by requiring the students to "purchase" their materials (with make-believe money). Determine a value for each building material. For example, you may charge $2.00 per stick of spaghetti, 50 cents for each elbow macaroni, and $1.00 per centimeter of tape. Explain to the design teams that their task is to not only build a structure that meets the specifications and holds the most weight, but also to do so at the least cost. Adding this component will not only integrate a real-life, economic aspect into the activity, but also encourage the students to avoid being wasteful of materials.

Physics. This activity may be integrated into a physics unit about structures and designs. For example, concepts such as force, compression, load, and tension can be explored. Students may also research the engineering aspects, and construction, of popular towers around the world (e.g., The Leaning Tower of Pisa in Italy or The Sears Tower in Chicago). Students will be able to develop an understanding of engineering designs as they recognize and apply geometric ideas and relationships. You may even want to introduce the notion of variables to this activity. For instance, invite the students to try to design towers using different varieties of pasta, such as angel hair pasta or fettuccini.

Writing. Create a classroom newsletter that highlights the spaghetti tower models. Have students take digital photos of their towers during the building process. Each group should write an article discussing their tower.

Additional Challenges. Looking for more team building ideas? The *Building Big Activity Guide* (Macaulay, 2000), sponsored in part by The National Science Foundation and Siemens, is an outstanding resource that presents a collection of team-building challenges for students in Grades 5-8. The *Building Big* interactive web site can be found at http://www.pbs.org/buildingbig .

The following have been modified from the *Building Big Activity Guide*. In the *Domes Building* and *Bridge Building* challenges, student teams need to design and build the widest dome possible that will support their science book, and the strongest bridge possible that spans a distance of 50 cm, respectively. For both challenges, offer the following building materials: paper clips, tape, yarn, and straws.

Conclusion and Final Remarks

Many science teachers are raising questions about how to establish cooperative learning teams that maximize student engagement and participation. It is essential to implement team-building activities before new groups of students embark on the academic study of science concepts. Students need to have opportunities to learn and practice collaborative skills. Often, the ability for students to work cooperatively is assumed, and little time is spent establishing effective cooperative learning skills. This assumption usually backfires, and results in groups that are off-task, disrespectful to each other, and unorganized.

Activities such as the one described in this paper served as a critical component to the collaborative design of my former ninth-grade, integrated science classroom, and is also a critical component of my current university science methods courses. I engage my classes with several team-building lessons during the first weeks of school in order to create a collaborative classroom climate. However, when I first began my teaching career, I was unaware of how to implement managerial roles, cooperative learning structures, or methods of assessing cooperative skills. After several frustrating experiences, I began collaborating with colleagues and attending professional development classes aimed at improving my understanding of how to effectively implement cooperative learning in the science classroom. What I learned is that it is vital to spend time on group-building activities that engage and interest the students early in the school year. Investing time through team-building activities helps establish highly-functional cooperative learning teams in the classroom. Also, discussing cooperative skill strengths and weakness with each group is a critical component that helps to solidify the importance of these skills for future collaborative experiences.

My personal experiences are that this *Pasta Power* activity has been positive and effective in promoting the group-building process. However, my students experienced several phases throughout the duration of the activity. Although they initially felt a level of frustration with this new constructivist experience, the students were able to transition to a comfortable level where they were able to embrace the group-building experience. Too often, students are blocked by frustration when they would be better working through it. Because the students were not accustomed to being challenged, they became frustrated and tended to shut down. However, with practice in a non-threatening classroom environment, they can learn to embrace the challenge of a novel problem and enjoy figuring out a solution. This is one of the reasons why it is crucial for teachers to provide these types of experiences early in the school year. It can be expected that the students will encounter challenges with their cooperative skills. However, being a patient facilitator can help them to overcome their weakness. I learned that it is important to be a good listener throughout group-building activities, and to provide alternative solutions that encourage student dialog.

I desired to have cooperative learning become an opportunity for my students to interact with each other, both intellectually and socially. I therefore had to spend the necessary time and energy learning how to establish a cooperative classroom. This learning process takes patience and time. However, the long-term benefit to student learning is well worth it.

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Science Poetry

Reading and/or listening to poems that have been composed by other children their own age can inspire and reassure students as to their ability to understand and write poetry, and the science poems in this regular section of *SER* may be used for this purpose. Please find information about the *International Science Poetry Competition* at http://www.ScienceEducationReview.com/poetcomp.html .

Science

Why do shoes wear out in different places?
And how come the skin is so soft on our faces?

Why does our complicated brain,
Tell us we're in terrible pain?

What causes dust to float through the air,
And cause all the fuzzy bits in our hair?

What are the answers to these questions?
Does anyone have any suggestions?

Everyone, you should take the chances,
As the study of Science has all the answers!

Lauren Maroney, 9 years
Australia

Natural Disaster

I wait patiently for a huge asteroid
unknown to us and with no name
tumbling nonetheless somewhere
through space towards earth,

massive dark rock of destruction,
beast predicted to some day smash us
like the one that carved in an instant
the coast of Yucatan with a vast

fireball cloud of smoke and dust.
I wait patiently for the great quake:
lurch and buckle of land; for the flood,
fire, damning plague, the shiver of shock,

for each great natural disaster that
shakes us loose from who we are
to raise our spirits in a new
conflagration of despair and hope.

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http://www.celticcatpublishing.com

Students' Alternative Conceptions

Students' alternative conceptions have been variously called misconceptions, prior conceptions, preconceptions, preinstructional beliefs, alternative frameworks, naive theories, intuitive ideas, untutored beliefs, and children's science. The tasks in this regular section of *SER* are based on the literature and may be used at the beginning of a constructivist learning segment to arouse the curiosity of students and to motivate them, while simultaneously eliciting their ideas or beliefs. They are designed to address areas about which students are likely to have an opinion, based on personal experiences and/or social interactions, prior to a specialist learning sequence, or areas that might be considered important for the development of scientific literacy.

Label each of the following statements as *true*, *false*, or *not sure*.

a. Air consists of many identical particles.
b. Air pollution can be natural.
c. Air is a single substance.
d. Air pollution can cause heart disease.
e. Hydrogen makes up a major part of air.
f. Air that smells alright is not polluted.
g. Plants can be a source of pollution.
h. Acid rain is natural.
i. Unpolluted air contains carbon dioxide.
j. An excess of a substance that is normally present in air can result in pollution.
k. The Greenhouse Effect is natural, and necessary for the survival of plants and animals.
l. Acid rain is needed for plant and animal life.
m. Unpolluted air contains nitrogen.

Comment: Statements b, d, g, i, j, k, and m are true. Natural sources of air pollution include plants (decomposition), animals (emission of hydrocarbons), volcanoes, forest fires, and ocean spray. Hydrogen is found only in trace, and transient, amounts in the atmosphere. While the Greenhouse Effect is a natural phenomenon, it is the Enhanced Greenhouse Effect that is a concern.

Source: Skamp, K., Boyes, E., & Stanisstreet, M. (2003). Teaching about air quality. *Australian Science Teachers' Journal*, *49*(2), 12-21.

Please send to *SER* any suggestions you may have, based on your own experience or the literature, for adding to or otherwise modifying the items in this task.

Teaching Techniques

This regular section of *SER* describes thinking, cooperative learning, and other teaching techniques.

Periodic Grouping

The following is one way to form random student groups at the beginning of the school year. Copy (even enlarge) a Periodic Table and cut out the element squares. Place in a box the same number of squares as there are students in the class, choosing elements so that there are three (or four, if you want groups of four) from the same chemical family (i.e., vertical group) of the Periodic Table. Invite each student to draw an element square from the box. With the Periodic Table displayed, students reseat themselves in their chemical family (e.g., He, Ne, and Ar form a group).

Each student may then receive a number (1-3, for example, for groups of three), with a corresponding job description (e.g., 1. Manager, 2. Director, and 3. Speaker). The number of each student should vary with the different activities in which they participate, thus providing all students with experience in each role.

After each term (a quarter of a year, say), it is advisable to rearrange the groups. This may be done so that each group comprises one higher, one lower, and one middle achiever (or two, if you use groups of four), but without sharing this criterion with students.

Respond to any student objections, about working with a particular peer, with the observation that, just like in working life, one typically cannot choose coworkers. Personalities must therefore be put aside so students can work professionally for the period of time.

Your Turn

Try this very effective method for questioning groups. Each student in each group should know his/her number, 1-3 (or 1-4, if using groups of 4). The teacher prepares three cards, each with "Your Turn" printed near the top. Either on the back, or near the bottom, number these cards 1-3 so that when held, students cannot see the numbers. Invite a student from a group to select a card, and the student whose number is chosen is the one who is invited to respond (or submit a paper, perhaps).

This technique fosters individual accountability of students. As an extension, the positive interdependence of students can be encouraged by turning this questioning of groups into a game, where points are allocated to teams for correct responses.

To provide an opportunity for students to think before being asked to respond, this technique is best used in conjunction with another. For example, it might be the last step in a 1:3:Share (see "Think:Pair:Share," Volume 1, p. 17).

Task Cards: A Tactile Resource

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Here is an idea for a very easy, tactile resource you can use to review material at the end of a unit of work in the classroom, or to summarise desirable prerequisite knowledge for a unit. Prepare a set of numbered questions (or the beginning of statements) on a piece of paper. The answers (or completion of the statements) are written, in the same order as the questions and one under the other, on the back of cardboard that has a picture or diagram on the other side, and the cardboard is cut into strips. Cereal box cardboard, for example, works well. Students then have the task of ordering the cardboard pieces to answer the questions. To check if they are correct, they turn the cardboard pieces over to reveal a complete picture. To make the task more challenging, extra (unnecessary) response cards can be provided.

A variation is to prepare both the first and second parts of each question/answer pair on separate pieces of card, and have a figure, such as a smiley face, arrow, or picture on the back of these cards. Matching pairs have the same figure, so students can check their responses by turning the cards over and checking for matching figures.

If you want to use this activity as a review exercise with a class, invite each group of students to prepare a set of task cards about a different section of the unit you are reviewing. Once the groups have made the task cards, get them to test their cards on at least two other groups. In this way, your students will review at least three sections of a unit of work in about 15 minutes. Once you have checked for any errors (although usually the other students will have done that in their trials of each other's work), you can keep the task cards and use them for future reviews of the material with another group of students.

The beauty of this activity is that as the cards are self-correcting, the teacher is not needed to ensure the activity is done correctly, or to check that students got the right answers. That frees you up to spend time with other students, or to organize something else in the classroom while your students are interacting with the material. Students can also do this activity alone, not needing to worry if they get it wrong initially as they can continue working until they have it all done correctly.

Many of the students who fail in our traditional classrooms do so not through lack of intelligence, but simply because the information never comes to them through their preferred learning mode. Our traditional classroom caters to visual and auditory learners; all those tactile and kinaesthetic learners tend to miss out. This activity gives something back to the tactile learners amongst us. I encourage you to give it a go at least once. You may get a very pleasant surprise.

Ideas in Brief

The 7E Learning Model

The learning cycle continues to evolve. We have seen the three-phase *exploration*, *invention*, and *discovery*; the *exploration*, *term introduction*, and *concept application* cycle; and the 5E model comprising *engage, explore, explain, elaborate,* and *evaluate*. Based on our latest insights from research on how people learn, Eisenkraft (2003) has refined the extremely effective 5E model to propose a 7E learning cycle.

The modification involves two changes. First, to emphasise the importance of eliciting prior understanding, the *engage* element is expanded into an *elicit* and an *engage* phase. Second, an *extend* element is added to the *elaborate* and *evaluate* phases. The 7E model looks as follows:

Elicit:	Elicit students' prior conceptions (e.g., by using a "What do you think?"question).
Engage:	Motivate students by arousing their interest.
Explore:	Have students make predictions, design experiments, collect and analyse data, draw conclusions, and develop hypotheses. Various degrees of teacher and student ownership and control are possible.
Explain:	Introduce concepts, terminology, laws, etc., and summarise the results of the exploration phase in these terms.
Elaborate:	Provide opportunities for students to practise the near transfer of learning. Simple applications of the new knowledge are made to new domains. This may include solving related numerical problems, or posing a different (but similar) question and exploring it.
Evaluate:	Use both formative (e.g., as occurs during the *elicit* phase) and summative evaluation, and items addressing aspects from across the entire learning experience (e.g., experimental design, interpreting data from a similar experiment, questions about the labs, and *extend* items [see following]).
Extend:	Provide for the more distant transfer, to new contexts, of the new concepts and understanding (e.g., following a study of safety belts in cars, investigate the use of airbags and how they work).

Reference

Eisenkraft, A. (2003). Expanding the 5E Model. *The Science Teacher*, *70*(6), 56-59.

Modifying Labs for Inquiry I

A traditional, cookbook-style activity in chemistry is to have students calculate the molar volume of a gas after reacting a given quantity of magnesium with excess hydrochloric acid, and measuring the volume of hydrogen produced. However, as Bernstein (2003) says, such a verification exercise requires rather little thought by students.

She modifies the activity by assigning students to groups and asking each group to produce a different volume of hydrogen. Prior to the lab, students are given only the range of volumes to be assigned, and are invited to come to the lesson with a sample calculation. On the day of the lab, the apparatus to be used is introduced and associated techniques are explained. The volume of hydrogen required to be produced by each group is assigned, and students calculate the length of magnesium that will be needed. Each group's results are checked for safety, but not for accuracy, before the group commences experimental work.

Students' questions are answered with questions (e.g., "Do I need to . . . ?" might receive the reply "What would be the consequence if you didn't?"). Results are graded by giving 10/10 for a result within ± 1.0 cm^3 of the assigned volume, and subtracting 0.5 marks for each 1.0 cm^3 further away from this value, with a minimum 5.0/10 for an error greater than 10.0 cm^3. This modification to the lab also has the advantage of allowing a group to repeat the experiment, time permitting.

A number of benefits, associated with this approach to inquiry-based laboratory experimentation over the traditional approach, have been observed. Students are better prepared, ask more focussed and creative questions, are more enthusiastic about experimenting (some even discuss the experiment before arriving for the lab), work more carefully, and interact with each other to a greater extent. Overall, the students become more active learners.

Reference

Bernstein, J. (2003). A recipe for inquiry. *The Science Teacher*, *70*(6), 60-63.

Modifying Labs for Inquiry II

Volkmann and Abell (2003) suggest the following for changing a traditional, cookbook lab into an inquiry activity:

- Instead of providing students with the aim of the activity, challenge them with a question that is relevant to them. Students may even engage in an activity that encourages them to propose their own questions.
- Plan for students to communicate their understanding, including their prior understanding, to others using discussion, writing, and/or drawing.
- Omit the recipe (or part of it) for the lab and invite students, or groups of students, to make predictions and design investigations.
- Have students analyse the data, propose evidence-based explanations, and evaluate these explanations on the basis of further evidence.
- Encourage students to work together and communicate.
- Use textbook reading and teacher explanations after, rather than before, the lab.

Reference

Volkmann, M. J., & Abell, S. K. (2003). Rethinking laboratories: Tools for converting cookbook labs into inquiry. *The Science Teacher*, *70*(6), 38-41.

United Nations Illiteracy in America: Thoughts on Integrating the United Nations Into the Science Curriculum

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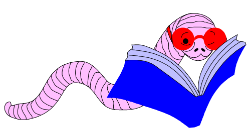
Abstract

To provide an international perspective, and to get American students focused on the United Nations (UN) as a legitimate scientific institution, the United Nations and its role in addressing global environmental concerns should be taught in the American science classroom. The target audience for this paper is high school teachers. The United Nations is a huge organization, and an associated curriculum is not easily broken down into manageable lessons. There is a lack of pedagogical research on the use of the United Nations in the science classroom. I have provided instructional techniques on how to present a Model UN in the science classroom, as well as information on how to go about developing a lesson on the UN.

To read the full text of this article (9 pages), please **click here**.



Research in Brief

Teachers' Use of Students' Prior Understanding

Identifying students' preconceptions is the first, essential step in facilitating conceptual change. To determine how teachers might be doing this, Morrison and Lederman (2003) used observations, interviews, and the analysis of documents to study the practice of 4 experienced (6-34 years of teaching), exemplary science teachers in Southeastern Washington, United States. Two of the teachers taught biology, one taught physics, and the other earth science. They had been recommended, by their administrators, on the basis that they were considered knowledgeable about current reforms in science education.

The discrepancy between these teachers' beliefs, and their practices, is a concern. While they all thought that eliciting students' prior ideas was important (although their reasoning was weak), and that they were doing it via questioning, their questions required largely factual recall. No formal tools, such as pretests, concept maps, journal writing, or interviews, were used, although one teacher did use class discussion to allow students to express their ideas. It is acknowledged, though, that in-depth, individual interviews with students are probably not practicable, in terms of the time required, for the classroom teacher. In short, the teachers did not have a repertoire of techniques for determining students' prior ideas, let alone use any.

It appears that the teachers may also not appreciate the nature of students' preinstructional understanding. It is not, for example, limited to what has been learned in previous courses. None of the teachers were familiar with the terms constructivism or conceptual change teaching, nor did they appear to build lessons on students' prior knowledge.

Both inservice and preservice education could increase teachers' understanding of the basis of current science education reforms, and their awareness of teaching practices needed to implement them. "The most valuable tool they could be given would be an understanding of a few of the most general preconceptions students may hold in specific science content areas" (Morrison & Lederman, 2003, p. 863). Teachers could then design curricula using both the documented, and their students' own, preconceptions.

Reference

Morrison, J. A., & Lederman, N. G. (2003). Science teachers' diagnosis and understanding of students' preconceptions. *Science Education*, *87*, 849-867.

(*Editor:* These findings and recommendations support what we are trying to achieve, in this journal, via the content of the "Students' Alternative Conceptions" section of each issue.)

Conceptual Change Need Not be Difficult

Can the reading of science text, without provision for associated discussion or other activities, induce conceptual change? Palmer (2003) interviewed 87 Grade 9 students (14-15 years of age), from a southeastern Australian city, to find that 36 (44%) of them displayed the misconception that some living things have no role in nature. These students then read, for less than 2 minutes, either text that refuted this alternative conception, or control text that described ecological role didactically.

A posttest, and a delayed posttest, were used to conclude that both types of text were capable of facilitating the desired conceptual change. Sixty-eight percent (a majority) of students who read the refutational text displayed accommodation (i.e., the misconception had been eliminated as a result of replacement or reorganisation of the central concept), while a somewhat fewer 41% of those who read the didactic text did the same.

Care needs to be taken in interpreting these findings, as conceptual change may have been assisted by factors which include that the chosen students were highly interested in learning and motivated to learn, the research process encouraged metacognition, and the misconception being studied is less robust than, for example, some others in the physical sciences. However, it appears that if students want to learn, this misconception can be overcome without resorting to conceptual change strategies that are difficult and time-consuming. Reading can be a valuable activity in science, and particularly if it involves refutational or reading cycle text combined with other techniques such as demonstration.

Reference

Palmer, D. H. (2003). Investigating the relationship between refutational text and conceptual change. *Science Education*, *87*, 663-684.

? ? ? ? ? Your Questions Answered ? ? ? ? ?

This section of *SER* responds to readers' queries, so please submit your question to The Editor at editor@ScienceEducationReview.com . Have that long-standing query resolved; hopefully!

Unlike most materials, a stretched rubber band contracts when heated. Why? (*Editor:* To demonstrate this, suspend a rubber band from a support, stretch it by hanging a mass from its lower end, and use a hair-dryer to heat the rubber. Some rubber bands work better than others, so you may need to experiment.)

This is the classic example of a chemical process in which the effect of heat (enthalpy) change is dominated by the entropy change. Essentially, as the temperature increases, the molecules of rubber move about more violently and thus take up more space. However, when the rubber was initially stretched, the long-chain molecules became aligned and considerably more ordered (lower entropy) and, on average, the ends of the chains were stretched further apart. Shaking these chains more violently--as the temperature is increased--results in, on average, the ends of the chains trying to move closer together, so either the piece of rubber gets shorter or the tension increases.

Note that this effect is found only in stretched rubber, or other polymers, in which the molecules are aligned. I believe that even for stretched rubber, the volume of the sample increases when the temperature increases, even though the length decreases.

It is also interesting that when rubber is stretched quickly, its temperature increases, and when allowed to contract it cools. This can be "observed" by first stretching a fairly thick piece of rubber, and then allowing it to contract quickly whilst it is in contact with your lips. Take care of hygiene issues and ensure that the rubber does not hit you in the face. NEVER try to do this for another person.

Alan Goodwin, Manchester Metropolitan University, UK

Is it necessary to include history of science in the development of the curriculum? If so, why?

Yes, history and philosophy of science provide the mental framework for instilling of the scientific way of thinking.

Vladimir Garkov, USA

I believe it is very important to include some history of science in each context of science taught. The reasons are many and varied. As a young student in school, many, many years ago, I remember thinking there was no way I could go on in science, as I just didn't have all that background knowledge or wild imagination. What my teachers failed to show me was that discoveries in science seldom are the work of just one researcher, but rather build on work done by others, in other countries and in other time frames, which may have been relevant at the time, or not. History also allows you to draw pictures of life in other times, the commitment of researchers, the important contributions of women, and so forth. This allows you to draw some reluctant students into your class, students you might otherwise miss out on having there, such as the English or History student who doesn't feel they can do science.

Vickie Lawson, New Zealand

Yes, it is important to include History of Science, albeit as briefly as necessary, because our understanding of science is framed in the pacing and sequence of events that slowly led to our understanding of the world around us. One discovery opened the door to understanding another part of it, and so on to the present, and so on into the future. The people who made those discoveries, how they lived their lives, and the context of what was going on in their surroundings provide insight and inspiration to our ability to understand and emulate those scientists. Including the history of science in science textbooks lets us learn that those scientists were also human, had families or were solitary, and that they were not that different from us. In that way, we can understand them more and possibly be like them. Knowing the history of science will bring the concept of science out of the cold, insensitive world of a few of us, and into the living, breathing world of all of us. It is to make science, via the history of science, more palatable to even the unscientific and broaden the reach of science, and the interest of science, to more people. My own study of Nikola

Tesla and his life, as compared to his rival Thomas Edison, led to me seeing Tesla as the more tragic of the two, that he had more to offer the world, but was portrayed in a more sinister light, when it was Edison and Westinghouse who sought to cheat and ridicule him. And today it is the evil scientist, not unlike Tesla with his death ray, which is the unfortunate spectre of scientists.

Richard Moore, USA

My opinion is that we can't really understand how we got to where we are unless we stand on the shoulders of the giants who came before us and look at how far we've come. If we don't look at what has gone on in the past, we are likely to keep making the same mistakes over and over again.

Pamela Galus, USA

Yes, I strongly recommend the inclusion of history of science in the development of the curriculum. The history of science tells us which difficulties were faced by scientists at various stages and how they circumvented those difficulties. In brief, if one wants to make new discoveries or inventions, you must know how the relevant past was built. My favourite example for putting emphasis on history is the scientists involved in the development of atomic physics; Dalton, Thomson, Rutherford, and Bohr. Today, all are historic, but who was the first in this sequence? Who was the last? Students have to understand this sequence properly. Hence, I am in favour of including history of science in the curriculum. In fact, I recommend establishing both a BHS (Bachelor of History of Science) and a Master's degree.

Dileep V. Sathe, India

I think it is. I think that students can key into the excitement of the people and times. It makes the subject come alive a bit.

Michael Crescimanno, USA

Science relates to daily life (e.g., our health and weather conditions) and to everything that we eat, breathe, wear, and do. It is the knowledge of our surrounding world and the process by which we learn and obtain it. Therefore, it is appropriate to include the history of science in the development of the curriculum.

Science, which is ongoing and ever-changing, has developed and progressed over the years. The bar of soap that is used today dates back in history. Some believe that the Babylonians knew how to make soap about 5,000 years ago. However, most historians give the Romans the real credit for discovering soap. The Romans knew that heating goat fat with extracts of wood ashes (containing strong bases) produced soap. The manufacture of soap came to America in the 1600s with the arrival of European soap makers.

It should be mentioned that science is an international effort with famous contributors throughout the world. In 1903 Madame Curie, a native of Poland, was the first woman to receive the Nobel Prize in physics for the discovery of radioactivity. She shared this award with her husband Pierre and Antoine Henri Becquerel of France. Albert Einstein, who was born in Germany, is generally recognized as the most brilliant theoretical physicist of the 20th century. He received the Nobel Prize in physics in 1921. Today many countries are collaborating and carrying out science experiments aboard the International Space Station (ISS).

It is important to promote an understanding and appreciation for science and to show its relevance to daily life. This can be accomplished by including the history of science in the development of the curriculum. In addition, it may encourage and motivate today's students to pursue science and become the needed scientists of the future.

Dana Barry, USA

Invited commentary by Marianna Papastephanou, University of Cyprus, Cyprus.
The issue about the inclusion of history of science in the development of the curriculum has engaged the attention of many educators, students and academics alike, and it is no accident that the above responses are affirmative. In explaining why the answer to the question is "yes," the responses reflect the increasing general interest in, and appreciation of, history of science and its potential contribution to the improvement of science teaching. They also voice very convincingly genuine concerns regarding the sensitivities, the touch with reality and everyday life, the imaginative reach of research and laboratory work, and the grasp of past human endeavour that remain under-developed when history of science is left out of the classroom.

My own work has led me to also conclude in the affirmative, while my personal experiences of being taught science as a student are quite similar to those described above. I agree with Vladimir that history of science is indispensable in encouraging a scientific way of thinking in schools. This is so because, amongst other reasons, such a subject provides a kind of "reenactment" of the past that presents scientific discovery in its true and rich entanglement with real life, human needs, and cognitive desire. Richard and Dana provide very telling illustrations of how history of science serves this purpose, illustrations demonstrating that science has not just been about data, laws, and outcomes but also about lived experience, intellectual biography, and context as well as community values and world-interpretations.

The significance of teaching history of science extends from the offer of scientific role models (as Richard mentions in passing) and the avoidance of past mistakes (Pamela's remark) to making science teaching more exciting (as Michael states), accessible, and lively. I also agree with Vickie that history of science heightens the students' perspective and imagination and enlarges their scientific horizons while depicting scientific progress as the result of joint and communal effort to conquer truth through trial and error. The genetic approach that Dileep refers to (i.e., the sequence of scientific events and who came up with this or that law or discovery) helps students build a solid background. But, even more importantly, it uncovers for them a wide spectrum of issues, chiefly amongst them those of gender bias, eurocentrism, the crucial ever-going debates on the ontology and epistemology of truth, and the political and ethical pertinence of scientific research.

Apart from what I have mentioned so far, we must also take into account the pedagogical import of the topic as such. Regarding this, I am sure that all of us can draw from our own educational experiences in the position of the student and the teacher and recall the refreshing effect of historical interpolations. A touch of adventure is always there in a museum visit related to the subject, and the visual learning that comes from photographs or videos is a relaxing alternative to textual and laboratory study. Within the historical-scientific scope, one may find exciting thought-experiments that keep students alert and mobilize their imagination, and anecdotal material that facilitates the imparting of difficult ideas. One may also find forms of scientific contact (such as Einstein's exchange of letters with quantum theorists) that transmit the sweet agony involved in scientific quests for truth and the agonistic dimension of arguing and trying to convince the scientific community. Finally, through history of science one may emphasize the relation of the cognitive and the affective aspects of scientific life, showing the extent to which seeking progress in knowledge intersected with agonizing existential and metaphysical questions about the self and the world.

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Further Useful Resources

Evolution Lessons

http://www.indiana.edu/~ensiweb/evol.fs.html

Many high school lessons on evolution patterns and processes. Sections comprise Geological/Paleontological Patterns (General); Human Evolution Processes; Classification; Hierarchy; Relationships; Adaptations, Imperfections, Contrivances; Variation and Natural Selection; Speciation; and Macroevolution.

Internet Detective

http://www.sosig.ac.uk/desire/internet-detective.html

An interactive, web-based tutorial on evaluating the quality of resources found on the Internet. Available in three languages, and may be downloaded for offline use.

How Everyday Things are Made

http://manufacturing.stanford.edu/

Covers over 40 different products and manufacturing processes. Includes candy, cars, airplanes, packaging, and bottles, and the processes of forging, casting, and injection moulding.

University of Maryland Fermi Problems Site

http://www.physics.umd.udu/perg/fermi/fermi.htm

A collection of estimation problems, categorised as General, Mechanics, Oscillations and Waves, Thermodynamics and Kinetic Theory, Electricity and Magnetism, and Modern Physics. Also, a list of publications about Fermi problems.

A Species in Denial

Charles Darwin's *The Origin of Species* connected humans with nature. Biologist Jeremy Griffith attempts to take the next step, and use biological understanding to confront and explain the dilemma of the human condition, our capacity for good and evil. Why are we competitive and aggressive when the ideals are to be cooperative and loving? By so doing, this book aims to bring about the maturation of the human race.

Contents include an *Introduction* on the human condition and four essays: *Deciphering Plato's Cave Allegory*, *Resignation*, *Bring Peace to the War Between the Sexes*, and *The Demystification of Religion*. Available from FHA Publishing and Communications, http://www.humancondition.info .

biography-center

http://www.biography-center.com

25,495 biographies, with 10,890 in English.

New Outlooks in Science and Engineering (NOISE)

http://www.noisenet.ws

Aims to raise awareness of science and engineering amongst young people. Includes articles that discuss the science behind everyday life and information about role models. Funded by the Engineering and Physical Sciences Research Council (EPSRC), UK.

Detectives in the Classroom

http://www.montclair.edu/detectives

A free, online epidemiology curriculum that explores health-related issues relevant to middle school students. Helps students learn how we can study the distribution, and determinants, of health-related conditions, and apply that knowledge to the control of health problems. Prepares students to make personal and collective, evidence-based decisions.

Web-Based Inquiry Science Environment (WISE)

http://wise.berkeley.edu

Students examine real-world evidence, and analyse current scientific controversies, in this free, online learning environment for students in Grades 4-12. Topics include the possibility of life on planets outside our solar system, water quality, rainforest interactions, earthquake predictions, hypotheses about deformed frogs, genetically modified food, controlling the spread of malaria, and origins of the universe.

Humour

Did you hear about the entomologist who got sick? *He caught a bug.*

Did you hear about the astronomer who moved to Hollywood? *She wanted to be a star.*

Did you hear about the student who enrolled in meteorology? *He thought it would be a cool change.*

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The Science Education Review (*SER*) is an international, peer-reviewed periodical aiming to provide primary and high school teachers with the latest, and best, ideas in science education from around the world. *SER* also publishes original articles, including research articles, and much more.

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