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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Each cubic kilometre of seawater contains about 4 kg of dissolved gold.

Science Story

Skin Colour Change

During the 1700's, women in some parts of the world used a preparation containing bismuth to give their skin a fashionable, chalk-white appearance. One young lady, so prepared, decided to bath at the spa town of Harrowgate, England. To her great surprise, her skin turned black! She reportedly shrieked and fainted, as did her gallant escort.

The problem was solved, though, by simply using soap with hard scrubbing. This removed both the black colouring and the lady's anxiety. The relevant chemistry may be written: $2Bi(OH)_2NO_3 + 3H_2S \rightarrow 2HNO_3 + 4H_2O + Bi_2S_3$.

Using Primers to Motivate Your Students

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Abstract

Primers are used to motivate and uplift your class. They come in many different styles and can be used in a variety of ways. Making primers relevant to students helps them to learn and makes them feel appreciated and knowledgeable when they participate. Using primers in the classroom to make students feel valued brings much success.

Imagine a classroom where the students were excited to learn and anxious to come to class each day, readily participating in discussions and sharing thoughts and ideas with one another. What if students were as excited to learn as the teacher was to teach? Wouldn't it be great if students even contributed to the lesson for the day, bringing materials to share with the rest of the class that are relevant to students at his/her age or ability level?

Does this sound too good to be true? It's not! We, as educators, simply need to find that "spark" for our students. We need to vary our approach to teaching and learning and involve students in any way we can. The learning has to be relevant to their lives and the world around them for students to see the need to learn the material we are teaching (Phillips, 2001). For our purposes, primers are defined as that which prepares or encourages future action or learning, and may be just what you've been looking for in your classroom.

Perhaps students are not a lot different to adults. Think about what gets you excited about learning when you enter a classroom. Is it a special experience you've had via a workshop, a life experience, or seminar? Is it what you see, feel, or hear? Is it the enthusiasm or expertise of the instructor or leader? Is it a demonstration or a "show and tell"? Is it because you're with friends or you have a lot of fun and challenging technology at your disposal? It's probably a combination of a lot of these, and more, for us as well as for our students! This article will address many of the various primers I use in my classroom and why I use them. My hope is that the reader can use these ideas to spark his/her own ideas for motivating his/her own students.

Ideas or activities for motivation include ice breakers, demonstrations, stories, Show and Tell, videodisc pictures or short video segments, microscope camera, Internet photos, articles, questions (teacher or student), share what you know, comments, brainstorming, and magic/tricks. Primers are used to break the ice, reach standards, motivate, change or bring different ideas, reach various learning styles, find out what they know, spark curiosity, get everyone involved, avoid boredom, make students feel good about what they know, and get students excited and ready to learn.

Icebreakers are especially good at the beginning of a new term because they allow students to meet each other and feel more comfortable in their new learning environment. They can be used with any grade level, and in any content area. I use several kinds in my high school biology classroom, depending on the group and time available. For example, in my cell biology class, I give students a diagram of a typical cell and we label the organelles together. This is followed with a discussion of treating others with respect - an important component of a successful classroom. Next, the students go around the room and make a positive comment to someone else, and ask if that person would be a cell organelle buddy. Each pair of students exchange names and write them next to an unsigned organelle, thus becoming nucleus buddies, golgi buddies, and so on. Students continue doing this until they have one different name signed next to each organelle. After getting the required number of buddies, they return to their original seats and I explain that this "buddy" sheet will be used for future partner activities. If we do a lab the next day, I may say "use your nucleus buddy," giving students a random way of picking lab partners instead of always picking their friend(s). Students learn about the parts of a cell and the value of being positive toward others, and become more comfortable in their learning environment.

Similarly, in my Aquatic Ecology Class, I use an icebreaker called "Raining Cats and Dogs." Students pick a water-related phrase such as sink or swim, wet your whistle, sandbagging, get your feet wet, and so on, and then have to draw a picture on an index card that reflects the phrase they chose. The teacher has to ensure that no two students use the same phrase. When everyone has finished their drawing, students walk around the room with a copy of the phrases and their picture, share what they drew, and guess which phrase the other student is trying to depict. They write the name of the person who drew the phrase on their paper in the blank next to the phrase. This allows them a chance to get to know each other and usually stimulates many questions about water.

Primers can also initiate effective discussions. For example, one day I had two adult mice that had babies, and the next day students had to close their eyes and hold their hands open. I put a baby mouse in each student's hand and they had to figure out what it was without looking. They loved it and it led to a huge surge of questions. "How many babies do they have? What do they weigh? How often do they have babies? How much damage do mice cause? Where is the hair? Won't they die if I touch them?" Students are motivated without realizing it. One day a curious student brought in a fat perch (I ask students to bring things in all the time to share or ask questions) and wanted to know why it was so fat. We squeezed it and milt (fish sperm) came out. We put a sample on a slide and showed the entire class live fish sperm swimming around under the microscope camera. Wow, did this ever bring a wave of discussion! With the help of my students, I have collected well over 500 different kinds of specimens, which I put on display in my room. Collected specimens include over 50 preserved skulls, several preserved organisms including fetuses, hundreds of seashells, beehives, feathers, hair, skins, pelts and more. Students love bringing in what they have found in nature. At the beginning of a lesson I may grab a piece from my "specimen collection" and have each student write down a comment or question, from which I then choose at random to answer. These are all great Show and Tell items, sometimes from our own "backyard."

There has been a tremendous amount of educational research done on learning styles and it has been found that no two students learn in exactly the same way (Jenson, 1998; National Research Council, 2000). This can be addressed nicely by varying the primer activity. For example, ask students to draw a picture of photosynthesis, or write down what they know about a starfish. Ask them to tell what you could find in a cigarette, or play a song and have them write down how it is relevant to what we are doing. To reach every student you must change and do different things everyday. You may spark the interest of a deeply abstract creative type of brain without reaching the visual, kinesthetic type of mind. By changing and adapting everyday you will reach all learning styles.

I do not believe that primers have to coincide with a specific lesson you are presently teaching. Good teachers never let a teaching moment escape. One of my students totaled her car in a drinking-related accident and wanted to pass the message on to her classmates not to drink and drive. We had a heartfelt discussion and then I showed some graphs and charts off a videodisc specifically related to what happens biologically when you drink. This led to discussions on blood alcohol levels and much more. Again, I probably didn't reach every student, but maybe I saved a life. Have you ever wondered if anything you've told your students has been life saving? I think about it all the time and really believe we make a huge difference in the life of a student. Primers can be related to the seasons. Why do fall leaves turn colors? What makes snowflakes different? Capitalize on students' curiosity.

Make use of current events in your primers. Students often wonder about the world around them and what they hear in the news. For example, the attacks of September 11th provided an example of a teachable moment. We discussed decaying bodies, search dogs, building materials, DNA identification, and much more. I sometimes also will use date-specific primers such as Earth Day or Arbor Day to remember a famous scientist or major event. Many primers are also lesson specific. For example, I may walk around the room with an open container of perfume to demonstrate diffusion. I may show a model of something we're going to make that day, or perhaps I'll have a student read a poster related to our topic. The possibilities are endless!

Many times teachers get into a routine where they do the same kind of thing from day to day without thinking about what the students are getting from it. By doing various kinds of primers, it forces you to do different things. It tends to keep you "sharp" as you prepare and deliver each and every lesson. I have found that my enthusiasm for the topic is often contagious with the students, especially when the topic is made relevant to the lives of the student(s). Sometimes I'll even ask students to write about how some topic we discussed was relevant to them. This may be especially relevant when dealing with a sensitive topic such as the lesson on drinking, or when reading an article on anorexia or bulimia. It is good to let students give you ideas for primers or deliver them themselves. Students may bring in deer antlers, and we discuss nutrients, genetics, and so forth. This is a good chance for extra credit and many times students will let you know what is relevant to them. It gives you more ideas. Many of the primers lead to curiosity and a lot of discussion and follow-up questions.

One of the standards in the National Science Education Standards (National Research Council, 1996) reads: “ The program of study of science for all students should be developmentally appropriate, interesting, and relevant to students’ lives; emphasize student understanding through inquiry; and be connected to other school subjects” (p. 45). By adding primers you certainly meet that standard as well as many more. Many times we reach so many standards that it’s impossible to keep track of all of them. With primers, you’re generating and encouraging curiosity, as well as challenging students to accept and share responsibility for their own learning. As a matter of fact, the students are usually having so much fun that they don’t even recognize they’re learning! The bottom line is, no matter what you do, you are going to reach students and you are going to address the standards.

It is critical to get everyone involved in the primer activities, and there are some important things to remember. When you ask a question, give plenty of wait time. Have all students write a question down, or write a comment, or let all of them see something up close rather than just standing in front with a small specimen and talking about it. Walk around with the specimen, or have them get up for a closer look. If appropriate, allow students to touch the specimen. Perhaps the students could team up with a neighbor or two to discuss something relevant to the topic. There are many ways to involve all students, but the bottom line is that you need to figure out a way to get everyone involved. It is important to acknowledge and use student comments in the discussion, even if they’re not especially insightful ones. This makes a student feel valued and that they’re a part of something. We all know that there are too many kids today who do not get the support they need outside of school. It’s up to us to make every attempt to bring out the positive things students have to offer, and in turn they will respond much better and take more ownership and pride in what they do. If we want students to succeed, we have to make them feel good about what’s important to them. Primers will often help students realize they know more than they thought.

On the last day of each class I ask students to fill out an evaluation of the course. One thing that continuously rings out on these evaluations is that they love the primer activities. They tell me these activities motivate them to come to class. Some say they’re really excited because they don’t know what they will see or hear in class the next day. If all educators can use some sort of primer, even if it takes just a few minutes, you will motivate your students, increase their excitement about learning, bring relevancy to the curriculum, and promote higher student self-esteem. You will make them feel better about themselves and what they know. You will help foster success in their lives. These primers can come from almost any source, and many can be made up on the spur of the moment. You could tell a story, use the Internet, a demonstration, or Show and Tell, or do just about anything to get a student excited about learning. What could be more important than getting all your students involved in your class, and making them feel appreciated and valued? By using primers, you will "raise the bar" for both your teaching and your students' learning.

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Demonstrations

The Falling Cards

Needed. A deck of playing cards and a draft-free room.

Invitation. Hold a playing card in front of you, with the card in the vertical plane and its longer edges at the bottom and top. It is best to hold the card using your thumb and forefinger near the top corners of the card, so the card does not stick to them. Invite a student to come out, hold the card (engineer things so that he holds the card the same way you did, but without making a big deal of it), and drop it so that the card lands on the floor directly in front of him. This will be impossible. Give him a few trials, and try a few other students also.

Exploration. Tell students that it is possible to drop the card so it behaves as required, and invite further students to try. If necessary, hint that it may be productive to hold the card in some different way. The only way to achieve this feat will be to hold the card horizontally before releasing it. Ask students why the vertical orientation will not work.

Concept introduction. When the card is held vertically, it is impossible to release it in a perfectly vertical plane. The card is always slanted slightly one way or the other, and as it falls, one side of the card gets pushed harder by the air than the other side, causing the card to rotate to one side. When the card is held horizontally, the air flows evenly around it and it falls straight down.

Concept application. Invite students to devise a method for sorting cards, in this way, into three different piles. Each student in the class could even be given a card with which to experiment. They must be able to predict where a card will land before it is released. Students will readily establish which way a card needs to be slightly slanted in order that it rotates to the desired side.

Odd Bottle Behaviour

Needed. Coloured water, spill tray, and two empty plastic bottles (e.g. glue bottles) with transparent sides, one having a circular base and the other an elliptical base.

Invitation. Completely fill the elliptically based bottle with coloured water and ask students to predict what will happen when you squeeze the sides. They will be amazed to find that, when you squeeze the narrow sides, the water not only does not overflow, but that the water level decreases. Repeat by squeezing the wider sides, and then using the bottle with the circular base, to find that in both cases the bottle overflows.

Exploration. Ask students why the bottle did not overflow in the first demonstration, and invite them to experiment with materials to answer their own questions. Also, try the following activity.

Tell students to assume they have been given 16 km of fencing, and that they are to use it to enclose different shapes. Try a square, different rectangles, a trapezoid, a circle, etc. and calculate the area of each enclosure. Compare the areas. Are they the same? What shape gives the maximum area?

Concept introduction. For a given perimeter, different shapes have different areas, and a circle gives the greatest area. Similarly, for a given surface area, different shapes occupy different volumes. When the bottle with the elliptical base had its narrow sides squeezed, it became rounder and its volume increased.

Student Experiments

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

Wrinkled Skin

Have you ever noticed how loose and wrinkly the skin on your hands becomes after washing dishes? Why? Try this experiment to demonstrate.

Needed. Two glasses, warm water, and table salt.

Fill each glass with warm water to a depth of about 5 cm. Add as much salt to one glass as the water will dissolve (i.e. make a saturated solution). Put one finger under the water in each glass and wait for at least 5 minutes. When you remove your fingers, the skin on the one that was in the plain water should be looser.

Explanation

Our fingers, like the rest of our bodies, are composed of many cells. Each cell contains, among other things, various salts dissolved in water and is surrounded by a cell membrane. The membrane is flexible, allowing the cell to expand and contract.

Water particles (molecules) can move through the cell membranes, and the direction in which the water particles move depends upon how concentrated the salt solution is on either side of the membrane. Water always moves from the solution containing the lower concentration of salt to that with the greater concentration of salt, and this process is called osmosis.

When your finger is in the plain water, some of the water in the glass therefore moves into the skin cells of your finger (the more concentrated salt solution), causing these cells to become bigger. With all the cells becoming bigger, your skin effectively becomes too big for your finger, and appears loose and even wrinkly. On the other hand, when your finger is in the concentrated salt solution, some water moves the other way, leaving your cells (lower concentration of salt) and thus making them smaller. The skin tightens.

After you remove your fingers from the glasses, the skin on both will return to its normal size. The effect is more pronounced in warm, compared with cold, water because the heat energy increases the kinetic energy of the water molecules, causing them to move through the cell membranes more readily.

Make a Rock

Needed. A small (e.g. yoghurt) container, concentrated solutions of common salt and sugar, sand, dessert spoon, and a bunsen burner.

Ask students if they can explain how sediments are changed to rock. The following activities might be used as part of the ensuing development of concepts.

Method 1. Fill a small container with sand and add as much concentrated solution of common salt as the sand will absorb. Allow the water to evaporate and note how hard the top surface becomes.

Method 2. This approach takes less time. Saturate a level dessert spoonful of sand with concentrated sugar solution. Evaporate the water by holding the spoon over a bunsen burner for 2 or 3 minutes. After the sand cools, it should be quite hard. You have made sandstone.

Explanation. While these activities demonstrate how sand particles can be cemented together to form a rock, there are some important differences between what you have done and the rock-making process that occurs in nature. First, you used salt and sugar to cement the sand particles together. Sugar solutions have never been observed in the earth. Rather, calcium carbonate and iron compounds are common cementing substances. In some places on Earth, common salt is found as a cement in rocks under the surface, but it is not found in surface rocks. This is because rainwater would quickly dissolve it.

Second, in the above activities, the cementing occurred as a result of the water being evaporated. In nature, the compounds in solution cement the grains together as the solution cools and the cementing chemical precipitates out of solution. The water is still present.

Science Poetry

Ants

I was digging in the garden and I got such a fright,
When an ant crawled up beside me and looked like it would bite.

I cried out to mum and begged her for a box,
And in the box I put those ants and a few little rocks.

I took the box inside with me and watched them constantly,
But one small ant got loose and bit me on the knee.

I swiped at that mean ant quite fast more than I can say,
And that ant I'm sad to say, it won't see another day.

I picked up his small body and put it on a book,
Then I got my magnifier so I could have a look.

It had six legs, a body and funny little eyes,
I'm sorry that I swiped you and said my last goodbyes.

Joshua Besant, Year 5
Jinibara State School
Queensland, Australia

Science Teachers Take Themselves Too Seriously

Oh great, double science in three and four
I just can't take it anymore!
This subject is such a bore
Oh how embarrassing, I'm starting to snore!

Molecules, electricity, minerals and space,
When I hear these words I scrunch up my face,
Science is put there to pass people's time,
So they can act important and earn a dime.
There's so many things we don't need to know,
So why not just sit back and go with the flow?
Don't get me wrong, if it interests you
Then study it all day and all night too.

But if you force us to tediously study it,
You can't complain when we don't care a bit.
Quite frankly I couldn't care less how plants eat
So I just sit here, rocking my feet.

The Earth itself knows how to run,
So why must we always jump the gun,
And assume there's things we need to know . . .
And make school hours go so slow.

The Earth will continue to spin and rotate,
Whether or not we study it in Year 8.
What does it matter about the Earth's core?
When all you want to do is get out of the door?
I'd rather learn about something interesting
Like poetry, drama or how to sing . . .

But as I sit and stare out the window,
At the little girl sneezing down below,
I realise she is suffering from the flu -
She could use an antibiotic or two!
I guess some things we just need to know
To keep this world up and on the go.

Take penicillin; it would not exist
If it weren't for Fleming, the scientist.

Here comes Mrs Bowern, arriving in her car.
I wonder if she lives close by the school, or far?
It's because of science we have this machine -
I guess I've been really quite mean
Science gave us TV's and hair dryers,
It even gave us the equipment to put out fires!

So in the end I've come to see,
The many ways science has helped me.
Maybe Science doesn't take itself too seriously -
It's the teachers who teach it that make us bored,
Deliriously.

Learning about chemicals, rockets and space
Really shouldn't make me scrunch up my face.
Perhaps the teacher should liven the pace
Without the white jacket and sterile lab,
Who knows . . . Science could even be quite FAB!

Stefanie Valenti, Year 8
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(*Editor*: Stephanie's poem reinforces the challenge being faced by those of us designing science curricula for students during the compulsory school years.)

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 which might be considered important for the development of scientific literacy.

1. What is the main job of leaves on a plant? (Choose one only)

   a. To shade the tender young shoots of the plant from the hot sun.
   b. To catch the rain and dew which plants need to live.
   c. To capture the warmth of the sun.
   d. To make food to keep the plant alive.
   e. I have a better idea. (Please explain)

Comment. Option d is the accepted answer.

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

   a. Plants get their food from the soil.
   b. Plants make their own food.
   c. Plants make some of their food, and obtain other food from the environment.
   d. Water is absorbed through the leaves.
   e. Carbon dioxide is absorbed through the roots.
   f. Photosynthesis is a substance.
   g. It is not the light, but rather the heat energy, from the Sun that is needed for plants to thrive (i.e. to live and grow).

Comment. Statement b is the only true one.

3. Which of the following are plant food? Water, soil, fertilisers, minerals, sunlight, air, carbon dioxide.

Comment. This question addresses the distinction between nutrients and the scientific concept of food. None of the items given are food for a plant.

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 given in any of the above tasks.

"Spoon feeding in the long run teaches us nothing but the shape of the spoon." *E. M. Foster*

"Whether you stay 6 weeks, 6 months, or 6 years, always leave it better than you found it."

Teaching Concepts and Developing Reasoning Skills Using Learning Cycles

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Abstract

The learning cycle teaching method is a three-phase inquiry approach consisting of *exploration, term introduction*, and *concept application*. The approach has proven effective at helping students construct concepts and conceptual systems, as well as develop more effective reasoning skills, primarily because it allows students to use *If/then/Therefore* reasoning to test their own ideas and to participate in the knowledge construction process. Three types of learning cycles exist (*descriptive, empirical-abductive,* and *hypothetical-predictive*) that represent points along a continuum from descriptive science to hypothetico-predictive science. This article includes a theoretical rationale for its use, a chemistry learning cycle example, and a brief review of key studies that have found it effective.

To read the full text of this article (19 pages), please **click here**.

Teaching Techniques

The Signature Game

This activity, adapted from May (2002), may be used most beneficially with especially a new class. It provides the teacher with a way of introducing some of the course topics, allows her to share aspects of her approach to implementing the curriculum, and allows both students and the teacher to get to know something about one another before working together.

Each student needs a copy of the game card (next page). The grid content may be chosen to reflect the circumstances, and I have included aspects of curriculum, learning styles, multiple intelligences, and students' interests and other features. Students move around the room, asking questions like "Do you enjoy looking at the moon, planets, and stars," and collecting signatures from students who answer in the affirmative. A student's signature may not appear more than once on any one game card. May (2002) plays the music "Getting to Know You," from the *King and I*, three times during this process before inviting students to return to their seats.

Go through the game card, one statement at a time. Ask students who agree with a statement to stand. The teacher should similarly stand when a statement applies to her. Items such as "My body temperature is 37.5°C" (which is normal) and "Ghosts haunt some houses" could be used to introduce the course topics of physiology and sceptical science, respectively. Similarly, explain how other items relate to your course, such as the opportunities you may be providing for them to allow assessment to reflect their different aptitudes.

The Signature Game

I enjoy looking at the moon, planets, and stars. ………………….	I need silence to study. ………………….	I play a musical instrument. ………………….	I have a sister. ………………….	Ghosts haunt some houses. ………………….
I find mathematics fairly easy. ………………….	My family grows vegetables at home. ………………….	My body temperature is 37.5°C. ………………….	I learn best late at night. ………………….	I have a pet that is a bird, reptile, or amphibian. ………………….
I'd like to learn more about electricity. ………………….	I enjoy public speaking. ………………….	I have a brother. ………………….	Studying living things gives me satisfaction. ………………….	I like to draw. ………………….
I like fishing. ………………….	I enjoy working with a computer. ………………….	I have a pet that is a mammal. ………………….	I enjoy reading and writing. ………………….	I like athletics. ………………….
I want to learn more about chemicals. ………………….	I like working with other people. ………………….	I wear spectacles or contact lenses. ………………….	I learn better if I eat snacks while studying. ………………….	I look like my ______________. (Mother, grandfather, …) …………………………..
Learning about fossils and dinosaurs is fun. ………………….	I enjoy doing experiments. ………………….	Summer is my favourite season. ………………….	To remember something, I need to write it down. ………………….	I enjoy learning about nature. ………………….

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The KWL Chart

Divide a page into three columns, 1-3, and label them as follows: *What I **K**now*, *What I **W**ant to Know*, and *What I Have **L**earnt*, respectively. At the beginning of a unit (e.g. on photosynthesis), ask students to complete columns 1 and 2. In column 1, they write all the things they already know about the topic, and doing this may also elicit some alternative conceptions. Then, in column 2, students write questions to which they would like answers. By providing a focus for the unit, this process can motivate students.

At the end of the unit, invite students to complete column 3 by writing all that they have learnt during the unit. Such revision reinforces learning. Also, check to see if all column 2 questions have been answered and, if not, make sure they are addressed.

Does Music Sooth the Savage Beast? A Pedagogical Attempt to Cross the Cultural Divide

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Abstract

A cultural divide exists in the classroom, with each participant (teacher and student) having rarely-coinciding objectives for a session. In this paper, the authors wish to reflect on the teaching and learning of science as a process of creating understanding from both sides of this cultural divide. Gary, the second author, describes the theoretical and social context of the teaching intervention and reflects on the outcomes for his pedagogy. Pip, the first author, presents the outcomes of his research into whether emotional mood is affected by music. Pip's research is far from perfect or conclusive. Rather, the manner in which the pedagogy has been applied has been successful in engaging Pip in the doing of science.

To read the full text of this article (7 pages), please **click here**.

Ideas in Brief

Interdisciplinarity in Science Education

Scientific literacy requires an understanding of the interconnections among science and other fields. Browne (2002) uses the example of how economic concepts can enrich environmental education to promote the benefits of interdisciplinary science education.

The tensions between economists and environmentalists are exemplified by World Trade Organisation (WTO) protests. The two fields tend to differ in the ways they examine the world, to have conflicting conceptualisations of environmental degradation, to expect different results from environmental policies, and to have different concepts of "self" and interpersonal relationships. It has been argued that economics is people centered, labels environmental degradation an economic problem, seeks compliance using monetary incentives to shape behaviour, and perceives people as individuals who navigate their own personal journey through life. Environmentalists, on the other hand, focus on the interdependence of species, view environmental degradation as a moral transgression, advocate education to change the value system that guides behaviour, and perceive “self” as something that emerges from a wealth of interdependent social interactions.

However, while some economists and some environmentalists almost never converse, there is much variation in the perspectives of individuals within each group. There is not deep disagreement between all economists and all environmentalists, and there is scope for conversation between the two groups. Many are willing to listen to the thoughts of those in the other discipline, and even respond. For example, the depletion of non-renewable resources has been included in the Index of Sustainable Economic Welfare, a measure of economic well-being developed by World Bank economist Herman Daly, and environmentalists need to take cognisance of costs in their analyses. Browne (2002) cites Meadows, Meadows, and Randers (1992) as an example of the conversation that can exist. The authors are trained in both business and environmental issues, and treat the economy and the environment as a single system.

Trade-offs are a feature of any decision-making process. For example, how important is the funding of pollution-free air compared with the need to feed starving people? Given finite funds, which local habitat is best preserved? Perhaps the spotted owl in northern California, USA could be saved at the expense of a loss of income for loggers if an employment program for unemployed loggers was part of the package?

Economists and environmentalists may not agree with one another, but do need to work together to build stronger environmental legislation. The scope for such collaboration is illustrated by the successful use of tax incentives for landowners in promoting wildlife preservation, and the positive impact that the implementation of deposits on bottles and cans has had, in some places, on recycling rates.

Interdisciplinary school science can foster an appreciation of issues from multiple perspectives. This in turn will better prepare students for future decision-making roles.

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Science and World Citizenship

Joseph Rotblat is a trained nuclear physicist and joint recipient of the 1995 Nobel peace prize. He recognises the great 20th century changes in economics, politics, the military, and science/technology (Rotblat, 2002), and that the latter has produced both benefits and dangers. The benefits result mainly from advances in transportation, communication, and information which, by moving us closer to becoming world citizens, are also promoting peace in the world.

The chief example of the dangers is the development of weapons of mass destruction (biological, chemical, and nuclear). For the first time in history, we have the technical means to destroy all humans in a single event. It is ironic that, at the same time as bringing us great benefits, progress in science and technology has made the human species an endangered one. We cannot afford wars in a nuclear age.

How do we deal with these dangers? The United Nations is trying. The Chemical Weapons Convention, adopted 5 years ago, aims to eliminate chemical weapons, and is presently being implemented. The Biological Weapons convention has a 30-year history, although there is disagreement as to how to enforce it. There is no Nuclear Weapons Convention. Rather, the Nuclear Non-Proliferation Treaty (NPT) sees 98% of member states agreeing that non-nuclear states will not acquire nuclear weapons and that the five nuclear states will dispose of their arsenals. However, while the latter have reduced their arsenals, they still adopt a policy of deterrence. Besides, even if the arsenals were eliminated, one cannot erase knowledge about how to build them, and such knowledge would surely be promptly used in the event of major conflict.

Rotblat (2002) suggests that we need to go further than simply eliminating the implements of war, and eliminate war itself. Some will regard this as unworkable because, from the beginning of civilisation, we have been governed by the Roman maxim “If you want peace, prepare for war” or, more recently, “If you want peace, stay armed to the teeth.” This may have applied to primitive man, who had to kill for survival (competition for food or for a mate), but there is now no need to kill for survival - if only we could share the world’s resources equitably.

There is evidence that we are indeed slowly learning that war is futile, and that we are moving towards a war-free world. Despite some terrible incidents, the number of international wars is decreasing, military regimes are being replaced by democracies, and members of the European Union have learned to solve problems without military confrontation. (France and Germany were mortal enemies during the two World Wars.)

However, for lack of wars to be universally accepted, and for war to be made illegal, Rotblat (2002) says we urgently need education for peace, education for world citizenry. The new dictum for the Third Millennium might be: “If you want peace, prepare for peace.” This will require two things. First, we will need a new approach to global security. The sovereignty of nation-states needs to be replaced with autonomy, with the right of a nation-state to make war eliminated. Nation-states are already surrendering sovereignty rights, in the broader interests of the world community, when an agreement on trade, or an international treaty, is signed. The United Nations will need to evolve to embrace some form of global governance role, with national military forces replaced by some form of police accountable to a global authority.

Second, we need to foster a loyalty to mankind. People need to extend, but not replace, their loyalties from smaller groups, towns, and nations to an even larger group, humanity. By promoting increasing economic, social, and cultural interdependence between nations, advances in science and technology are making the prospects brighter.

Because science and technology can make both positive and negative impacts, scientists need to be guided by ethical principles and accept responsibility for the consequences of their work. Teachers need to stress the global impact of the applications of scientific research, the need to preserve the human race, and the need for everyone to behave as a member of a world community.

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Controversial Issues in the Curriculum

Controversial issues are those where people hold conflicting views. They arise quite naturally during science courses, and include surrogacy, organ transplantation, abortion, and screening for genetic abnormalities. Dawson (2001) points out that by ignoring controversial issues in the science classroom, students are likely to form the inappropriate impression that science is value neutral.

The factors that impede controversial issues being addressed in science curricula include:

- lack of teacher expertise in the area,
- lack of teacher skill/experience with appropriate learning activities,
- a scarcity of resources,
- insufficient teaching time,

- beliefs about the nature of science,
- students not morally or emotionally ready to evaluate controversial issues, and
- the preferred learning style of some students' (e.g. those who are shy or quiet) not suiting the class discussion and group work which characterises many of the learning activities.

Dawson (2001) suggests that science courses need to be designed to provide both the time and resources to examine one topic in depth, and this may require the modification of existing courses. A topic may even be examined over an extended period, with students preparing a portfolio or oral presentation. In addition, teachers may need professional development to update their understanding in emerging areas of science, and to equip them with the skills and resources needed to facilitate learning about controversial issues. Appropriate learning experiences include discussion forums, structured debates, hypotheticals, role-playing, student-led seminars, drama, and simulation games, as well as community service and social action. The latter could include writing letters to the editor of a local newspaper, attending a protest rally, writing a petition, lobbying politicians, and conducting a study of local waste management practices.

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Traveling Through The Curriculum: A Method of Holistic Teaching

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Abstract

Reality-based teaching methods involve the meaningful application of knowledge. The goal of this holistic method is to apply knowledge about specific geographical locations to the curriculum. First-hand knowledge of a location enables teachers to constantly address the student question "Why do I have to learn this?" As a result, students are better prepared to associate cultures, subjects, and interests across curricular lines.

"Why do we have to learn this?" was the student-mumbled phrase that plagued my first years of teaching. Anxious that I was not demonstrating the applicability of Earth Science in everyday life, I changed the way I presented the curriculum. The solution was to use the curiosity of my students to drive the curriculum. By focusing on the *how* and *where* of Earth Science concepts, I reorganized the curriculum via sites and locations both close to home and around the world. Since I first utilized this teaching technique, my students have been better able to explain why the course and content are pertinent.

Locations that the teacher has visited can be used to cover many curricular points, and usually have the greatest application value to the classroom. Earth Science is a cornerstone to understanding various other subjects and interests, even across cultural and political lines. It therefore provides an easy-to-use vehicle for presenting ideas and concepts. To date, Pennsylvania (Gettysburg and Johnstown), New York (Syracuse and Tully), Kentucky (Mammoth Cave), Norway (BodØ and Svartisen Glacier), Alaska, Ireland, Idaho, Montana, China, Iceland, and Costa Rica are locations I utilize in addressing numerous curricular points. The information that follows focuses on how to best prepare for using such travel experiences to integrate locations into the teaching repertoire.

Although locations most frequently can be used to cover one obvious topic (e.g. Alaska with glaciers), most can be enhanced for use by researching the local sites, mines, geologic events and so forth. More often than not, the value of a site can be enhanced by using it to cover portions of many different topics. By way of storytelling, maps, slides, student-/teacher-gathered props (paraphernalia gathered while traveling to a location), and student questioning, a locale can come alive for students who may never have considered the site before.

Engaging the Students

Introduction to a location via storytelling engages students more earnestly than any other technique I have found (Wilson, 2000). It “sets the stage” for the upcoming topic, while promoting student curiosity and inquiry. Though initially time consuming, students’ interest and the quality of questions that result makes this technique worthwhile. Quality time spent on this interaction prepares students to understand the relevance of the curriculum.

I have yet to find a location that can adequately and efficiently cover all detailed points within a topic. Therefore, it becomes necessary for the teacher to organize the points addressed by a location into the topic, eventually to be tested. Fortunately, this site-based method permits students to question openly what they see and readily relate memories of previous discussions (review) to new information. Using a particular location as a vehicle, students have an easier time making the connections between the two seemingly unrelated topics within the curriculum. These transitional topics permit the students to spend more time reviewing previous curricular points without needing a structured introduction. Students walk away with a good overall understanding of why the information is important, where it is used, and when they may need to use it. For example, students who have studied the basic tenets of topographic mapping in its relation to the Battle of Gettysburg are better prepared to understand the concept of gradient and how in Alaska, glaciers flowing over high gradients develop crevasses.

Points within the curriculum are addressed via slides and paraphernalia collected during my own and my students' travels. When students practice slide interpretation, it is first necessary to explain what they are observing, and help them put the images into perspective. Students are given time to observe and question their interpretations of the slides. For students who have traveled to these and other locations (previously polled in class), this stage becomes highly interactive. I point out the item used for scale, I explain where the image was taken, and share an unusual aspect of the location that they can relate to. After the first slide, I ask open-ended questions of the students (Reynolds & Peacock, 1998). Later, students are asked to explain all details observed (including scale), predict probable events in that environment, create safety plans, or simply explain the results of these events. This practice enables students to question more openly and vigorously. After only 1 or 2 days, students' skills improve to the point where we can revert almost entirely to vocabulary and processes evident in the slides.

One slide I use every year shows myself standing on the Sheridan glacier (Alaska), and in the distant background are sharp-peaked, snow-capped mountains. I am dressed in shorts, short-sleeved shirt, and hiking boots standing in full sunshine, obviously comfortable with my surroundings. One of the first things I would do as a facilitator is not to say anything. Silence enables the students to first observe and then gather information about what they think they see, before I tell them what they see. Often, this short time to observe in silence will foster questions. How far away are the mountains? Why are you in shorts if you are standing on ice? How cold is it there? Is it dangerous to walk on the glacier? What season is it? If necessary, I would explain the scale of the objects in the slide (how far away the mountains are from me in the picture, etc.) before addressing their questions. Of course, this opens various lines of discussion and the flexibility of the teacher to make choices about the curriculum that is required. Allowing the students to address their interests first allows the teacher to proceed with an interested audience. It also makes it much easier to help the students apply previously covered topics and information to the photograph.

Objects used in photographs to provide scale are invaluable for successful interpretation. Periodically, I will make myself (or my husband) the object of scale. As a result, students observe how my appearance has changed over the past 6 years, and as a result they become more personally involved in the photograph. Engaging the students in topical discussions becomes easier, but only after they comment on how short my hair was or ask why I wasn't cold on that glacier (in shorts!).

Assignments and assessment vary, but include critical thinking exercises, questioning, and the application of existing knowledge of curricula. Hands-on, inquiry-based activities directly related to the locations and the curriculum, repeated verbal assessment, and written and verbal inquiry of meaningful current events (about the localities) are all utilized, as well as the typical quizzes and written tests, where appropriate. Activities that assist the more kinesthetic or tactile students include an earthquake epicenter-location activity (focusing on an epicenter in Alaska), and a Plate Tectonics activity that focuses on both the subduction zone along the Aleutian Trench (earthquakes) and the Ring of Fire (volcanism). Students also create a topographic map of the Gettysburg battle area.

Students will often inquire about their own travel experiences as they are able to better apply the concepts covered in class. These impromptu, inquiry discussions can serve as an important vehicle for review, or to launch into the next area to be addressed in the curriculum. For this reason, the teacher must be well versed in the curriculum that remains to be covered, and keep track of those points that have been covered throughout the year. Written quiz and exam questions often ask students to observe a slide/object. Depending upon the information and skills being tested, the students may be asked to explain the ramifications of an event shown in the slide, or explain basic information about the stream age, climate, topography, and so on. Students would be asked to relate this information to the curriculum that had been covered, as well as to the topic that may have been most recently addressed in class. The written exams pose a challenge for the teacher, due to the possible changes made in the order of topics throughout the year, the integration of current events, and line of student questioning. This teaching method provides an opportunity to show how various topics are interconnected, but it makes the traditional test on something like ‘sedimentary rocks’ obsolete. Testing must constantly reflect the select areas of the curriculum that were covered - the slides used, current events, student questions, and the curriculum points that the teacher chose to cover.

Overwhelming support for this approach was evident in evaluations filled out by students. Mainly, they didn’t feel like they were doing the “same old thing.” Comments and assessment revealed that students with strengths in visual and auditory learning benefited most from the slides and verbal questioning. The tactile or kinesthetically-oriented students benefited more from the hands-on activities designed and implemented to integrate their strengths. Of the various locations I use each year, Ireland, Alaska, and Gettysburg (Pennsylvania) provide some of the best examples for implementation.

Ireland and Rocks

The United States has always had forested land to build shelter and burn for fuel. These uses of wood have shaped our American culture. The lack of wooded land has shaped the Irish culture. Their main heat source (even today) is peat. Undecayed vegetative matter that has accumulated over thousands of years builds up in bog areas and can today be cut by a family, stacked in bricks, dried over a period of days to weeks, and burned as fuel in the hearth. There remains so much peat in certain locations that it is commercially harvested.

Though not obvious to the students at first, this information relates directly to the Earth Science curriculum. Deposition rates, rocks, radiometric dating, and geologic time are all topics that can be addressed in detail from this one location. Though I use this to introduce the topic of sedimentary rocks, I will tell the story of one of the bog people to gain initial student interest (Deem, 2002). Later in the year when I cover climate, details of absolute age dating, and radiometric decay rates, it is appropriate to relate back to the location, culture, and curriculum points already addressed.

Gettysburg (Pennsylvania) and Topographic Mapping

In introducing topographic mapping, I begin with a storyline that begins with the location of Gettysburg, Pennsylvania. Students follow the storyline I lay out for them about the Battle of Gettysburg, and some recall facts they have learned about President Lincoln and the American Civil War. I concentrate at first on the historical significance, how it came to be that the troops came to meet at Gettysburg, the strategy used by the commanders, and the importance of the commanders' knowledge of local geology and geography to win the battle, and so on. Both road and topographic maps of the Eastern U.S. (New York and Pennsylvania) are used as props during the story. Students question me throughout as I transition from story (history) to the ongoing significance Gettysburg poses in our classroom and lives (Wilson, 2000). Knowledge of topographic skills, awareness of local geology, and proficiency with latitude and longitude are the points I stress from this visceral battle of the American Civil War.

I apply information about the Gettysburg location to demonstrate differences in active erosional agents between New York and Pennsylvania, transported versus residual soils (and why), chemical and physical weathering, porosity, permeability, capillarity, the water cycle, and climate factors. Due to the great differences in underlying bedrock (and therefore soil), I also touch upon curriculum points on the mineral and chemical composition of underlying bedrock, and the amount of time required for soil formation (and the Geologic Time Scale). Depending upon student interest and questions, I can even cover the differences between soil and regolith that can lead a short discussion on terrestrial planets. Though Gettysburg is introduced early on, it is constantly revisited via student questioning and new topics throughout the year.

Alaska and Plate Tectonics

The entire topic of Plate Tectonics is presented via the Alaska locale. Slides of the West Coast and Alaska Tsunami Warning Center (in Palmer, Alaska) are used to introduce tsunamis and stimulate questions on how they work (Sokolowski, 2002). The “Travel Section” of my website (McArdle, 2002) links to the Tsunami Warning Center website, where we analyze updated earthquake data that may have created tsunami’s during the last hour. This initiates more discussion and questions. Seismology, volcanology, and Plate Tectonics are all easily related to Alaska.

Due to climatic differences from New York State, and other locations around the world, glaciology can also be addressed in detail. Glaciology can be tied in to visible geologic damage (via slides) from the 1964 Earthquake. Landslides resulted from seismic waves shaking steep-sided slopes and vast amounts of angular debris were deposited atop glaciers (Sheridan and Sherman Glaciers). Topographic maps are used to determine latitude, longitude, and landscapes and hands-on critical-thinking activities are used to stress these concepts.

Implementation Challenges

As with any large scale change to the methods teachers use to teach their curriculum, this one will take some practice to utilize well. Each of the following challenges, though, is surmountable.

Time and flexibility. Undertaking to teach the curriculum differently every year (depending upon student travel and current events), in a seamless flow that enables students to inquire about relationships among subjects, locations, and interests, is a challenge.

Poor photographic skills. Options exist for the teacher with poor photographic skills. Students willing to share images of their own travels or observations have made for better student inquiry than some of my own. Student photographs of recently drought-reduced reservoirs prompted immediate inquiry from students and resulted in an impromptu presentation of curriculum points. Slides available for purchase are taken during good weather and from advantageous angles. Images are readily available on the Internet, although they often require permission for use and appropriate credits (Reynolds, 1998).

Getting started. Before traveling to a location you may want to use for this teaching method, look for opportunities for curricular integration by researching local governments, state/national parks, the culture, and languages used. Survey your students about their travel experience. Use your working curricular knowledge to plan for integrating images and props from your travel, and that of your students, in a holistic presentation. Travel with a camera (remember film and batteries), items for scale, Zip-close bags (for carrying rock or soil samples home), permanent marker, pocket-sized field notebook, and special writing implements, such as a grease pencil in tropical climates.

Implementation Benefits

There are many benefits in sharing the curriculum with students via personal experience and specific localities. These include:

- Low cost to implement.
- Applicable to all locations on Earth.
- Provides meaningful student work for a substitute teacher during the absence of the regular teacher.
- Addresses why, when, and where the importance lies in understanding Earth Science.
- Engages students in inquiry and higher-level thinking skills.
- Students begin to inquire and view Earth Science with a global perspective.
- Students become holistically aware of science, interests, events, and subjects.

Engaging students in discussion and hands-on activities about Earth Science globally and here at home improves their inquiry skills and potential for success in other fields of study. Students' abilities to interpret their observations and identify holistic connections between the curriculum and locations improves quickly with practice. Engaging students in the identification of scientific and cultural ties to different locales permits students to use higher-level thinking skills to address current events. Holistic methods require organization, flexibility, and perseverance toward integrating a location into the curriculum. Student inquiry of the applicability of their travel experiences to the curriculum becomes the means to successful integration of the curricula into their lives (McArdle, 2002). Methods involving travel experiences not only enrich the classroom experience and enliven the interests of individuals and communities they share, but lead one toward becoming a holistic educator.

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Research in Brief

What Science Education do Students Need?

Science curricula are typically determined by academic scientists, school science teachers, and academic science educators. Duggan and Gott (2002) recognised the usefulness of starting at "the other end," and used case studies to determine what science students need, after they leave school, to function effectively in society.

Using semi-structured interviews and scrutiny of relevant documents, data were collected in the UK from 2-4 employees of each of four science-based companies, an arable farmer, members of community action groups involved with science-based issues, and 2 parents. The companies were involved in biotechnology, the development and manufacture of colourants for food and other products, analysis of environmental samples, and engineering, respectively. The community groups were concerned with the effect of burning recycled liquid fuel (RLF) in a cement kiln near a village and the positioning of a mobile phone base station near a primary school, and data were collected from the 2 parents about their personal decision-making concerning immunisation of their children.

The results are discussed in terms of procedural knowledge/understanding and conceptual knowledge/understanding. Procedural understanding refers to "the thinking behind the doing" of science, and includes the principle concepts of evidence, the overarching concepts of validity and reliability, understanding of the choice of a particular instrument, deciding how many measurements to take and over what range, the concepts of repeatability, error, accuracy, risk, and uncertainty, and how to analyse and evaluate data. Procedural understanding was found to be essential for those working in the higher levels of industry, and for persons interacting with everyday issues. At the lower levels of industry, employees typically simply operate protocols. It therefore follows that school students need to be equipped with procedural knowledge and understanding, as well as the ability to use it to critically evaluate evidence or to recognise a lack of it. More able students seem to pick up such understanding during school science courses, but the majority of students do not. Procedural knowledge and understanding therefore needs to be taught explicitly.

Conceptual knowledge/understanding relates to a knowledge base of concepts which are in turn based on scientific facts, and include such things as Newton's laws of motion, respiration, and solubility. Beyond basic concepts, conceptual understanding was found to be so specific to an industry that it was acquired on a need-to-know basis. It would be impossible to incorporate all such knowledge in any curriculum, and some is probably best learned in the workplace context. For members of the public, most concern is about “new science” issues, issues that did not exist 10 years or so ago when the adults were at school. When so motivated, the public can readily access and gain specific, up-to-date conceptual knowledge when required, using especially the Internet. School students therefore need to know how to access, and apply, conceptual knowledge.

Hence, Duggan and Gott (2002) recommend that a greater emphasis needs to be given in schools to the explicit teaching of procedural understanding, and that time for this could be found by reducing both the conceptual content that is presently taught and the amount of associated assessment. For 11-14 year-olds (Key Stage 3), they suggest advantage be taken of the enthusiasm of these students for investigative work by using a problem-based curriculum. The problem solving would involve the collection and analysis of data and the creation of solutions or the making of decisions, and the conceptual knowledge required to allow students to make sense of their investigations would need to be included.

For 14-16 year-old students (Key Stage 4), they advocate developing a contemporary issues-based approach to promote scientific literacy. Issues might include the effects of recreational drugs and the effectiveness/risk of various birth control methods. They acknowledge, though, that this approach would present a difficult challenge for teachers. In addition, options addressing traditional science concepts could be offered to the minority of students wishing to continue to study science at higher levels. The authors distinguish, though, between the goal of their proposed curriculum in empowering future citizens to actively participate in science-based issues and the goal of curricula that advocate a passive understanding only of topical science-based issues.

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How do Students of Project-Based Science Courses Perform on Standardised Tests?

Reformers are recommending student-centered, inquiry-based practices in science education, and a number of such programs exist (Minstrell & Van Zee, 2000). Inquiry approaches support students’ construction of knowledge, and can lead to deep understanding. However, there is some concern that, by reducing the amount of content to which students are exposed, students may be disadvantaged on large-scale achievement tests.

Schneider, Krajcik, Marx, and Soloway (2002) aimed to investigate this concern as it applied to one such enquiry approach, project-based science (PBS), as practised in an alternative, Midwestern USA public high school. PBS engages students in projects that typically last 8 weeks, but possibly extending up to 16 weeks, and in which the use of technology and collaboration with peers, teachers, and members of the community feature strongly. Students find solutions to real-life problems by asking questions, designing investigations, analysing data, drawing conclusions, and reporting their findings.

The school is not a magnet school for science, nor considered one of the top schools in the district in terms of student achievement. Students interested in science generally chose to attend one of the other district high schools that offer more traditional science programs, including advanced placement courses. Staff had developed a 3-year, integrated, PBS curriculum called Foundations of Science (FOS) (Huebel-Drake, Finkel, Stern, & Mouradian, 1995). The driving questions for projects included "Is Traver Creek ecologically balanced?" and "Is our climate changing? Does it matter?" The majority of students were white and middle-class, and completed their science projects in groups of 2 to 4 using block scheduling, where science classes met for two 90-minute classes and one 45-minute class each week.

The sample comprised 142 10th- and 11th-grade students. The research design required that they complete the 12th-grade version of the 1996 National Assessment of Educational Progress (NAEP) science test, an instrument used across the United States to assess achievement in science in Grades 4, 8, and 12. It comprised multiple choice questions, constructed response questions, and performance tasks. These students' scores were then compared with those of Grade 12 students across the nation who sat the NAEP test and who composed subgroups that most closely matched the white, middle class sample. It is acknowledged that the Grade 12 students were older than the sample students, but that they may not have taken a science course in 2 years.

It was found that the PBS students scored as well, or better, on almost all 34 test items. PBS students outscored the national sample on 44% of the items, and were outscored on two items. Students find some content more difficult to understand, and the patterns of difficulty were similar for both sets of students. However, while both groups found the same content difficult, PBS students performed better than students in the national sample on the more easily understood content. PBS students also displayed an advantage over the national sample on items that required an extended constructed response.

The researchers used these results, together with results that existed from two different measures of the success of students in PBS, to conclude that PBS promotes student learning in science and that PBS students were prepared for the NAEP test. Teachers should be encouraged to implement inquiry-based approaches in their classrooms without fear that their students will be disadvantaged on large-scale achievement tests.

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Using Enrichment and Extracurricular Activities to Influence Secondary Students' Interest and Participation in Science

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Abstract

A quasi-longitudinal case study was used to determine the effects on secondary students of participation in a program of enrichment and extracurricular science activities in terms of their interest and enjoyment in being involved in science activities, their motivation to continue to participate in science, and their perceptions about scientists and about the role of science in society. Two groups of students in an Australian school were followed simultaneously, a junior cohort through Years 8 to 10 and a senior cohort through Years 10 to 12. Data were collected from 20 students; 5 girls and 5 boys from each cohort. A strong positive relationship was found between changes in students' interest and enjoyment and changes in their motivation, and both these variables increased, in an overall sense for the combined student population, during the study period. All students generally held a high perception of both the normality of scientists and the importance of science in society throughout the study period. Participation in science activities impacted overall positively, but to varying extents for different activities, on all four dependent variables. Suggestions for the structure and/or conduct of competitions, excursions, and practical work, including the design of museum exhibits, and implications for further research are presented. The paper is based on the first author's doctoral dissertation.

To read the full text of this article (16 pages), please **click here**.

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

How can I explain photosynthesis to my middle school students?

Photosynthesis is a very important process in the biological world, and is difficult to teach (Finely, Stewart, & Yarruck, 1992; Johnstone & Mahmoud, 1980). There are many ways by which the required learning might be facilitated. As you do not provide information about your context, such as whether developing an understanding of photosynthesis is part of a broader theme or whether it is an individual, shorter-term unit, please allow me to share some ideas upon which you might draw when designing your lessons, and invite readers to make further suggestions. Table 1 summarises 14 activities comprising one possible learning sequence. You will find descriptions of the techniques used for implementing these activities (bracketed) in the *Teaching Techniques* section of issues of *The Science Education Review*.

Photosynthesis is the process in which green plants make their own food. Light energy from the sun is absorbed by the green chlorophyll in the leaves, causing water in the leaves (obtained from the soil through the roots) to dissociate into oxygen, hydrogen ions, and electrons. In a series of complex steps, carbon dioxide from the air is then consumed to produce a simple sugar (glucose), during which further oxygen is produced. This sugar is then used, in conjunction with nutrients like nitrogen, sulphur, and phosphorus from the soil, to make starch, fat, proteins, vitamins, and other compounds essential for life. In the word photosynthesis, *photo* refers to light and *synthesis* means "to make," so photosynthesis means "putting together with light." At the introductory level, the process is often simply expressed as carbon dioxide plus water, in the presence of sunlight and chlorophyll, give food plus oxygen.

In developing a series of lessons, one might draw on recommendations for facilitating a social constructivist approach (Eastwell, 2002). In particular, this will mean eliciting students' existing ideas, connecting learning with everyday contexts, and providing activities that involve a variety of multiple intelligences (intrapersonal, interpersonal, visual/spatial, body/kinesthetic, musical/rhythmic, verbal/linguistic, and logical/mathematical) (Gardner, 1983) and cover a range of levels of a modified Bloom's taxonomy (remember, understand, & apply [lower cognitive levels], and analyse, evaluate, & create [higher-level thinking]). As well as developing students' understanding of the process of photosynthesis, I have chosen to include activities in Table 1 that relate photosynthesis to interactions between living and non-living parts of the environment and to the issue of global warming. In addition, let's use a broad, overall learning cycle strategy (Lawson, 2002), comprising invitation, exploration, concept introduction, and concept application phases.

Table 1
Summary of Activities for a Photosynthesis Learning Sequence

	Remember	Understand	Apply	Analyse	Evaluate	Create
Intrapersonal					14. Complete KWL (Indiv.)	
Interpersonal			6. Repeat A/C questions (Cooperative quiz)			13. Other strategies (1:4:P:C:R)
Visual/Spatial		9. Concept map (Indiv.)				
Body/ Kinesthetic			5. Act out "Photo… Song" (Whole class)	4. Design & carry out activities (Prac. work)		
Musical/ Rhythmic				1. "The Rain Forest Song" (Whole class) 10. Sing again		
Verbal/ Linguistic		11. Report – choice of format (Paired interviews)		8. Video - greenhouse (Whole class)		
Logical/ Mathematical	3. Explore prior ideas (KWL/Silent Round Robin)	7. Newspaper article (Noisy Round Robin)	2. A/C questions (Indiv./ collate)		12. "Two children" strategy (PCQ)	

Invitation

To welcome students to the topic, and to suggest a real-life context, invite students to sing along with "The Rain Forest Song" (a track on the *Singin' Songs of Science* CD, available from Educational Innovations at http://www.teachersource.com), also asking them to identify the three benefits provided by rainforests mentioned in the song. Tell them that the content of the song is linked to the question we need to answer, "From where do plants get their food?" and that we will return to the song later.

To arouse students' curiosity, and to ascertain some of their existing ideas, invite them to individually answer a set of questions designed to elicit their alternative conceptions. The questions in the *Students' Alternative Conceptions* section of this issue, and the previous issue, will be useful here. Have students swap answer sheets (to ensure anonymity) and collate the answers and reasoning for the class. Ask students to return answer sheets to their owners and, to further arouse curiosity, invite them to briefly compare and discuss their answers with a neighbour. Tell them that we will be returning to these questions after further developing our understanding, and you may wish to keep a record of the class distribution of responses for comparison with later responses.

To further explore students' prior knowledge about where plants get their food from, remind them that all living things (plants and animals) need food to live and grow and use a KWL chart, completed as a Silent Round Robin. As they complete the "What I ***K***now" part of the KWL, monitor their entries and probe further with questions like "What do plants need to grow?" and "Why do plants need sunlight?" Following the initial rotations, ask each group to summarise their knowledge on a group KWL chart, and then share with the whole class. Return to Silent Round Robin mode to complete the "What I ***W***ant to find out" part of the KWL, again summarising on each group chart and sharing with the whole class. Tell students we will return to these charts at the end of the unit, complete the final "What I have ***L***earnt" section, and check that all of their questions have been answered.

Exploration and Concept Introduction

The foregoing activities will have hopefully identified a number of alternative conceptions held by students. These might include that plants get their food from the soil, that fertilisers are plant food (which, while they actually provide nutrients, is how fertilisers are commonly advertised!), that water is absorbed through the leaves, and that it is heat, rather than light, energy from the sun that plants need.

The challenge is to design a series of activities, comprising both practical, hands-on (where appropriate) and other experiences, that challenge students' prior views, introduce the scientific concept of photosynthesis, and convince students that the latter provides preferred explanations. For example, some students may think that sunlight is necessary to keep a plant healthy (acting a bit like a vitamin, perhaps!), but not that it is directly involved in the food-making process, so the traditional experiment of covering part of a broad, green leaf with aluminium foil for a period, removing the chlorophyll, and testing for starch with iodine solution might be used. Any of a number of standard experiments could be used to demonstrate the passage of water up a stem and into the leaves. The stem of a white carnation might even be stood in coloured water. Involve students in the experimental design process. Some resources and pedagogy will have to be determined as needs emerge.

To reinforce the process of photosynthesis, students could be asked to act out the process while singing the "Photosynthesis Song" (McLaughlin, Hampton, & Moxham, 1999), sung to the tune of "Three Blind Mice." Participating students could hold cardboard visuals, like a yellow circle with rays drawn on it to represent sunlight, blue drops for rain, a green circle for chlorophyll, and white cardboard pieces with formulae written on them for carbon dioxide and oxygen. This reinforcement activity could be repeated at the beginning of consecutive lessons, with different students playing different parts each lesson. Explicate the interdependence of plants and animals in terms of the relationship between the oxygen produced during photosynthesis and that needed by animals like us. Finally, further reinforce understanding by returning to the questions used at the beginning of the unit to elicit alternative conceptions and invite students to answer them again, this time in cooperative quiz mode (see Volume 1, Number 2, pp. 72-74).

Concept Application

We now seek to apply students' understanding of photosynthesis to the real-life issue of enhanced greenhouse warming. Display a newspaper clipping about tropical forest clearing and global warming, and use a Noisy Round Robin to collect students' prior thoughts about the following question: "The clearing of trees in tropical forests, as well as vegetation in other places, is thought to be causing our Earth to warm up. How does clearing trees produce this effect?"

Use an enhanced greenhouse effect video to identify sources of carbon dioxide and other greenhouse gases in the atmosphere, asking students to briefly summarise what is meant by global warming and how it is caused. Supplement the student summaries with teacher-led question and answer, aimed at addressing any alternative conceptions identified in the previous activity and developing an understanding of global warming. Students might be asked to construct an individual concept map to summarise their understanding of photosynthesis, the related interdependence of plants and animals, and the enhanced greenhouse effect. Sing "The Rain Forest Song" again, emphasising the "it gives us air to breathe" line.

Ask students to research the clearing of rainforests and prepare a report, summarising information about reasons for the clearing, the rate of clearing, and the predicted consequences of enhanced greenhouse warming. Each report would need to include a description of photosynthesis and the enhanced greenhouse effect. Students might be given a choice of forms that their reports may take, such as an interview with a rainforest tree (questions and answers to be written), a poster, a written report, a role-play to teach others about the issues, a board game, a children's book, a poem or song, a computer presentation, or some other form negotiated with the teacher. Monitor student progress using the paired interview technique, with questioners recording notes and submitting them to the teacher. After submission of the reports, recapitulate the main points with the whole class.

One of the reasons for tree clearing is the need for more agricultural land to meet the demands of the world's expanding population. To further promote higher-order thinking, defined in terms of the upper three levels of Bloom's taxonomy, one might use the whole-class PCQ (***P***ros, ***C***ons, and ***Q***uestions) technique to ask students to respond to the following suggested solution to the problems resulting from tree clearing: "Limit every woman in the world to giving birth to a maximum of two children."

Taking this one step further, use the 1:4:P:C:R (individual, fours, publish, circle, and refine) technique to encourage students to suggest other possible strategies for solving the problems associated with tree clearing. Ensure that the concept of sustainable yield is canvassed.

Finally, ask students to individually complete a copy of the "What I have learnt" part of the KWL chart constructed by their group near the beginning of the unit. Also, ensure that all questions from the "What I want to find out" section of the class charts, as well as any others that have arisen subsequently, have been answered.

I trust this overview provides some useful ideas, and I invite readers to contribute their suggestions to The Editor at editor@ScienceEducationReview.com .

Peter Eastwell

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Further Useful Resources

What Science is and How it Works

Authored by Gregory N. Derry, and published in 1999 by Princeton University Press, *What Science Is and How it Works* is a book that uses examples of people, issues, and phenomena to identify the essential elements of scientific thinking, how science operates, and how it connects with our daily lives.

A consideration of the relationship between science and topics such as religion, ethics, and philosophy illuminates both the power and limits of science. Is parapsychology a science? Are paranormal effects real? How does one distinguish science from pseudoscience? What is the status of cold fusion, global warming, the effect of power lines on public health, and creation science?

Promoting Bioscience Literacy

http://www.actionbioscience.org

Provides peer-reviewed articles examining bioscience issues, together with accompanying lessons for high school-undergraduate levels. The lessons are written by educators and are correlated to the NSES standards (USA). Topics include biodiversity, environment, genomics, biotechnology, evolution, new frontiers in the sciences, and education.

Science History Tour

http://www.ncusd203.org/north/depts/science/chem/marek/

Yvonne Twomey (ytwomey@mindspring.com) and Lee Marek (LMarek@aol.com) will be conducting their Sixth Annual Science History Tour, June 25 - July 10, 2003. Participants will touch many facets of science, from astronomy through chemistry to zoology, and learn more about the culture and cuisine of each country visited.

In the Netherlands, you will visit world-renowned museums such as the Boerhaave and Teylers, see one of the world's oldest medical museums, and also visit the botanical garden where tulipmania began. Additional visits will be made to a porcelain factory and to one of the world's largest flower markets. Those who wish will have time to see lovely Vermeers and Van Goghs in Amsterdam, or to explore places of personal interest. On your way to Belgium you will visit one of the largest sea barriers in the world, built after the disastrous floods which devastated large areas of the Netherlands in 1953. In Belgium, you will stay in the fascinating old city of Ghent, and pay visits to Bruges (the European City of Culture last year) and Brussels, where a study of the chemistry of Belgian beer is on the agenda. From Calais, you will take the ferry across the English Channel to Dover and spend a day on the Isle of Wight, the birthplace of Robert Hooke (1635-1703). In London you will attend a conference, held jointly by Gresham College and the Royal Society, to mark the occasion of the 300^{th} anniversary of Hooke's death and to honor this under-appreciated genius. You will also make other visits in London, and take a day trip out of town.

For details and a registration form, contact Yvonne or Lee at the above addresses. The Web site above contains presentations on past trips.

Exploratorium Science Snackbook

Square Wheels and Other Easy-To-Build, Hands-On Science Activities, developed by Don Rathjen, Paul Doherty, and the Exploratorium Teacher Institute, is the second book in the Exploratorium Science Snackbook Series. It contains instructions for preparing 31 intriguing physical science demonstrations, experiments, and exhibits which are safe and that use readily available materials. The activities, aimed at middle and high school, are accompanied by explanations. Available from the Exploratorium Store, San Francisco (http://www.exploratorium.edu).

Humour

Changing Times?

The Year 1 class was enjoying a lesson on birds. Discussion lead to the fact that birds eat fruit. One student remained puzzled, though. "But Sir," she asked, after raising her hand, "how do they open the cans?"

Food Groups

Question: Name the four basic food groups.

Answer: Fast, frozen, take-away, and delivered.

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The Science Education Review

Table of Contents

Volume 1, Numbers 1-4, 2002

Did you Know?

Science Stories

Articles

Demonstrations

Research in Brief

Your Questions Answered

*   *   *