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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

The total length of hair grown on a person's head during a lifetime is about 900 km (2.5 cm each minute).

Developing the ability to estimate quantities like this is a valuable learning experience for students. However, an estimate is not the same as a guess. An estimate requires approximations, judgement, and reasoning, whereas a guess is based on intuition alone. The game called ***Fermi Questions*** was invented by the Nobel Prize-winning physicist Enrico Fermi, and requires students to determine the order of magnitude of some extraordinary quantities.

Try asking your students to estimate things like: the number of hairs on the head of a typical student, the total length that fingernails grow in a lifetime, the volume of blood pumped by a human heart during a year (and compare this with the volume of, say, a swimming pool), the number of blades of grass growing on a football field, the number of words in a book, the length of a 3-hour video tape, the time a person spends sitting on the toilet during a lifetime, or the dollars spent by students at the school canteen each year. It is interesting to compare the different methods used by students. Also, ask students to devise their own estimation questions to try on other members of the class.

Science Stories

We all enjoy a good story, and anecdotes will enliven any science classroom. Stories about the history of science, the lives of scientists, and the blunders of science can encourage learning, help students to remember facts, and motivate and inspire them. Stories can illustrate the evolution of scientific developments, features of the nature of science, the human aspects of science, and the relationship between science and cultures.

Every science teacher can use a repertoire of stories to enrich lessons and make them more interesting, and this regular section of *The Science Education Review* (*SER*) will provide a selection from which to choose. There is no need to memorise stories verbatim, or to necessarily remember all specifics like dates and places. Rather, picture the stories as images in your mind and allow them to develop further each time you tell them. Quotations, though, are great because they add realism. Why not even invite your students to research and share their own stories?

Lord Kelvin

This story might be told during a lesson on temperature scales. It reinforces that even scientists and science educators can have a sense of humour!

Lord Kelvin was born in Ireland and educated at Scottish and English universities. He began life as William Thompson, received the title Baron Kelvin of Largs, and was knighted by Queen Victoria for his work as the electrical engineer in charge of laying the first successful transatlantic telegraph cable in 1866. He proposed the Kelvin temperature scale.

As a professor of natural history (what we now call science), Professor Thompson was a somewhat dramatic and eccentric lecturer who was well liked by students. Due to another commitment, he one day left the following notice on the lecture room door: “Professor Thompson will not meet his classes today.” His students, thinking they were being rather clever, proceeded to erase the “c” from classes and wait for his subsequent reaction. When they returned, they were most surprised to find that Thompson had further removed the “l” from lasses to leave: “Professor Thompson will not meet his asses today” (Robacker, cited in Folino, 2001).

Suggestion. Write Professor Thompson’s notice on the board and erase letters as appropriate, allowing students to read and comprehend the amended messages without you needing to speak them.

Why Sb for Antimony?

Sb is actually short for stibnite, the ore from which antimony was discovered. A French monk accidentally discarded some stibnite, left over from an experiment, into buckets containing pig feed. The pigs became sick, but recovered with an increased appetite and grew much larger than ever before. Noticing that his fellow monks were also somewhat lean, he decided to also feed stibnite to them. Unfortunately, they died! He then proceeded to travel and spread the word that stibnite was not good for monks. Hence, the word antimony: *anti* meaning *not good for*, and *moine* for *monks*.

Source

Folino, D. A. (2001). Stories and anecdotes in the chemistry classroom. *Journal of Chemical Education*, *78*, 1615-1618.

The Nature of Science

Introduction

Science is often referred to, particularly in curriculum documents, as one way of knowing, one way of describing, classifying, and understanding our universe. For students to become scientifically literate, they need "to engage in the discourses . . . about science" (Eastwell, 2002), so developing an understanding of the nature of science (NOS), including both its strengths and limitations, is an integral component in a "Science for All" curriculum. It is also a commonly neglected one. However, there are also other ways of knowing, other ways of understanding our universe. These include aesthetic, interpersonal, intuitive, narrative, formal, and practical modes of knowing. Only by being aware of at least the broad characteristics of these various ways of knowing are we in a position to appreciate the role of scientific knowing within the broader perspective, and some distinguishing features of these other modes of knowing will be discussed in future issues of *SER*.

NOS might be defined as "the values and assumptions inherent to science" (Lederman, 1992, p. 331). This article will identify and discuss these values and assumptions, address some misconceptions associated with them, and make some pedagogical recommendations. Other sections of *SER* will offer related student activities. First, though, allow me to make two introductory remarks.

In broad terms, the discipline of science is characterised by its central commitment to evidence as the basis of justified belief about material causes and the rational means of resolving controversy (Siegel, 1989). Science is also progressive and universal (Good & Shymansky, 2001). However, at the level of fine detail, scientists, philosophers, and science educators differ in their opinions about NOS (Fourez, 1989; Lederman, 1986; Meichtry, 1993). For the purposes of school science, though, considerations at this level of sophistication are not necessary and would, in fact, be inappropriate (Abd-El-Khalick & Boujaoude, 1997). This article adopts such a pragmatic approach.

Second, some features of NOS, such as creativity and the presence of competing explanations/theories, are also features of other ways of knowing. The following features of NOS are therefore presented in two parts, as described by Smith and Scharmann (1999). The first part contains distinguishing features of NOS, those features which tend to make a question or field of study "more scientific" rather than "less scientific." The second part gives important non-distinguishing features of NOS. The listing is a modified composite of items from Niaz (2001), McComas, Clough, and Almazroa (1998), Moss, Abrams, and Robb (2001), Smith and Scharmann (1999), and Taylor and Fraser (n.d.).

Features of the Nature of Science

Distinguishing features:

1. **Scientific knowledge demands evidence, and science is derived from, and guided by, experience or experiment.**

2. **Scientific claims are testable/falsifiable.** Popper (1968) suggested that only ideas that are potentially falsifiable are scientific ideas. Hence, a term like *creation science* is an oxymoron, because the notion that fully-formed species were placed on Earth by some supernatural force is a religious belief and not part of the scientific paradigm, because it cannot be tested/falsified.

3. **Scientific tests or observations are repeatable.**

4. **Scientific knowledge is tentative and developmental, and hence fallible.** While this statement is true, in an overall sense, it does hide much detail and is consequently potentially misleading. There are different degrees of tentativeness associated with different types of scientific knowledge. We are, for example, rather certain about Boyle's law, that copper is a good conductor of electricity, and that the Earth is round rather than flat, but far less certain about the origins of modern man, that an asteroid caused mass distinction of the dinosaurs, or that there is no life on Mars. I am quite sure that people who travel in aeroplanes, drive over suspension bridges, or take medicines appreciate that some scientific knowledge is quite reliable!

5. **Science is self-correcting.**

Non-distinguishing features:

6. **Scientific progress is characterised by the invention of, and competition among, hypotheses/theories.** Wegener's suggestion that the continents had once been one, and drifted apart, was regarded at the time as almost lunatic. Groups led by Rutherford and Thompson obtained very similar results for the scattering of alpha particles by materials, yet they bitterly disputed the two different models (nuclear and 'plum pudding,' respectively) that they proposed for the structure of

the atom, to the extent that Rutherford accused a colleague of Thomson with having ‘fudged’ data to support Thompson’s model.

7. **Different scientists can observe the same things, and interpret the same experimental data, differently.** There have been countless cases of scientists having either not seen certain things or, based on their expectations, deeming what they did see to be unimportant, leading to the conclusion that observations are theory-laden. Holton’s (cited in Niaz & Rodríguez, 2002) examination of Millikan’s handwritten notebooks revealed that, in preparing the crucial paper, Millikan had discarded the results for 59% of oil drops because they did not support his hypothesis of the elementary charge. Ehrenhaft, on the other hand, obtained very similar experimental results and postulated fractional electronic charges.

8. **Science cannot provide complete answers to all questions/problems.** This is true, but at the same time science does answer many questions very well indeed. Science cannot, though, answer moral, ethical, aesthetic, social, and metaphysical questions, although it may provide some useful insights. It is inappropriate, for example, to ask science to determine whether or not abortion is acceptable.

9. **Science is a social activity, both influencing society and being influenced by people’s values and opinions.** Personalities, funding, social movements, public opinion, the media, politicians, and others drive Science.

10. **Logic, imagination, curiosity, and serendipity contribute to scientific exploration.**

Some Myths

Let us now discuss four myths, four widely held yet incorrect ideas about NOS. These misconceptions are perhaps due to a combination of the way terminology is used by leaders and others in our communities, the lack of NOS content and real science research experiences in teacher education, and the shallow treatment of NOS, the omissions of key aspects of NOS, and the explicit inclusion of faulty ideas about NOS, in school textbooks.

Myth 1: A universal scientific method exists. This myth probably stems from the series of sequential steps, commonly termed the *scientific method*, which appear in many school texts, and may also be reinforced by the standardised format used to present articles in science journals. The steps vary from text to text, but the following are typical: observing, forming a hypothesis, testing the hypothesis, reaching a conclusion/s, and reporting the work.

Rather than working to a standard research plan, scientists use a multiplicity of ways to obtain and organise knowledge, including intuition and chance. Newer texts are adopting the approach of discussing the *methods* of science, rather than any particular scientific method alone, and this will assist in overcoming this myth. At the same time, though, the above steps do appear in the history of most scientific work, even if their order is found to vary.

Myth 2: A hypothesis is an educated guess. The following explains some terms associated with the progress of science (Baxter & Kurtz, 2001; Eastwell, 1996):

Law (or ***rule*** or ***principle***) – a generalised statement which summarises the observed regularities or patterns in nature (e.g. Charles' law and Archimedes' principle).

Hypothesis – a possible explanation for the observed facts and laws (e.g. Bohr's hypothesis).

Theory – an explanation, which has stood the test of time and in which we therefore show much faith (e.g. the kinetic theory of gases and the atomic theory). A theory may be a broad explanation derived from the convergence of many hypotheses.

Model – a mental picture of, or analogy for, the phenomenon, involving a system which is well understood and which appears to behave in a similar manner to the system under consideration (e.g. the particle model of a gas).

Test hypothesis (or ***test theory***) – accomplished by determining whether or not the hypothesis, or theory, is in accord with new experimental evidence. Experiments are purposely designed to test a prediction of a hypothesis or theory. The new experimental evidence is said to either support or refute the hypothesis or theory. If refuted, the hypothesis or theory may be either modified or abandoned completely. A hypothesis or theory can never be proven absolutely correct, because subsequent evidence could always refute it.

Returning to Myth 2, when school students are asked to propose a hypothesis during experimental work, they are really most often being asked for a prediction, which is different. A prediction is an educated guess about the expected outcome of a test and is likely to be factual, and most predictions can be evaluated by observation. Hypotheses, on the other hand, are possible reasons/explanations for the observations, being stated in a manner that makes them amenable to testing and falsification. Virtually all contemporary biological research also incorrectly claims to test hypotheses, when in fact the research describes patterns rather than testing mechanisms underlying the patterns (McPherson, 2001).

Myth 3: Hypotheses become theories, which in turn become laws. A hypothesis might become a theory, but laws and theories are different kinds of knowledge. While laws summarise regularities or patterns in nature, theories attempt to explain these generalities. For example, we have the law of universal gravitation, but presently we do not have a well-accepted theory of gravity.

Myth 4: Science is a solitary pursuit. Contrary to the view commonly portrayed in texts, only rarely does a scientific idea arise in the mind of an individual who then also validates the idea before the scientific community accepts it. Rather, scientists work in teams, and scientific ideas arise from negotiation. Today, 95% of biology research reports are multiauthored, compared with 5% a century ago (Hurd, 2001). The awarding of Nobel prizes to individuals, rather than research teams, may be reinforcing this myth.

Pedagogical Considerations

Contrary to common practice, it is unrealistic to expect students to automatically come to an understanding of NOS simply by being involved in enquiry activities (Abell, Martini, & George, 2001; McComas, 1998). This is like expecting students to come to an understanding of the operation of an internal combustion engine by watching a motor running, or like giving them the pieces to the left-hand side only of a 1000-word jigsaw puzzle and hoping they have enough information to get the whole picture (Osborne, 2000). Rather, there is a need to address NOS explicitly (Moss et al., 2001). This might be achieved by linking aspects of student activities to NOS, by using specific learning experiences which address NOS, and by including in science courses stories or case studies about discoveries, the lives of scientists, and controversies. While there is much literature on the theoretical aspects of NOS, there is relatively little in the way of strategies to facilitate student learning about NOS. Such learning experiences may be found in this, and future issues, of *SER*.

Peter Eastwell

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Demonstrations

Invisible Glue

Needed. A glass bottle (with a relatively long, V-shaped tapered neck), paint (or paper and sticky tape), bottle cork, rasp or file, length of string (cotton, for example, which exerts an appreciable frictional force when rubbed, rather than a more slippery string), and a beaker (or other clear container).

First, we need to construct our apparatus and practice using it. Paint the outside of the bottle to prevent students from seeing inside. Alternatively, wrap paper around the outside of the bottle and tape it in place. Rasp the cork till it is spherical, with a diameter just larger than the inside diameter of the bottle opening. Force the cork into the bottle and allow it to fall to the bottom. The aim is then to suspend the bottle in mid-air using the string only. To do this, hold one end of the string and allow the rest of the string to hang inside the bottle. Tilt the bottle past the horizontal, even upside down, so the spherical cork rolls to the top of the bottle. A gentle tug or two on the string (keep a tension on the string after the final tug) should result in the cork being jammed between the bottle and the string, and you can then turn the bottle right-side up and suspend it in the air by holding the top end of the string only.

Now to the student activity. Have the string outside the bottle and tell students you are going to suspend the bottle in mid-air by holding the string only, and that you will accomplish this by sticking the string to the inside of the bottle using invisible glue. Proceed to dip the string into make-believe invisible glue in the beaker, appearing diligent while students are probably gaining the impression that you have really lost it this time! Then, place the string in the bottle, tilt the bottle while explaining to students that it may take a short period of time for the glue to set, and suspend the bottle from the string. Magic!

Students will be rather curious and doubting of your explanation, and ask them if they have a problem. They are likely to reply that they think it is you who has a problem! Ask them what they think of your explanation and, apart from any student who displays the utmost blind faith in you, it will probably be impossible to find a student who believes you. That being the case, ask students to devise their own hypotheses, their own possible explanations. Invite them to draw a model, a representation of what they think could be inside the bottle. Typical student hypotheses include that there is a hook, magnet, or velcro strip at the bottom of the bottle, or that there is some kind of spring loaded trap-door in the bottle.

Repeat the demonstration, but this time, with the bottle hanging from the string, offer another hypothesis; that you have trained a pet mouse to hold the string, and also to release the string when you tap the bottle three times. Tap the bottle three times and, hey presto, the string comes away freely. What you actually did was to gently press down on the cork with a finger and free it while tapping the bottle with your other hand. Invite students to confirm that your explanation is another hypothesis. Share student hypotheses and, where possible, test them (and your mouse hypothesis) by testing associated predictions. Before showing students what is actually in the bottle, explicitly relate the processes they have experienced with aspects of the nature of science, stressing that scientists typically cannot "look into the bottle."

Tie Water Streams Together

Needed. Water, a sink or other receptacle to catch water, and a plastic softdrink bottle, with three holes about 5 mm apart drilled side-by-side in the side of the bottle near its bottom. (The holes may also be made using a drawing pin, followed by a ball-point pen.)

Exploration. Fill the bottle with water and observe three streams of water running through the holes and into the sink. To "tie" these streams together and make a single stream, use your thumb and forefinger to pinch the three streams together. To separate the streams again, run a finger downwards across the three holes. Invite students to hypothesise; i.e. to propose possible explanations for their observations.

Concept introduction. Where practicable, test the student hypotheses by testing predictions which follow from them. Water is made from water particles, or water **molecules** as they are called. When water particles are brought close to each other, they attract one another and stick together. We say that the particles **cohere**, and call the force of attraction, which holds the particles together, the **force of cohesion** between the particles.

Concept application. Invite students to identify other everyday phenomena that demonstrate this explanation. For example, spilt water forms drops or pools. When you spill water on the floor, say, it doesn't spread out all over the floor. Rather, the water particles stick together and form pools of water. Also, when you turn a shower tap well on, the water comes through the showerhead in many separate streams. As you turn the tap off, the water will slow down and form one single stream.

Hint. Experiment with the amount of water in the bottle, and perhaps even the distance between the holes. The fuller the bottle, for example, the greater the pressure at the bottom and the more difficult it is to tie the streams together.

Student Experiments

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

Science in a Bag

This activity, adapted from Spurlin (1995), works well with students of all ages, as well as with adults, and demonstrates very neatly a number of features of the nature of science (NOS).

Needed. A can of air freshener spray. For each student, a sheet of A4 paper and pencil. For each group of students (4 students, say): A large brown-paper carry bag or similar (it is important that students cannot see through the wall of the bag, so paper lunch bags are too thin), a plastic produce bag as found in supermarkets, four objects of varying shape and size to place in the plastic bag (at least one of these should be fairly small, and none of them should have sharp edges which could tear the plastic bag), and a letter (or fold back) clip.

Prior to students arriving, place the four objects in the plastic bag, fill it with air and tie it, place it in the paper bag, fold the top of the paper bag over and hold it closed with a letter clip (so students cannot see inside), and spray the outside of the paper bag with air freshener. Tell students that today they are going to work like scientists and, holding a bag up, that their task is to work out what is in the paper bag. However, they may not touch the bag.

Place a bag with each group and tell them that the only sense they may use to work out what is in the bag is their sense of smell. Invite students to smell the bag (no touching!), one at a time, and discuss what they think could be inside. Share some of these ideas with the whole class. Ask them to draw a model of their idea, a picture of what they think could be inside. Different students may have different opinions.

Ask students what other senses they have, and list these (hearing, touch, sight, and taste) on the board. Conclude that although scientists might rarely use their sense of taste in experiments, this is not one of those times! Invite students to use their sense of hearing by, in turn, holding the bag at the top (not by the letter clip) and shaking the bag gently near their ear. How many items are in the bag? What size are they? What shape are they? Discuss with other members of the group. Ask for a show of hands of students who have changed their minds in the light of new evidence. Share some new ideas with the whole class, and ask students to draw a revised model. (Students who have not changed their mind should draw the same model again.)

Repeat for their sense of touch, asking students why they are making the inferences they are (i.e. what is their evidence?). Distinguish between an observation and an inference. By this time, students will be very eager to open the bags, to use their sense of sight. Invite them to do so, and after their expressions of surprise and/or delight subside, invite them to draw their fourth model.

Links With NOS. During the activity, or after it, explicitly link what students are about to do, or have done, with features of the nature of science. Ask students what they have discovered about science, and about the way scientists work. Point out that scientists not only use their senses to collect data, but also extensions of them such as microscopes and telescopes. Scientists construct models, and revise them in the light of new data (e.g. changes in our view of a flat earth, or our understanding of the solar system as a result of the Voyager missions). Tell students that you sprayed the paper bag to provide them with misleading information, ask them how what they initially smelled influenced them, and explain that scientists sometimes also have difficulty in ‘letting go’ of incorrect ideas, or use small pieces of information in incorrect ways.

Ask students to describe their feelings during the activity, and descriptors like curious and sceptical may arise. Ask who felt they improved their ideas as a result of cooperative work; discussing their ideas with others and learning from what others had to say. Ask who felt a need to be honest about their observations and drawings. Link these feelings and characteristics with the way scientists work, and with what is expected of scientists. Perhaps conclude by reminding students that they have been working like scientists, and ask them if they can do science. The response is invariably an overwhelming “We certainly can!”

Reference

Spurlin, Q. (1995). Put science in a bag. *Science and Children*, *32*(4), 19-21.

Upset Stomach

Needed. A small empty softdrink bottle, measuring cylinder or similar, funnel, tablespoon, sodium bicarbonate (baking soda), balloon, vinegar, and safety glasses.

Measure 50 mL of vinegar and pour it into the empty bottle. Stretch the open end of the balloon over the end of the funnel and use the funnel to add one heaped tablespoon of sodium bicarbonate to the balloon. Remove the balloon from the funnel, and stretch the opening of the balloon over the mouth of the bottle without allowing any sodium bicarbonate in the balloon to fall into the bottle. Hold the opening of the balloon firmly in place around the top of the bottle while you use your other hand to lift the balloon so that the sodium bicarbonate falls into the bottle. Observe.

What happened? Did the balloon expand? Remove the balloon from the bottle and wash out the bottle.

Explanation. When vinegar, which is an acid, is mixed with sodium bicarbonate, carbon dioxide gas is produced and fills the balloon. A similar thing happens when you make a fizzy drink. The powders you use contain an acid like citric acid and, when added to water, they also produce carbon dioxide gas bubbles. This causes the drink to fizz.

We can now understand how a fizzy drink can relieve an upset stomach. Food contains air and, if you eat too much or too quickly, the air can get trapped in your stomach and give you a full feeling. When you drink a fizzy drink, the carbon dioxide gas fills your stomach even more and pushes out the trapped air. This is why you often burp after a fizzy drink and feel much better for it. Carbon dioxide is also the gas used in the manufacture of softdrinks, causing a softdrink to bubble and fizz when the bottle is opened.

Poetry: Adding Passion to the Science Curriculum

Introduction

This article considers some potential benefits of providing poetic learning experiences within a science curriculum, and provides practical classroom techniques and resources to support the strategy. Allow me to begin by sharing two poems recently written by students.

"It's Change . . ."

Mum I don't want to go to school today,
'cause I fear our world is in decay.

I feel my teachers are part of the plot,
I'm the only one who sees through the rot.

Scientists are cloning pigs and sheep,
Saying, it's change – a quantum leap.

Biologists are making stem cells grow,
Saying, it's change – the way to go.

Geologists are finding cracks in our earth,
Saying, it's change – predicting it's birth.

Archaeologists are digging up fossils and bones,
Saying, it's change – time for clones.

Yes, scientists *are* causing me great concern,
Giving us kids too much to learn!!!

Emma Gorrie, Year 8
St. John's College, Dubbo
New South Wales, Australia

I Want to be a Scientist

I want to be a scientist
I want to own a lab
I want to be a specialist
You might think I'm mad
I want to use a laser beam
I want to win awards
I want to measure gravity
And study different laws
I don't want to be a circus clown
I don't want to be a nurse
I don't want to be an undertaker
And drive around in a hearse
I don't want to be a fireman
And battle fires all day

I want to be a scientist
A scientist of today!

Adele O'Driscoll, Year 6
St. Peter's School, Rockhampton
Queensland, Australia

Reasons for Using Poetry

Science poems can be meaningful, profound, and critical, or frolicsome, amusing, and diversionary, and may be further categorised as emphasing observation, imagination, or emotion (Watts, 2001). Reading or hearing quality poetry can enliven traditional science content and extend learning. A common response to good poetry is: "I never thought of it in that way."

Poetry can also enhance students' understanding of scientific developments and the role of scientists. Abisdris and Casuga (2001), for example, use the poetry of Robert Frost in a unit on atomic structure. They define symbolism, metaphor, and analogy for their students, point out how these are also important parts of science, and give examples of each from science, literature, and everyday life.

There are at least three further good reasons for making provision for at least some students to write science poetry. First, Gardner (1983) suggested that we have at least seven different intelligences, where intelligence means the ability to solve problems or create products of value within a cultural setting: linguistic, logical-mathematical, visual-spatial, musical, bodily-kinesthetic, interpersonal or "social," and intrapersonal or intuitive. He has recently added a naturalistic intelligence, and is working on a spiritual intelligence. Future successful adults will need to be resourceful and flexible, and use many of these different ways of being intelligent, or smart. For example, one can combine science with drama and music to create, in an audience, an increased awareness of how scientific discoveries are affecting, or may affect, our lives.

Second, poetry can help us to be creative. When one writes poetry, the whole brain is needed; both the left side (e.g. language and logic) and the right side (e.g. visualisation and creativity). Many employers, for example, are looking for people who can be creative by using their whole brain. We want scientists to be creative problem solvers, and exceptional scientists are those who look at the same things everyone else looks at but see something different. Third, like music, the rhyme and rhythm of poetry can help us remember things.

Much traditional science education has been found to alienate students (Eastwell, 2002). The affective domain is important in education, because feelings and emotions shape attitudes, tastes, moods, and motivations for learning. Re-humanising school science may have a positive impact in the affective domain (Taber & Watts, 1996; Watts & Bentley, 1983), and the use of science poetry could be one vehicle for achieving this. For at least some students, poetry may foster a sense of wonder, enthusiasm, and interest in science.

Strategies and Resources

One needs to avoid selecting poems that are beyond the developmental level of the students, such that the meaning must be laboriously explicated for them. This may not only turn students off science, but also promote a resistance to reading and writing poetry. Randle (2001) has recently authored an excellent collection of poems, including six science poems, for primary students. At http://www.gwjudge.eurobell.co.uk one will find many original poems about geology, fossils, oceanography, mathematics, nature, and physics. Watts (2000) contains a collection of science poems submitted by students and teachers, together with descriptions and discussions of the use of poetry in science classrooms. This author (the Editor of *SER*) would be pleased to receive recommendations for sources of quality science poetry, as the subsequent publication of these sources will create another useful teacher resource.

The teacher might read a poem to students, or students might read silently or to others in pairs and then to a larger group, or a choral format could be used. Choral reading can include *line-at-a-time* (individual or small group speak a line or two, and alternate with another individual or group), *antiphonal* (two groups, each formed on the basis of same sex or similar pitch of voice, alternate in speaking a piece), *refrain* (one student speaks most lines, with a group chiming in at the refrain), and *unison* (whole group speaks all lines together).

When it comes to encouraging students to write poetry, Cecil and Lauritzen (1994) suggest an eight-step plan: 1. Provide a literary scaffold, or framework. This might include imitating an existing poem, beginning each line with “I dream . . .” or “I wish . . . ,” or using each line to describe different feelings about a particular colour, perhaps using each of our five senses. 2. Read a poem that uses this scaffold. 3. Use the scaffold to write a group poem. 4. Celebrate the product. 5. Invite students to write their own poem, using this scaffold or one of their own choosing. 6. Revise, after peer review. 7. Edit, following a conference with the teacher. 8. Share the finished poem with various appreciative audiences, and perhaps even collate the class poems into a book.

Randle (2001) provides guidance and advice for primary students in writing couplets, parodies, limericks, narratives, acrostics, haiku, and shape “poems,” and includes a section on poetic language, although she does advise against novice writers attempting acrostics and haiku. At the high school and adult level, Randle

(1998) gives step-wise guidance for writing poetry, together with advice for performing poetry, including entering competitions. Listening to poems that have been composed by other children their own age can inspire and reassure students as to their ability to read, write, and understand poetry, and such science poems will be a regular feature of *SER*.

Writing poems could form optional, or compulsory, parts of a science curriculum. For example, demonstrating understanding in poetic form could be an assignment option for particular tasks during the year. For another task, such as summarising laboratory rules, all students might be asked to compose a poem. Writing science poetry could also be a task for some students during an enrichment program.

Students may enter their compositions in *The International School Science Poetry Competition* (http://www.ScienceEducationReview.com/poetcomp.html), which also has divisions for the *New South Wales* and *Queensland Science Poetry Competitions* (Australia), or another competition. Selected entries in the above-mentioned competitions are published in *The Science Education Review*, and the poems in this article are such entries.

Conclusion

Science is one of various ways of knowing, including the aesthetic mode of knowing. Using poetry in science education can be an aesthetic experience, stimulating students' observation, imagination, and emotion. As such, this strategy may make just one small contribution to the efforts of science educators aiming to ensure that the study of school science proves to be a fulfilling experience for, ideally, all students.

Peter Eastwell

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Randle, C. (2001). *I Need a Poem, Mum*. Preston, Queensland: Author. (Available directly from Carmel Randle, M/S 852, Preston, Queensland 4352 Australia)

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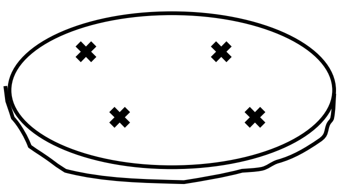
Students’ Alternative Conceptions

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.

When eliciting prior conceptions, it is critical that students realise that misconceptions are perfectly normal and are to be expected, and that they should not be concerned about “giving the wrong answer.” To the contrary, the expression of misconceptions is a great aid to subsequent meaningful learning. One technique for quickly surveying a class response to a task, while ensuring that student responses are, for the most part, anonymous, is to have nearby students exchange answers randomly before asking for a show of hands for each option.

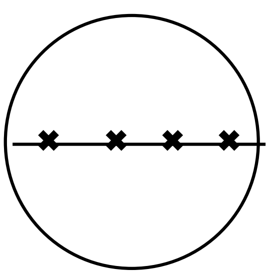
1. Which of these shows your idea of four people standing at different places around the whole world? (You may choose more than one.)

a.



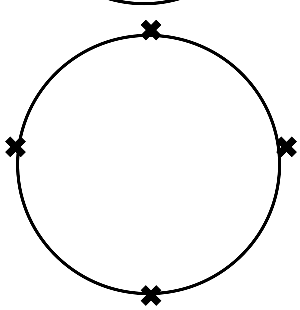
The Earth is like a giant pancake.

b.



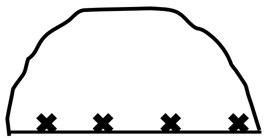
People stand on a flat part inside a ball.

c.



People stand on the outside of a ball.

d.  The Earth is flat.

e.  People stand on flat ground under a curved sky.

f. I have a better idea. (Please draw your idea.)

Comment. Choice C is the scientifically acceptable idea.

2. When does life begin in a living thing, like a human being? (You may choose more than one answer.)

    a. At fertilization/conception.
    b. Sometime before birth, but not sure exactly when.
    c. At birth.
    d. When he begins breathing after birth.
    e. When she feeds or drinks after birth.
    f. In the womb as the mother feeds.
    g. After all limbs have formed.
    h. Don't know.
    i. Other (Please write your idea).

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 either of the above tasks.

Catering for Individual Student Needs: Learning Styles

(Part 1)

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In the last issue of *SER*, we identified some individual differences that are likely to exist between students: different prior thoughts and experiences, different talents, different learning, working, and thinking styles, and different temperaments. We also began a consideration of ways to cater for these differences by surveying some strategies for eliciting students' existing ideas. In this issue, we continue the theme of catering for individual student differences by presenting the first of a two-part series addressing learning styles.

The articles in this series are written by international presenter, Margaret Underwood. Margaret has trained in whole brained, or integrated, learning with Dr. Noah Gordon and with Professors Ken and Rita Dunn at the Learning Styles Institute in New York, to where she has returned on several occasions to maintain her training with the Dunn and Dunn Learning Styles Model. Margaret has developed an intensive 3-day workshop on this model and works full-time in this area with teachers and schools in Australia, New Zealand, the United Kingdom, and the USA. Over to you, Margaret.

Introduction

This article is written from my experiences over the past 10 years of sharing information about the Dunn and Dunn Learning Styles Model with teachers, students, and parents in many countries. I am a teacher; not a writer or academic. If you need an academic approach, please refer to the bibliography at the end of this series of articles. The very best people to read on learning styles are Dr Barbara Given and, of course, Rita and Ken Dunn themselves, especially if you want more specific information about their model.

As a former classroom teacher I asked myself what I would want to know about learning styles if I were to be presented with this information for the very first time. I have responded with six key questions:

1. What is learning style?
2. What background and general research information is available to assure me that learning styles:
    a) is well researched and b) works?
3. How does one implement it?
4. What may happen if it is used?
5. What do I need by way of training, resources, etc. to be able to use learning style strategies?
6. What sort of problems might arise, and how can I deal with them?

In this article, I will do my best to address points 1, 2, 4, and 5. I offer a 3-day (24 hours) workshop that addresses points 3 and 6, as well as the above points in much more detail.

What is Learning Style?

Learning style is about how each individual learns. A simple definition from Dr Rita Dunn is: “Learning Style is the way in which each learner begins to concentrate on, process, use, and retain new and difficult information. That interaction is different for everyone. No learning style is better or worse than any other. Each style encompasses similar intelligence ranges.” Dr Ken Dunn says: “If children don’t learn the way we teach them, we must teach them the way they learn.” This is the crux of learning styles. Learning style is teaching children in the way they best learn, not expecting them all to learn in the same way, at the same time, at the same age. We are all unique and different.

The concept of students having an individual learning style has been around since 1894. Many people have researched how people learn and have all come to the same conclusion; that every individual has a unique way of learning. Many models have developed from this research. I have chosen to work with the Dunn and Dunn model because I have found it to be the most comprehensive and widely researched of all the models. The model can be represented as five strands relating to the environment and the emotional, sociological, physiological, and psychological needs of an individual.

Extensive research, as well as feedback from the many teachers with whom I have worked, has demonstrated conclusively to me that this model works. Drs Ken and Rita Dunn began developing their model in 1970 and over the past 32 years they have developed and expanded the model through extensive research in the field to include 21 elements that may affect an individual’s learning. It is, to date, the most widely researched learning style model worldwide.

Every piece of research on the Dunn & Dunn model has shown consistently that when the model is implemented correctly, and students are taught according to their individual learning style, their academic achievement increases, as does their attitude towards school, themselves, and others and their self-esteem, discipline, and outlook towards the future. Even correctly introducing one or two elements of the model into a learning environment will have a beneficial effect on the individuals affected by those elements.

As an example of the outcomes that can be achieved, Dr Ross Cooper, in a pilot study with college students at City and Islington College, UK, found students who would previously have been counselled off the Intermediate GNVQ course in Health and Social Care were able to achieve merit by being taught through, and understanding, their learning style. Dr Cooper’s conclusion was that the least successful students were those who lacked awareness of their own learning style, *whatever* it was.

One of the most powerful pieces of feedback I consistently get from teachers who have implemented a learning styles approach in their classrooms is that they would never go back to the way they taught before they learned about, and implemented, a learning style approach; a result of the changes they have seen in both their students and themselves. I have even heard this from teachers who have openly admitted that they found it hard to make the transition to giving children more control over their learning, and who believed that it couldn't work but gave it a go following the urging of principals or fellow teachers. I have also had this feedback from many teachers who were already excelling in the classroom and who were well respected in their communities and schools.

Learning styles has brought children running to classrooms, instead of away from them. It has turned children who viewed teachers as enemies into avid learners who now see their teachers as allies in the learning process. I have seen children's faces light up when they found they could learn easily. And I personally know of many children either at university, or planning to attend university who, prior to learning styles, had never thought that could be possible. Let's consider the five strands of the Dunn and Dunn Individual Learning Styles Model shown in Figure 1, and the 21 elements which comprise them.

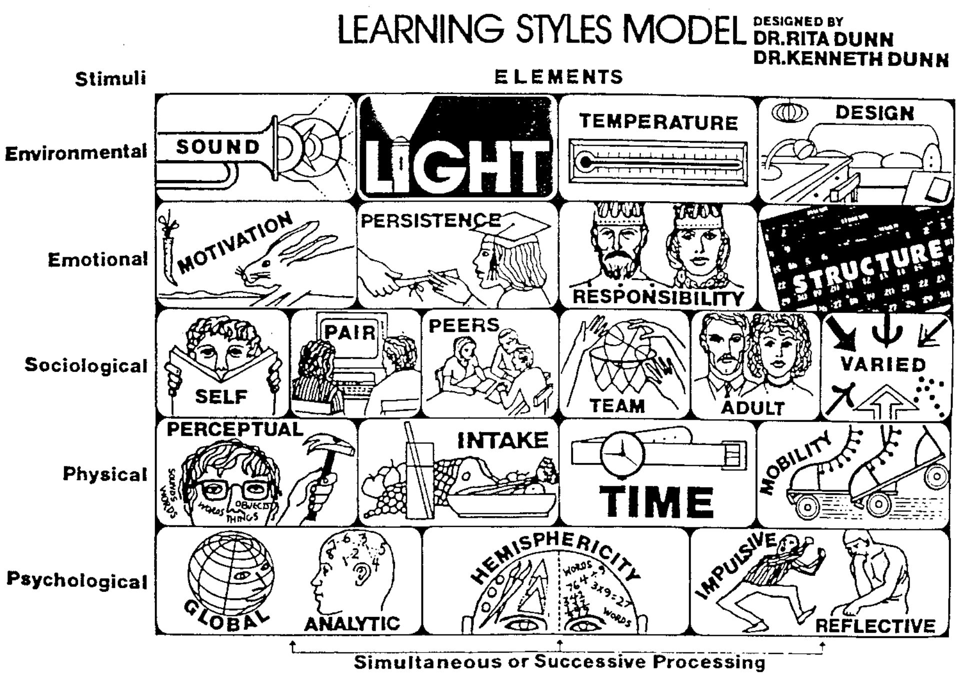

Figure 1. The elements of the Dunn and Dunn Individual Learning Styles Model.

Environmental Strand

Sound. Do you like to listen to music or have some background noise when learning, or do you require silence? Traditionally, we believe that silence is needed for learning to happen, but this applies to some students only. Many children need sound. It appears sound may help to activate the brain; especially the right hemisphere. If you don't provide it, students will. These are the children who hum, tap, sing, and talk, and when you tell them to stop it, they look at you in bewilderment and ask: "Stop what?" Many teachers I have worked with have extolled the value of music in the classroom in terms of helping students to better concentrate and in lowering overall noise levels. Students who need silence have benefited enormously from the use of earplugs.

Light. Unfortunately we have a belief that bright light is necessary for good eyesight. This is not so. We all have different light needs and, generally speaking, the younger we are the less light we need, because of the nature of the lens on the eye. Most of our classrooms are lit for the adults in them and not for the children doing the learning. Many schools I have worked with have saved a lot of money by turning off the lights, while at the same time improving classroom behaviour and learning. The research is also very clear on this; if you meet student's individual light needs you will see improvements in reading, learning, and test results, as well as behaviour.

Temperature. What temperature needs do you have when it comes to learning? We often dress children according to our own temperature needs. We need to be sure that those who need warmth can have it, and that those who need cooler places to learn in can also have those. And if you are teaching in a cooler climate, please do air your classrooms out regularly. The brain consumes 20 to 25% of the oxygen we breathe; we need fresh air to be able to think clearly.

Design. The design element is the final one in the environmental strand. It refers to the fact that for some of us a hard seat is fine for learning, but for many students (40 to 50% in high schools) softer, more comfortable seating is required. As someone once said, the brain cannot absorb more than the bottom can endure. So we need more cushions, bean bags, sofas, and comfortable chairs in our classrooms. Another advantage of this is that classrooms start to look more like home for some students, and that makes it easier for them to relax and learn.

Implementing elements of the environmental strand can be a challenge, in terms of appearance, to the traditional classroom. It is not as hard to cater to all the different combinations of needs as one may first think. The payoff is students who enjoy being in school, who look forward to going to school, and who demonstrate improved outcomes. However, please do not try to do this without some prior training. We need to be very careful about how we implement learning styles in the classroom;

otherwise chaos may be the result. Rita and Tom Dunn recommend gradual implementation over a 3-year period. The schools I have worked with in New Zealand have found this to be a reasonable time period. Teachers, parents, and students all need to understand what catering to different learning styles involves before full implementation is possible. From my experience, the best way to implement change is slowly and gradually, and learning styles is no exception to that.

Emotional Strand

Motivation. The emotional strand looks at motivation. Who motivates the person? Adults (teacher or parent) in the case of a child, an authority figure in the case of adults, or peers? Or is he self motivated? Who motivates is one side to motivation, but there is another. We know that there are two things that are excellent motivators of human beings; success and recognition. I think this is one of the reasons for learning styles powerful effect on learners. Because learning styles is something you do *with* students rather than *to* them, learners are actively involved in the process of implementing and using a learning styles approach in the classroom.

In this process each child is recognised and acknowledged as a different and unique individual. Using this information, each child is then helped to learn in ways that are easy for them, that cater to their learning strengths as opposed to hammering away at their weaknesses (which we have done for far too long in many situations). As a result, learning becomes easy. Students understand how they learn, and they learn how to work with, and through, those strengths. As the learning becomes easy, it becomes enjoyable to be in school, and learning and the associated success makes them even more motivated. All the research, and certainly all the anecdotal stories I have heard, affirm that using learning styles increases students' motivation in the classroom and in completing homework. School becomes a place where they want to be. We all like to do things at which we are successful. I think one of our responsibilities as teachers is to create successful experiences for our students so they know they *can* learn, rather than teaching them that learning is difficult, frustrating, hard work and, worst of all, something they *can't* do.

Persistence. Are you someone who likes to do one thing at a time, finish it, and then move on to the next thing? If you do, I bet you find school bells and designated periods hard to deal with. Or, are you like me? You can't do one thing at a time and instead need to multitask, shifting from activity to activity until everything gets done. Having grown up in a large family of highly persistent people, I spent 32 years trying to do it their way. When I finally found out that being low in persistence was OK, I found I got so much more done simply by honouring my needs and setting up a number of work stations which I could move between while working or studying.

Responsibility. Responsibility is the next element. This refers to whether you are a conformist and like to do as you are asked or told to, or whether you are a non-conformist and simply don't like to do things you are told to do. Non-conformists cause many problems in classrooms because they dislike being told what to do and react negatively to an authoritative tone of voice. They like to have a choice and feel they have some control over their lives. Sometimes that choice could be as simple as: "Would you like to do this on the floor or at a table?" "A red pen or a blue one?" "Would you like to do the beans or the potatoes for dinner?" Or, in the classroom, enlarging the number of questions in an assignment and then giving the instruction: "You may answer as many questions as you like, but everyone must answer questions 2, 4, and 5." Most importantly, NEVER use an authoritative tone with a non-conformist . . . unless you want to alienate them.

Structure. Finally, there is the structure element. Students with a high need for structure need very specific guidance on how to do things. If you don't provide it, they will hound you until you do! "Should I underline this in red or blue?", "How many pages should I write?", "Do I need to do a cover page?" etc. One high school science teacher told me he calculated he saved about 20 minutes of each 60 minute lesson after learning about students' need for structure. He provided it up front for those who needed it, and that was that. Of course, there are also the students who don't need structure and who prefer to do it their own way. We need to respect their needs also. And, we can move students away from that need for structure gradually over time. We must start, though, by meeting the need. This has to do with the student feeling safe, and people who do not feel safe do not learn.

Sociological Strand

The sociological strand looks at with whom we like to learn. Were you aware that around 13% of students like to learn on their own? In fact, Rita and Ken Dunn claim these students can learn between 2 to 7 years of the curriculum in 1 year if you teach them how to teach themselves, and let them loose to do it. Other students like to learn with a friend beside them, and yet others need to learn in a small group. Some prefer team learning situations, where everyone contributes to a project. There are also students who need an adult present. Some like that adult to be a teacher (about 28%), while others want someone else. Some 28% of students like to learn with their peers, and they don't like having a teacher present.

This certainly adds to the challenge of how to teach them, but allow me to assure you that there are ways of ensuring they can not only learn, but also enjoy it. And then there are the students who need variety, students who like to do things differently each time! These students have their own gifts, gifts which are often unrecognised in the traditional classroom. Students with a preference against variety find change difficult to cope with, and this is another reason for taking things slowly while implementing learning styles.

Continued next issue

Teaching Techniques

Round Robin

As mentioned in conjunction with ways of determining students' alternative conceptions in the last issue, the Round Robin is an alternative to whole-class brainstorming that better engages more students. There are two versions: quiet and noisy.

In the Quiet Round Robin, students form groups of, say, 3 or 4 students each. Ask all students the same question or give them the same task, and invite them to respond individually in writing on a sheet of paper. No talking! After 30 s, or a minute or two, ask students to stop work and to pass their paper to the person one position clockwise, say, around their group. Each student then reads what is on the new sheet they have received before adding further responses as before. They are not allowed to repeat anything that has already been written on either of the sheets they have seen.

Repeat this process until each student receives their original sheet back. Each group should then discuss the responses and compile a brief group report for sharing with the whole class. This report might contain what students consider to be the best three or four ideas from the group, and might even be done on an overhead transparency.

The Noisy Round Robin follows a similar pattern, except that each group has one sheet of paper only. In conjunction with group discussion, the group scribe writes responses on the sheet before it is passed on. When each group receives a new sheet, one person in the group needs to read the responses written on it to the whole group. Both the Quiet and Noisy Round Robin can facilitate the energetic generation of many ideas rather quickly.

Hot Potato

The Hot Potato technique is similar to the Noisy Round Robin, except that each group has a different question or task, each of which represents a subtopic of the issue being considered. The question or task needs to be written at the top of the sheet of paper or the overhead transparency (the hot potato) and, when passed on, each group receives a different problem to consider. One person in the group reads the question or task, perhaps someone else reads the responses on the sheet, and perhaps yet another group member adds further responses which come from the ensuing discussion.

Dirty Tricks

It is not uncommon for students to supply a written response to a question which does not answer what was being asked. This example of a dirty trick provides a stimulus for discussing this situation. Provide students with some resource material and then a series of questions to be answered from it, but questions which cannot all be answered using those resources alone. Invite students to initially answer those questions they feel confident responding to, note how long it takes for some students at least to realise that insufficient information has been supplied to answer some questions, and notice how many students have copied out irrelevant information in response to those questions.

Another example is to discuss the aim and procedure of a practical task with students, and to provide them with additional, unnecessary equipment, such as a bunsen burner, tripod, and mat. After a little while, ask the whole class about the burners that perhaps some students have set up and reveal your purpose; to demonstrate that students should not accept what they are given uncritically.

Tricks like these should be used only once, or perhaps twice, a year with a particular class. Also, ensure that the follow-up discussion to a dirty trick is constructive and supportive.

Ideas in Brief

PLTL: A New Teaching Model

We are seeing a move towards facilitating more active student learning at all levels of education, and a common means to achieve this is to make greater use of cooperative learning. While Cracolice and Deming (2001) agree that this is a step in the right direction, they have some reservations about traditional cooperative learning; namely, that students do not function as a team, and that they lack necessary guidance. These authors believe that Peer-Led Team Learning (PLTL) is an even better choice, describing it as “cooperative learning that *really works*” (p. 24). Let us describe the PLTL model, note some challenges associated with implementing it, and consider some of its strengths.

Each group, or team, comprises 4 – 6 students, plus a peer leader. The groups meet regularly (45-60 minutes each time, about once every 2 weeks), during which time they use materials provided by the teacher to solve problems and reinforce concepts. The teacher does not interact with students during these group workshops. Peer leaders are students who have recently completed the course with a relatively high level of achievement (usually an A or B grade), who show leadership potential, and who have strong interpersonal skills. During the workshops, peer leaders facilitate discussion, prompt students toward solutions to problems, and help students to examine their thinking processes. The workshops need to be an integral part of the course, and students remain in the same team for the entire year.

PLTL has been used in colleges and universities, including 30 chemistry classes, for more than 5 years. More recently, it was introduced at Big Sky High School, Missoula, Montana, where an initially apprehensive teacher concluded that “he could not believe how effective this method was at encouraging active learning and keeping students interested” (Cracolice & Deming, 2001, p. 22). For successful implementation, it is critical that the program enjoys the support of the school community.

With the implementation of PLTL comes at least three challenges. First, there is the need to find peer leaders, and rigid timetabling in high schools can make this difficult. A teacher can work cooperatively with other science teachers to allow peer leaders to be released from other classes, and this works well if service as a team leader is a formal part of the more advanced course. For senior high school courses, nearby college students or students in teacher preparation programs are suitable leaders.

Second, the peer leaders need to be trained. At a minimum, this should involve general training prior to the first workshop, and content-specific training before each workshop. While the majority of training time usually focuses on content knowledge, training might also include pedagogical content knowledge (i.e. content-specific teaching strategies), questioning techniques, the provision of focus questions, consideration of the types of questions to expect from students and how to respond to them, how to be an effective leader, group dynamics, and tools for group work, such as Round Robin and paired problem solving.

Third, the teacher needs to select and/or prepare materials suitable for group work. He might use questions from textbooks, teacher’s guides, and commercial worksheets. At the secondary level, Cracolice and Deming (2001) prefer to write materials using a learning cycle format (e.g. introduction of real or hypothetical data, search for a pattern, introduce terminology, and further examples to consolidate understanding).

PLTL challenges students to take responsibility for their own learning. It is an ideal strategy for encouraging the intellectual growth of students, because they feel much more comfortable about sharing their ideas, including their misconceptions, in an environment where the teacher, who will also be grading them, is not present. In addition, gains have been observed for peer leaders in terms of enhanced knowledge and understanding, leadership abilities, and attitudes.

Reference

Cracolice, M. S., & Deming, J. C. (2001). Peer-led team learning. *The Science Teacher*, *68*(1), 20-24.

Testing, and More Testing

During the past 10 years or so the United States, there has been an increasing emphasis on accountability in education. Testing, being viewed as a relatively inexpensive and simple measurement of students' achievement of outcomes, is also often viewed as a way to measure academic accountability. Moore (2001) suggests that this business/industrial approach to education has contributed to an over-emphasis on testing and test-taking ability, with students being far too concerned about academic results, college/university graduation, and getting a job at the expense of experiencing the satisfaction which comes from learning for its own sake. Some students have in fact learned how to do chemistry tests without understanding the course material.

However, while the results of single, specific tests are useful, they are limited for the purpose of determining whether a student has successfully developed an understanding of chemistry. Moore (2001) reminds us of those students who found test-taking difficult yet excelled in science fairs or the research laboratory.

Reference

Moore, J. W. (2001). Testing, testing. *Journal of Chemical Education*, *78*, 855.

Great Lessons

Included among the lessons Patricia Blanton (2001) learned from the master physics educator Arnold Arons are the need to recognise gaps in students' prerequisite knowledge, to ensure students are actively engaged in their learning, to develop concepts before assigning labels, to take much care with teacher language, and to cater for students' multiple intelligences and different learning styles.

Reference

Blanton, P. (2001). Lessons learned from Arnold Arons. *The Physics Teacher*, *39*, 506-507.

Using a Timeline

Historical notes, such as who did what and when, are commonly included in lessons and texts. However, much is lost when such information is presented without putting it into an historical perspective. Folino (2001), for example, relates how research about the development of the periodic table made its significance more meaningful and led her to give greater credit to its discovery. Traditional chemistry classes had never made her aware that the developments discussed at the Chemical Conference meeting in Karlsruhe in 1860 took place about the same time that the United States was heading toward civil war, and that the exclusion of American scientists from the meeting was due to their relative isolation from Europe, with both correspondence and travel requiring lengthy times.

Ornstein (2002) has addressed this need by requiring her students to maintain a timeline. They keep a file of individuals and their contributions, and research their nationalities and where they lived (although this research could easily be extended). The timeline in each student’s book covers five pages; one page for each century, and four lines that each cover 25 years. The timelines are collected and graded every quarter. Students learn who lived concurrently, how science has changed through time, and that science and history are interrelated.

References

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Ornstein, A. (2002). Teaching history with a timeline. *The Science Teacher*, *69*(3), 69-70.

Democracy in the Science Classroom

Motivated by the desirability of preparing students to function in a democratic society by modelling democracy in our schools, Eick (2001) decided to make his middle school Earth Science classes more democratic. He wanted to create an environment in which decisions about classroom functioning (e.g. policy, rules, and consequences), and about what was to be studied, were seen as being determined by students and teacher together, and not by the teacher alone.

To address classroom functioning, he prepared a list of committees and asked that, in each class, each student choose one on which to serve. The committees comprised assessment methods, guidelines for make-up and late work, reward system, components of a “good” science class, homework criteria, student interaction and safety guidelines, and student justice policy. Each committee was given a task, and asked to draft an associated policy statement. For example, the homework criteria committee was asked to develop guidelines for meaningful homework, frequency, etc., and they responded by suggesting things which included no homework over weekends or during holidays, no tests on a Monday, and no meaningless worksheets and word searches. These policy statements were presented to the whole class for discussion and refinement. The teacher then synthesised the policy statements from each class into a draft document for all classes, before presenting, discussing, and modifying the draft with each class. “I truly felt that we were producing a final document together” (Eick, 2001, p. 29).

When it came to what was to be taught, Eick (2001), like most teachers, needed to address mandated objectives, and he was honest with students in sharing this obstacle. However, he did not use it to ignore the opinions and interests of students, and proceeded to seek these by asking students to work in teams and brainstorm topics of interest that related to the three sub-sections of the Earth Science course; Earth, space, and the environment. He compiled the suggestions from all classes, asked students to vote for those topics they would like to study, and rank-ordered the topics. In the first year of implementation, aliens, local water issues (Adopt-A-Stream), dissection, rocketry, stars, constellations, and black holes, and weather and the Internet occupied the top 6 of 37 positions, with air pollution issues (ozone, greenhouse), plant and soil studies, atoms, smog (air quality issues), erosion studies, and overpopulation issues filling the bottom 6 positions.

He discussed the ballot results with each class, saying that he would weave the topics which had been ranked in the top two thirds of the list into his mandated course objectives. He also told students that there were a few other topics which he was required to teach which could not be integrated with their list of interests, and students seemed to accept that it was reasonable for the teacher to also get some choice. A syllabus was then written and refined via discussions with students. Eick’s (2001) third democratic syllabus is available at http://www.nsta.org/middleschool .

Upon reflection, student behaviour was not brilliant during the first year of the democratic syllabus, but their motivation and achievement was higher than he had observed for students during his previous years of teaching. The democratic framework facilitated student accountability. There was a sense of student ownership of their academic achievement and behaviour. Eick’s (2001) enquiry approaches to teaching and learning flourished within student choices, and he came to truly begin to understand the meaning of student-generated questions and research projects in the *National Science Education Standards* (National Research Council, 1996).

It was not easy for him to relinquish the traditional degree of control and decision-making, not all teachers are ready to do so, and some work environments are too prescriptive to be conducive to enquiry learning. However, rather than lacking structure and promoting chaos, Eick (2001) reminds us that structure is in fact necessary for successful enquiry practices.

References

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National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

Science Education Needs to be Modernised

Many changes in both the nature and practice of science during the past century have made the career-oriented science curricula found in school textbooks outmoded (Hurd, 2002), and he draws the analogy of the difference between the education needs of medical researchers and medical practitioners. The traditional disciplines of biology, chemistry, earth science, and physics have become split into hundreds of research fields. Biology, for example, comprises more than 400 named fields, each with distinctive features and research methods, and there are probably more than 1000 unnamed fields.

Increasingly, research is being conducted by teams of 6-8 persons having expertise in different fields. This leads to an increased fertility in ideas for solving problems, and to multi-authored papers. In addition, science research continues to become more transdisciplinary, involving both the natural and social sciences and requiring new modes of scientific enquiry. Bioinformatics and biotechnology, for example, are absorbing more and more of the physical sciences, and science has become much more socially oriented, as witnessed by the debates about DNA fingerprinting and cloning animals.

The history of science education reform has been one of simply updating traditional subject matter, and this is inadequate for the present times. Hurd (2002) suggests the need for a new perspective on general science education. It should involve a lived curriculum, be student-centered, stress learning how to learn, be up-to-date on the nature of science technology, be focussed on the utilisation of science technology for the welfare of the public and the benefit of humans, and connect instruction to the new information highway.

Reference

Hurd, P. D. (2002). Modernizing science education. *Journal of Research in Science Teaching*, *39*, 3-9.

Pressure to Teach the Test?

Accountability is a good idea. However, measuring it by measuring the academic outcomes of students, especially using single tests, is fraught with danger (Moore, 2001). Highly effective teachers can make an enormous positive impact on the learning of educationally disadvantaged students, yet these students may still not achieve as highly as other students with a richer intellectual background. In any case, obtaining an accurate measure of students' outcomes is not easy, and the results of any single test are certainly inadequate.

In many states of the United States, high-stakes decisions are based on the results of a single test, and "teaching the test is almost a requirement" (Moore, 2001, p. 991). In Texas, for example, students are taking as many as five practice Texas Assessment of Academic Skills (TAAS) tests, some schools offer remedial TAAS courses, and textbooks and web sites offer coaching material. In New York, a school's ranking is determined by the results on tests in the fourth grade and, as one teacher said: "The test-prep books have basically become our curriculum" (Goodnough, cited in Moore, 2001). Some tenured teachers are avoiding this pressure by choosing to teach other grades.

Moore (2001) acknowledges the value of tests, including those prepared by persons other than the classroom teacher. However, too much of a good thing can be harmful.

Reference

Moore, J. W. (2001). Testing the teacher? Or teaching the test? *Journal of Chemical Education*, *78*, 991.

Introducing Cooperative Learning: Using A Quiz

The benefits to students of cooperative learning, in both the cognitive and affective domains, are well documented (Lord, 2001; Johnson & Johnson, 1989; Slavin, 1991), and Lazarowitz and Hertz-Lazarowitz (1998) in fact recommend that we aim to use cooperative learning for at least 30% of classroom time. However, cooperative learning, in contrast to simply group work, is not easy to implement. It can certainly require more planning than alternatives such as lecturing and, especially during the early stages, associated frustrations can tempt one to question whether all the effort is worthwhile. As Jensen, Moore, and Hatch (2002) have found, though, cooperative quizzes are a great place to start.

What is cooperative learning? While there are different approaches, I have found that of Johnson and Johnson (1997) to be very effective. The following five basic elements are essential and must be included.

1. **Face-to-face interaction.** The physical arrangement must allow discussion between students, so think circular instead of straight lines.

2. **Positive interdependence.** The overall task must encourage/require all students in each group to contribute, with each student needing to be concerned for the learning of others in the group. This might be achieved by assigning a group

grade (students “sink” or “swim” together) or by assigning roles and dividing labour.

3. **Individual accountability.** Different students have different abilities and achievement levels, and each student needs to be responsible for their own learning. We need to avoid students hitch-hiking on the work of others in the group. This may be achieved by assessing individuals, questioning students at random, and sharing the reporting back to the whole class.

4. **Cooperative social skills.** Communication, conflict management, and leadership skills are not only necessary, but can be taught.

5. **Group processing.** Students should celebrate a group success, using mutual congratulations or even a simple “high five.” Each group also needs to consider how their work could have been improved. These considerations need to be specific, so students should ask questions like: “What contribution did each of us make, and how could that have been improved?”

Let us consider an example of a cooperative quiz. Following a learning segment on the nature of science and related terminology, divide the class into groups of three or four students and ask students to determine whether each of a given set of statements, such as “There are no living organisms on Mars,” is a prediction, a hypothesis, or a theory. Tell students you are looking for the best team, and that the following rules apply.

1. Students in a group do not need to agree on any answer. However, the group receives the score corresponding to the lowest individual mark in the group.

2. Bonus marks will also contribute to the team score. Following group discussions, and before the correct answers are given, students will be chosen at random to answer a question, or to evaluate the response given to a previous question by another student. A correct answer rewards the team with a bonus mark, while an incorrect response results in a mark being deducted from the team score. A bonus mark may also be deducted from a team score for a student not paying attention, speaking without being invited to do so, or displaying other deviant behaviour!

Following group deliberation and the random questioning of students (during which time team scores are progressively displayed on the board), mark individual student answers, adjust each team score, and compare the scores. To avoid fudging of individual answers, it is a good idea for each group to mark the work of students from another group!

In this example, positive interdependence was achieved by the assigning of the lowest individual mark in a group as the group score, and by the use of bonus points. Students don't want to let their fellow group members down, so it is in their best interests to ensure that not only do they understand the reasoning involved in responding to this task, but that other members of the group do also. Individual accountability was addressed by using random questioning of students, although an individual follow-up test could have also been employed.

Cooperative learning can be a fabulous tool for engaging students and fostering deeper understanding. If you are not already using it in your classroom, why not get started with a cooperative quiz?

Peter Eastwell

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Johnson, R. T., & Johnson, D. W. (1989). *Cooperation and competition theory and research*. Edina, MN: Interaction Book.

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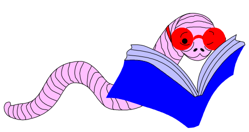

Research in Brief

Implementing School-Based Assessment

Yung (2001) adopted a phenomenographic approach to the study of three teachers as they implemented school-based assessment of biology practical work in Hong Kong. The assessment process in the school laboratory is complex, and such an assessment innovation, requiring significant changes in teacher's pedagogy, is not easy and necessitates teacher professional development.

Reference

Yung, B. H. W. [2001]. Three views of fairness in a school-based assessment scheme of practical work in biology. *International Journal of Science Education*, *23*, 985-1005.

Deeper Learning

To develop a deeper learning approach, in terms of the upper levels of Bloom's cognitive taxonomy, to an introductory higher education mechanics unit for 52 students, Booth and James (2001) introduced periods of informal cooperative learning to lectures. A greater emphasis was given to conceptual questions, and the form of the exam paper was also varied to accommodate this. Quantitative and qualitative data were collected in a pre- and post-test design which also included a comparison of students' results with those for the previous year's cohort. While the innovation was not shown to improve students' cognitive gain, as measured by the *Force Concept Inventory*, it did increase the enjoyment experienced by students and lecturer, evidenced by students asking why the approach was not being used in another module.

Reference

Booth, K. M., & James, B. W. [2001]. Interactive learning in a higher education Level 1 mechanics module. *International Journal of Science Education, 23*, 955-967.

Evidence Used by the Public

In the UK, Recycled Liquid Fuel (RLF) is being increasingly used as a fuel in cement kilns. The traditional fuel is coal. RLF is a blend produced by chemical companies, and contains waste solvents like paint thinners and ink solvents. Tytler, Duggan, and Gott (2001) report a case study involving particularly one village and concern over kiln emissions associated with the burning of RLF. The scientific evidence for the environmental advantage of the new procedure was equivocal, and the various parties tried to use science as a tool for promoting their particular interests and value positions.

Participants used three types of evidence in the debate: formal scientific, informal (such as personal opinion & common sense), and wider issues (like legal and environmental concerns). The researchers suggest the need for school students to learn, and practice, a range of specific evidential principles not presently found in science curricula. This would empower them to critically question, to manipulate various types of data (e.g. use computer modelling to weight data differently), to seek evidence, and to participate in debates about science-based issues of personal or public concern. The quantity of publicly available data on the internet is increasing.

Reference

Tytler, R., Duggan, S., & Gott, R. [2001]. Dimensions of evidence, the public understanding of science and science education. *International Journal of Science Education*, *23*, 815-832.

Which Information Should I Trust?

Do power transmission lines have associated adverse effects? Do they increase the risk of childhood leukaemia? Which is the better: overhead or underground lines? There is no consensus within the scientific community on the answer to these questions, and this seemed to frustrate the 22 16-year-old Norwegian students Kolsto (2001) interviewed in relation to a proposed local power line upgrade. He was interested in the strategies students used to assess the trustworthiness of information they had received, and the sources of that information. Students used one or more (some students used all) of four strategies: acceptance of a source as being authoritative, acceptance of a claim, the evaluation of an authority from the point of view of interests, neutrality, and competence, and the evaluation of a claim, although students' evaluations were rather shallow.

Most students displayed a dual attitude towards research, researchers, and the power company, a mixture of trust and scepticism. School science had apparently not prepared them to appreciate the uncertainties associated with scientific studies, and this lack of understanding can lead students to inappropriately interpret differences between researchers in terms of interests and incompetence. Greater emphasis is needed on knowledge of different sources of science-based information, and training is needed in evaluating such sources.

Reference

Kolsto, S. D. [2001]. "To trust or not to trust, . . ." – pupils' ways of judging information encountered in a socio-scientific issue. *International Journal of Science Education*, *23*, 877-901.

More Depth, Less Topic Coverage

In a study of nearly 1500 US undergraduate students, Tai and Sadler (2001) conclude that students who had experienced a high school physics course characterised by the in-depth treatment of less topics performed better in college/university physics than students who had experienced an "exposure" approach (i.e. a shallower treatment of more topics). Females achieved higher in introductory algebra-based, terminal undergraduate physics courses, whereas males outperformed females in the calculus-based courses which are prerequisites to further study in many science-based fields. They recommend that changes are needed in the climate of introductory undergraduate physics courses to ensure the success of women entering the physical sciences and engineering.

Reference

Tai, R. H., & Sadler, P. H. [2001]. Gender differences in introductory undergraduate physics performance: University physics versus college physics in the USA. *International Journal of Science Education*, *23*, 1017-1037.

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

This section of *SER* is intended to cater primarily for the needs of science non-specialists, so please send your question in and have that long-standing query resolved; hopefully!

Is water a satisfactory fire extinguisher for the kitchen?

No. A common type of fire in a kitchen is oil or grease burning in a pan. If you try to move the pan, you might spill some burning grease and spread the fire even more. While water will extinguish some fires, pouring water onto an oil fire may actually make things worse. Oils and water do not mix. We say they are immiscible. So, when you pour water on an oil fire, the water just sinks to the bottom of the oil and has no effect on the flames on top. Worse, though, the water sitting on the bottom of the pan will boil very quickly, and when it does the bubbles may cause the burning oil on top to spit and splatter widely. This splattering oil may ignite curtains or your clothes.

Provided the fire is not out of control such that you need to phone for emergency help, there are three actions you might take. There are different kinds of fire extinguishers, differing in what they are filled with. Typical contents include water, carbon dioxide, foam, and powder. Different kinds of fire extinguishers are used to put out different kinds of fires and, as we have already seen, the spray from a water fire extinguisher is not suitable for an oil fire. One can purchase a multipurpose fire extinguisher, so using that would be fine, and every kitchen should have one. Aim the spray at the base of the flames and sweep it back and forth.

Alternatively, you could smother the flames by covering the pan with a lid or nonflammable sheet. These prevent oxygen in the air reaching the oil, and things cannot burn without oxygen. A third alternative would be to throw baking soda (sodium bicarbonate) into the pan. Baking soda will not burn, and will likewise smother the fire. Also, when baking soda is heated, it produces carbon dioxide gas, which is a good fire extinguisher. However, don't use combustible powders like flour or powdered milk instead. They may also make the situation worse.

Is it true that you get wetter running in the rain than walking?

This is a common belief, based on the thought that the faster you move, the more raindrops you run into, and hence the wetter you get. Barbara Etherington and her students, at Proston State School, Queensland, Australia, are in fact investigating this question experimentally. They have erected a "raining apparatus," which uses a set of inverted sprinklers, and students are reportedly highly engaged in exploring the effects of changing variables. Well done, Proston folks. That is science in action.

The answer to the original question, though, is not a simple yes or no; it actually depends upon what one means by running/walking in the rain (over a set distance, or for a set time?) and the angle that the rain makes with the ground. Consider first the simpler case of rain falling vertically, and a person who needs to move between two fixed points. In short, the faster you move between those points, the less time you spend in the rain, and the dryer you remain. Evans (1991) has shown this result mathematically, while Volkmann (1993) presents a neat geometric treatment.

It is interesting to consider separately the two sections of your body that do get wet under these circumstances; the top of your head and shoulders, and your front. The faster you move, the less time the top of your head and shoulders spend in the rain, so the less wet they get. However, as Volkmann (1993) shows, the speed at which you move makes no difference to how wet your front gets. Your front gets just as wet when you walk as it does when you run. So, when these two contributions are combined, the faster you move, the less wet you get. If, on the other hand, you were wearing a broad hat to protect your head and shoulders from the rain, you would get just as wet no matter how fast you moved – so why not just relax and enjoy the stroll!

Alternately, if running/walking in the rain meant doing so for a set time rather than for a set distance, then the opposite answer would apply; go slow and stay dryer. This is because your head and shoulders would get equally wet whether you ran or walked but, the faster you went, the more rain drops your front would run into.

A more complicated situation arises when there is also a wind, and the rain is not coming down vertically. Evans (1991) has shown that, in this case, there is a critical speed at which you should move between locations for minimum wetness. Move any slower or faster than this critical speed and you get wetter. What is this critical speed? Imagine the rain coming down to be doing two things simultaneously; falling vertically, while at the same time moving sideways. For minimum wetness, you need to move in a direction such that the rain is coming from the back, and at the same speed as the rain is moving sideways. Under these circumstances, you might think of yourself as “just keeping up with the rain,” and the rain will appear to you to be falling straight down. Only your head and shoulders will get wet.

Finally, towards extremes, if you have to move far enough or for long enough in the rain, you are going to get drenched anyway. You may as well forget about running and just enjoy walking in the rain.

References

Evans, H. E. II (1991). Raindrops keep falling on my head . . . *The Physics Teacher*, *29*, 120-121.
Volkmann, M. J. (1993). To walk or run in the rain: A geometric solution. *School Science and Mathematics*, *93*, 217-220.

Further Useful Resources

Bureau of Meteorology, Australia

http://www.bom.gov.au/lam/Students_Teachers/learnact.htm

Contains student experiments about meteorology. Also includes interactive animated models (weather map, El Nino, low and high pressure systems, cyclones, clouds, and ozone layer), a cloud quiz, teacher lesson plans and student worksheets, and more.

Stanford Solar Center http://solar-center.stanford.edu/lessons.html

A collection of multidisciplinary, interactive exercises and activities, for Years 4-12, based on the Sun and solar science. Includes solar granulation, sunspots, the solar scale, accessing an online solar telescope, building a pinhole camera, "hearing" the Sun, and global warming.

How to Grow Your Own Crystals

http://www.geocities.com/dwibdwib/crystals/index.html

Background information on, and instructions for, growing crystals from water solutions, photos of crystals, and further links.

Bad Physics in Newspapers, Magazines, and Literature

http://www.jal.cc.il.us/~mikolajsawicki/bad_physics.htm

Examples of physics misconceptions found in media and other publications. Also, links to *Bad Physics*, *Bad Movie Physics*, and *Bad Astronomy* sites.

ScI-Journal http://www.sci-journal.org

Published reports of science investigations written by school and college students. The reports might provide fresh ideas for practical science investigative work, secondary data for analysis, or stimulus material for evaluation by students.

Classroom Animals and Pets http://www.teacherwebshelf.com/classroompets/

Information about keeping amphibians, birds, fish, insects, small mammals, and reptiles in the classroom, together with a "green" thoughts section. Addresses housing, food, maintenance, interesting information, more specific characteristics, teaching ideas, resources, and links for each featured species.

Humane Society International http://www.hsi.org.au/class.html

Argues against keeping animals in the classroom.

Humour

While we would never make fun of students' ideas in front of them, students sometimes say or write things which, in a quiet moment, will likely bring a smile to the face of any teacher. Try these.

"Someday we may discover how to make magnets that can point in any direction."

"Most books say that our sun is a star. But it still knows how to change back into a sun in the daytime."

"There are 26 vitamins in all, but some of the letters are yet to be discovered. Finding them all means living forever."

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