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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

If all the salt in the oceans was removed and spread across the land surface of Earth, the salt layer would be over 150 metres thick.

Scientific Literacy

The traditional goal of science education during the compulsory school years was the selection and preparation of future scientists. Within the past 20 years, we have seen a worldwide move away from this approach towards a "Science for All" philosophy, the general purpose of which is to develop the scientific literacy of all students, where scientific literacy might be described as the capacity:

1. for persons to be interested in, and understand, the world around them,
2. to engage in the discourses of, and about, science,
3. to be sceptical and questioning of claims made by others about scientific matters,
4. to be able to identify questions and draw evidence-based conclusions, and
5. to make informed decisions about the environment and their own health and well-being (Commonwealth Department of Education, Training and Youth Affairs [DETYA], 2001).

Taking the view that "education is the ability to meet life's situations" (Dr John G. Hilben, former President of Princeton University), this revised emphasis appears appropriate. Science-related issues play a prominent role in contemporary society, and the decision-making of the general population is fundamental in democratic societies. Having identified scientific literacy as our goal, the challenge comes in designing curricula to achieve the desired outcomes. Beginning with this issue, *The Science Education Review* (*SER*) will address each of the components of scientific literacy identified above; not just in theory, but also by providing appropriate classroom strategies. Allow me to preface what is to come with a couple of related remarks.

It is not uncommon to find "Science for All" curricula designed by simply reshuffling traditional science topics, making some cosmetic changes, and removing some of the more cognitively demanding material for at least some students in an attempt to make the curriculum more accessible. We have evidence to suggest that, in an overall sense, much more is needed; and not just in the area of curriculum change, but also in relation to pedagogy and even school structure. For example, the consensus of the literature is that the interest and enjoyment in being involved in science activities of Australian students declines (once again in an overall sense) as they move from upper primary school through lower high school (Adams, Doig, & Rosier, 1991; Baird, Gunstone, Penna, Fensham, & White, 1990; Rosier & Banks, 1990), and a similar decline in students' interest has been reported in the United States (Barrington & Hendricks, 1988; Hofstein & Welch, 1984; Piburn & Baker, 1993; Yager & Yager, 1985). Baker & Piburn (1991) even reported a decline in ninth-grade students' desire for science, the value they place on science, and their wish to pursue science any further in circumstances where the curriculum had been subjected to innovation and the content and process achievement of students was improving.

Reasons for this trend include course material being not relevant nor connecting with students' interests and experiences, the growing abstraction, complexity, and difficulty in understanding science, disenchantment with the teaching strategies used in secondary science classrooms (chalk-and-talk teaching, copying notes, working from a text, and "cookbook" practicals offering little challenge or excitement), a decline in both academic and social student-student and student-teacher interactions (less group or cooperative learning, and contact time with each teacher more limited), and increasing uncomfortableness with open-ended activities as opposed to achieving a single correct result (i.e. anziety associated with the perceived need to "get the right answer" (DETYA, 2001; Piburn & Baker, 1993; Speering & Rennie, 1996). A recent study in England concluded that "many students perceived school science to be a subject dominated by content with too much repetition and too little challenge" (Osborne & Collins, 2001, p. 441). In short, students are not engaged. Further, DETYA (2001) concluded that the programs in many schools do not develop outcomes which contribute to scientific literacy.

Woolnough, Guo, Leite, De Almeida, Ryu, Wang, & Young (1997) concluded, in their report of parallel studies in six countries, "fortunately . . . the type of science that appears to be most effective in encouraging future scientists and engineers, a stimulating, relevant, challenging and accessible curriculum, well taught and supplemented by opportunities for extra-curricular projects in science, seems to be equally appropriate for all." However, "science for all" does not necessarily mean that "one size fits all" (Lynch, 2001), and I suggest that a high priority for secondary educators is to develop approaches to learning and assessment which better respond to the diversity in student populations.

How this is done will be governed by local factors, such as school student population. Small schools, for example, may have the full spectrum of student talent and motivation represented within an individual science classroom. Some high schools have chosen to expose all students to a core scientific literacy program during the first part only of the compulsory years, with some students only choosing science as an option for continued study during those years. Other larger schools group students according to specified criteria. Another focus for this periodical will therefore be to share strategies for better catering for student diversity. My former experience as a high school science educator leads me to believe that we may have much to learn from primary teachers. I recall with much fondness the primary school education I received in a one-teacher school with about 13 students working simultaneously at six or seven year levels. I had to smile recently when a consultant shared the story of a high school teacher who was adamant that a particular strategy could not possibly work because it would require students in his classroom to be working from one of two (or, shock horror, posssibly more than two!) different resources at the same time. Just not manageable, he said! I challenge anyone to identify a more challenging task than effective teaching!

Peter Eastwell

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Demonstrations

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

Look Mum, no Glue!

Needed. Two books.

Lie two books on a table beside one other, with their open sides close. As you fan the sheets in each book simultaneously, allow the sheets to interlock, similar to the process of shuffling cards. Push the books closer together, and then invite two students to pull them apart. Impossible!

Comment. This is a great demonstration of the force of friction, and how it's magnitude increases with an increase in the area of the surfaces in contact. Why is it easier to push the books together than to pull them apart? While the books are being pushed together, the pages separate a little and the reduced contact area results in less friction.

The Disobedient Foot

Needed**.** A person, blank sheet of paper, and a pencil or pen.

Invitation**.** Invite a right-handed volunteer to stand on her left leg and practise rotating her right foot in clockwise circles just above the floor. Rest. Give her the paper and pencil, and ask her to again rotate her right leg in clockwise circles. Invite your audience to observe her right foot as she writes a large number "6" on the paper. They will be amused, even amazed, to see that she finds it very difficult to keep her foot rotating clockwise while writing the number. Why? Let's investigate.

Exploration**.** Invite students to explore this situation by experimenting, in groups, with different combinations of hands and feet. For example, they will probably find that, while using the right hand, rotating the right foot anticlockwise, the left foot clockwise, and the left foot anticlockwise are all easy. Students should record their data so as to aid the identification of any trend/s.

Concept introduction. Ask each group to review their data and to suggest a hypothesis, a possible explanation, for their observations. Share these hypotheses using a whole-class discussion, noting any predictions which stem from each hypothesis. If necessary, the teacher might guide discussion so as to ensure that at least one hypothesis accommodates the explanation given below.

Invite students to test the hypotheses by checking the predictions. Remember that data which are not in accord with a hypothesis refute that hypothesis, but that data in accord with a hypothesis support the hypothesis rather than prove it true, since subsequent evidence could always refute it. Hopefully, the data will support the following explanation.

Nerve fibres from the right side of our body are connected to the left side of our brain, and nerve fibres from the left side of the body to the right side of the brain. This means that the left side of our brain controls the right side of our body, and vice versa. Writing the number "6" required the left side of the brain to instruct the right hand to move anticlockwise and the right foot to simultaneously move clockwise. This requires a special effort, and I have only ever met one person who could readily achieve the feat. All the other options are easy because both hand and foot are moving in the same direction. For a left-handed volunteer, rotating the left foot clockwise while writing a "6" will prove difficult.

Concept application. Test this hypothesis by checking any predictions which follow from it which have not been previously tested.

"Criticisms are like homing pigeons. They always return home."

(The quotations in this issue of *SER* are from Carnegie, D. [1999]. *How to win friends and influence people*. Sydney: Harper Collins Publishers.)

"A great man shows his greatness by the way he treats little men." *Carlyle*

"A man convinced against his will, is of the same opinion still."

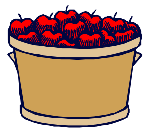
Student Experiments

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

One Bad Apple

Needed. Two paper bags, one ripe apple, and five unripe pieces of fruit (e.g. peaches, plums, pears, or tomatoes).

Invitation. "One bad apple spoils the whole barrel." Is there any truth in this saying? If so, can you suggest a hypothesis, a possible explanation? Discuss the student hypotheses.



Exploration. Invite students to design and carry out an experiment to answer this question, and to test their hypotheses. Share and refine the suggested experimental procedures before students implement them, paying particular attention to controlling variables. The following is one procedure which might be included.

Taste one piece of unripe fruit, and note how hard and lacking in sweetness it is. Put the apple and two pieces of the other fruit in a paper bag and seal the bag by rolling the top down. Seal the other two pieces of fruit in the other paper bag. (A possibility for another experiment might be to store these other two pieces of fruit without using a paper bag but in a dark place away from the bag with the apple.) After a day, taste one piece of fruit from the bag with the apple and one from the other group. Compare them. Do the same another day later, using the last two pieces of fruit. What do you conclude?

Concept introduction. The ripe apple causes the other fruit to ripen more quickly. This is because plants produce a gas called ethylene, and apples produce a lot of ethylene gas as they ripen. This gas causes plants to produce chemicals called enzymes, which do a couple of things. First, they cause starch and acids in fruit to change into sugar, thus making the fruit sweeter. Second, they weaken the cell walls, causing the fruit to soften. Placing the ripe apple in the bag adds extra ethylene to the bag. Also, as the fruit ripens, it produces more and more ethylene. So the saying "One bad apple spoils the whole barrel" is true. An overripe apple stored with other fruit can cause the fruit to ripen and spoil very quickly.

Concept application. Test if a ripe apple will also accelerate the ripening of other fruit, and whether there is another piece of fruit which is as effective as, or even better than, an apple for facilitating quicker ripening.

The Mysteriously Rising Water

Needed. Cup, water, food colouring (optional, but easier to see), test tube and holder, and large candle or alcohol lamp.

Exploration. Nearly fill the cup with coloured water. Put a little clear water, to a depth of no more than 5 mm, in the test tube. Hold the test tube near its top with the test tube holder, put on the safety glasses, and use the candle or lamp to boil the water. Careful: Don't burn the test tube holder! Also, don't point the open end of the test tube at another person, in case hot water spurts out.

When you see plenty of steam coming from the test tube, remove it from the flame, turn it upside down, and hold it so that the open end of the test tube is under the surface of the coloured water in the cup. Watch and wait. What happens? Did you see the coloured water rise up inside the test tube? Why does it do this (i.e. what is your hypothesis)?

Concept introduction. Where practicable, test different student hypotheses. When the water in the test tube is heated, some of it changes to steam, fills the test tube, and pushes some air out of the test tube. When the test tube is then turned upside-down in the coloured water, the steam in the test tube cools down and changes back to liquid water, leaving a shortage of air (and less pressure than normal) inside the test tube. Because the normal pressure of the air in the room (atmospheric pressure) is greater than the pressure in the space inside the inverted test tube, water is pushed up inside the test tube.

Self-Assessment: A Powerful Tool

If the ultimate aim of education is to shift to the individual the responsibility for pursuing his education, then self-assessment is a very valuable strategy. But first, a word about what self-assessment is not. Self-assessment does not mean students awarding their own summative achievement ratings. Vos (Dryden & Vos, 1997) recommends an assessment system for the 21st century comprising 50% self-assessment, 30% peer-assessment, and 20% teacher or boss assessment. Using this schema, self-assessment also does not mean that, for example, a student rates his achievement in a course as 9/10, he arranges for a friend to also rate his achievement as 9/10, he receives a teacher rating of 5/10, and exits the course with an overall achievement of (9 x 0.5) + (9 x 0.3) + (5 x 0.2) = 8.2/10, an A rating when in fact he is a C-achieving student! Let's take one example of self-assessment, identify why the strategy is such a valuable one, and then consider further ways in which it might be employed.

During the Science Enrichment Programs I conduct, upper primary and lower high school students spend much time participating in scientific demonstrations and carrying out experiments in pairs. They keep an individual, interactive journal which I collect at the end of each day and respond in overnight. To help monitor and improve classroom participation, I issue to each student and discuss, near the beginning of the program, a rubric in the form of a two-dimensional grid. Down the left-hand side are six criteria, and across the top are three column headings which represent participation ratings (*High* [5 points], *Satisfactory* [3 points], and *Needs Improvement* [1 point]). The criteria are as follows, and the bracketed description of 5-point behavior for each is also shown in the corresponding *High* performance column of the rubric: *Materials* (always brings notebook, pencil or biro, & covered footwear), *Effort* (willing to accept tasks set, apply yourself to them, & frequently volunteer for activities), *Respect for Others* (listens to others, encourages others, helps others, tolerates the shortcomings of others, displays good manners, & keeps noise level respectful), *Cooperation* (pays attention, accepts good advice and acts on it, works safely), *Journal* (entries are neat and complete), and *Communication* (shares ideas with mentor and other students, offers advice to others where necessary, participates in group discussions, & ask questions if you have them).

Near the end of the first day, each student is asked to complete the rubric by rating performance on each criterion, to sum the points and arrive at a total score, and to hand in the rubric. Sometimes I also ask each student to complete the rubric for the participation of her partner (it is important that this option is also discussed when the rubric is first issued), and at other times I leave this peer-assessment till the second day. When next we meet, I praise honest and accurate assessments and provide for opportunities to discuss rubrics with those students whose self assessment differs markedly from my observations.

Students have clear goals, in the form of desirable behaviour, and need to consider what they might do to score higher. Others have also noted the positive response of students to strategies like this, which also provide excellent practice in metacognition (Craven & Hogan, 2001; Thomas, cited in Harlen, 2001). The empowering of students in this way also builds self esteem, which is a very important component of personal growth. Black and Harrison (2001) found that such formative assessment can provide unplanned benefits for the teacher as well. For one teacher, self-assessment was the catalyst for further innovation, resulting in strategies like independent learning and group work being more than just phrases.

Self-assessment can easily be used in conjunction with tasks like project work, cooperative learning, practical reports, and homework, and these tasks also lend themselves to peer-assessment. It is interesting that students may take a peer's comments about poor spelling or messy handwriting more seriously than the same comments made by the teacher! Towns, Marden, Sauder, Stout, Long, Waxman, Kahlow, and Zielinski (2001) have even used electronic communication to imitate a professional discourse community at the tertiary level by having student work reviewed by students and staff at distant institutions. They remind us of the strong link between writing and learning, and how revising their work requires students to think critically about both their writing and the subject matter.

Self-assessment begins with identifying suitable criteria, and students may also be beneficially engaged in this process. One could also provide descriptions in all cells of the rubric, and even weight criteria. When used for assessing participation, the strategy should not be overused to the extent that students become desensitised to it. In a classroom setting, it might therefore be employed during a few short periods of time only of a semester. Extending the concept, Borba and Olvera (2001) report the improved outcomes from parent-teacher meetings since moving to student-led conferences, based on each student's portfolio. Students were empowered by the process of discussing their strengths, weaknesses, goals, and progress.

Peter Eastwell

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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 considered important for the development of scientific literacy.

While the tasks will reveal misconceptions, not all of them are designed to reveal the reasons behind the misconceptions. Some strategies which might be used to achieve the latter are mentioned in the *Catering for Individual Student Needs* section of this issue.

One might record students' individual responses to a task/s at the beginning of a unit, use the same question/s again at the end of the unit, and rejoice (hopefully!) in the progress made. The tasks may also provide a stimulus for classroom investigation. Since students' ideas will likely vary with age, and sometimes even with sociocultural context, you should feel free to modify them to suit your needs. At the same time, though, we have evidence for some fairly consistent patterns, across cultures, in some misconceptions held by students in particular age groups.

1. Classify each of the following as *living*, *non-living*, or *not sure.* Fire, centipede, robot, sun, tree, ghost, seed, book, cigarette, whale, bacteria, coal, water, statue, wooden log, mermaid, bomb, insect, active volcano, sea, snail, plant, food, sand, moon, stars, demon, electricity, paper, fish, burning candle, computer, stone, car, air, house, soil, aeroplane, ant.

Comment. Younger students may consider movement the most important criterion for life, so both moving non-living things (e.g. robot, car), and living things which move very slowly (e.g. snail), may initiate much debate. Some may refine this test even further by suggesting that although a car can move, it does not do so without a "live" person and so fails the test for a living thing! The three mythological inclusions may complicate discussions by introducing ideas which will be addressed in the *Nature of Science* and *Sceptical Science* articles of future issues of *SER*, and might be omitted.

2. In which of the following cases will gravity be acting on the object?

a. A bullet, which has just left a gun, after being fired downwards toward the ground.
b. A feather moving down through the air.
c. A person, in the air after jumping down from a ledge.
d. A parked car.
e. A dog sitting in a boat.
f. A piece of wood buried under the ground.
g. A bullet, which has just left the gun, after being fired upwards into the air.
h. A ball moving up through the air.
i. A person moving upwards after leaving a trampoline.

Comment. Gravity acts on the object in every case. Misconceptions may include gravity, which pulls things down, not acting on objects moving upwards, gravity pulling things to the surface of the earth but not acting underground, and gravity not acting in the absence of air (Item f).

3. Which of the following statements about radioactivity are correct? (There may be more than one.)

   a. Living things become radioactive after being exposed to radioactivity.
   b. After a diagnostic examination, objects in a radiographic room emit radiation.
   c. Radiation is a kind of gas.
   d. Radiation is a kind of dust.
   e. Radiation cannot penetrate a plastic suit.
   f. The radioactivity of a material is eternal (i.e. never stops).
   g. Radioactive milk can be made safe by boiling it.

Answer. All are misconceptions.

4. Indicate whether each of the following statements are *definitely correct*, *probably correct*, *maybe correct*, *probably not correct*, or *definitely not correct*.

   a. Most of us are not part of the environment. The few who are include hunters, who get their food from the environment, and people who travel to see an environment.
   b. Without human management, the environment would collapse.
   c. The more we buy, the more things we have to recycle, so the more we help the environment.
   d. People who are interested in the environment are not "cool."

Comment. All represent alternative conceptions. Statement c addresses the potential imbalance in views about recycling, reusing, and reducing. The latter two of these may even be forgotten. Buying as much aluminium can softdrink as you can manage, pouring the contents down the sink, and recycling the cans does not help the environment!

5. Consider the following possible causes of mountain formation, and label each as *definitely*, *probably*, *maybe*, *probably not*, or *definitely not* a cause.

   a. Minerals or rocks being pushed up from below the earth's surface.
   b. Minerals or rocks pushing up from below the earth's surface.
   c. Continents pushing against one another.
   d. Landslides.
   e. Wind blowing dirt, sand, and rocks into a heap.

f. The gravitational pull of the moon causing rocks to bend.
g. Ocean water evaporating and leaving deposits behind.
h. Oceans receding and leaving mountains behind.
i. Other (please explain).

Comment. Mountains are caused by continents pushing against each other (c).

6. When we talk about Darwin's theory of evolution, we are talking about:

a. a hunch, idea, or possible explanation.
b. an explanation which is well established.
c. a proven fact.
d. Other (please explain).
e. Don't know.

Repeat for Einstein's theory of relativity.

Comment. Choice b is the answer in both cases. It is interesting to compare the distribution of students' responses in the two cases. Despite both being theories, greater debate in the community regarding the former may result in students perceiving it to be less established.

7. Suppose medical practitioners suspect that a drug used to treat arthritis is not working well. Which one of the following approaches would be best to investigate the problem?

a. Talk with patients and get their opinions.
b. Use their knowledge of medicine to decide how good the drug is.
c. Give the drug to some patients and not others, and compare patients in the two groups.
d. Not sure.
e. Other (please give your reason).

Comment. Choice c is the preferred approach.

8. For each of the following statements, please indicate if you *agree*, *disagree*, or are *not sure*.

a. An atom is a solid sphere.
b. Atoms are flat.
c. Matter exists between atoms.
d. Atoms can be different sizes.
e. An atom may change size when it is heated.

f. Atoms may change size when they collide.
g. All atoms have the same weight.
h. All atoms are alive.

Comment. Item d is the only correct statement. Some students may consider atoms to be alive (h) because they move.

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

Research Project: An Invitation to You

You are invited to contribute to a research project, to be conducted by *SER* subscribers, aimed at further exploring students' alternative conceptions. The following process is envisaged, but please feel free to suggest an improved methodology.

Step 1: Subscribers are invited to submit topics which you think we might explore.

Step 2: I perform a literature review to determine the extent to which the suggested topics have already been investigated.

Step 3: A topic deemed to be in need of further scrutiny is chosen, and I or somebody else conducts some pilot student interviews.

Step 4: Subscribers who feel they have adequate background expertise in the chosen area volunteer to conduct one or more interviews with students, using a suggested interview protocol.

Step 5: A questionnaire is constructed, and field-tested with a small student sample.

Step 6: The revised questionnaire is administered, by volunteer subscribers, to as many students as possible.

Step 7: Each subscriber collates their data and submits it to me for compilation.

Step 8: The study is published, with all contributors acknowledged.

A series of such studies, each with the potential to contribute conclusions to the literature based on data from across cultures and student ages, will likely provide another valuable resource for classroom teachers.

What to Do

To begin the process, I invite you to please submit a suggested topic/s to Peter Eastwell at editor@ScienceEducationReview.com . Like the questions in the previous section, topics should have the potential to promote the scientific literacy of students during the compulsory school years. You might therefore include such things as heredity, radiation, the nature of science, or aspects of the earth about which students are likely to have had experience rather than, for example, Le Chatelier's principle, which would require students to have formal background social knowledge.

I encourage in particular anyone who has never had experience in eliciting detailed student conceptions via interviews to try it at least once. It can be a very enlightening activity, as Gerking (2001) found recently in connection with concepts about atomic structure: "I wouldn't have believed the responses if I hadn't heard them with my own ears" (p. 6). I look forward to receiving your suggested topic/s.

PHE

Reference

Gerking, J. L. (2001). What do your students know? *The Science Teacher*, *68*(5), 6.

Catering for Individual Student Needs

How does one meet the individual learning needs of so many different children in class? A response to this question might fill a book, if not several volumes! A useful starting point may be to identify some individual differences which are likely to exist between students, and consider strategies for addressing them. Students will typically have different prior thoughts and experiences, different talents, different learning, working, and thinking styles, and different temperaments. As a result, they will also require different times to learn new ideas and skills. A consideration of these needs might include techniques for eliciting students' existing ideas, Gardner's multiple intelligences, Bloom's taxonomy, and Dunn and Dunn learning styles. Please let me know what I have missed. Let's begin in this issue of *SER* by considering ways to determine students' prior knowledge, and follow up in subsequent issues with a treatment of the other topics.

Researchers often use individual student interviews in structured research to determine students' prior knowledge and understanding. However, individual interviews with all students are prohibitively time-consuming for teachers under typical larger-group circumstances, and other approaches are needed. Whole-class question and answer (including Predict-Observe-Explain [POE] activities) and brainstorming are common, with a record kept of student responses. When it comes to questions, some of the best one can ask stem from educational research. At the same time though, teachers can conduct similar research with their own students and, over time, build much experience about students' conceptions at different stages of their education. This teacher-as-researcher/learner approach can invigorate a teacher's role.

While brainstorming is useful and certainly has a place, it does have shortcomings. The information collected will likely be biased towards dominant personalities and many students may be largely passive. How might one do better? I like the Round Robin and Hot Potato strategies, and both these cooperative strategies will be described in future issues of *SER*. The Postbox, described in the following section of this issue, is also worth a try. Another approach is to try to determine what students know or understand by determining what they don't know or understand. Having introduced a topic (which may include some student activities and/or finding out what they do know about the topic), one can invite students to write questions they would like answered about the topic. Categorising these expressions of student curiosity, and asking the class to answer these same questions at the end of the learning sequence, are further valuable student exercises.

For convenience with large groups, it's hard to beat a written survey. This might comprise a multiple-choice, or other, test or require open-ended responses (e.g. writing a paragraph in response to a question). Again, test questions should be based on the findings of research. In particular, multiple choices should be genuine student responses derived from research data. On the negative side, surveys alone may lack validity as a result of students and teachers misinterpreting the meaning of what the other has written.

Peter Eastwell

"You cannot teach a man anything; you can only help him to find it within himself." *Galileo*

"Praise is like sunlight to the warm human spirit; we cannot flower and grow without it." *Jess Lair*

"Abilities wither under criticism; they blossom under encouragement."

Teaching Techniques

This regular section of *SER* will describe thinking, cooperative learning, or other teaching techniques.

Postbox

One first displays a set of questions to the class. For example, using the first item in the *Students' Alternative Conceptions* section of this issue, one question could be: "Is a robot a living thing, non-living thing, or are you not sure?" Ask the same question for other things listed, ensuring you have at least as many questions as you have groups of students, which may simply be pairs. Ask each student to write an answer, together with a reason/s, to each question on a different piece of unnamed paper. To get an indication of student's individual opinions, I like to do this without any student discussion. Then, collect the answers to each question in a different box.

Now is a great time to ask students to discuss with a neighbour, say, the answer to a question/s to which you feel there will be disagreement. Some lively debate is typical. "It can't be living, because it's made by humans." "Of course a volcano is a non-living thing, but an active volcano must be living." "Paper must be a living thing because it comes from a tree which is living." This is exactly the differentiation and integration of ideas needed for subsequent meaningful learning, and it motivates students to want to resolve their disagreements. Different groups of students then analyse the responses in the various boxes and present their findings to the whole class. Charts work well for displaying the answers, the range of reasons, and the frequency distributions.

In fact, it takes only one small further step to simultaneously use these results to introduce the concept of the characteristics of living things. A two-dimensional grid may be displayed on the board, with the "things" being considered listed down the left-hand side and enough as yet unlabelled vertical columns to represent the different characteristics of living things. As groups present their findings, the teacher can write evidence for something being a living thing in the appropriate cells, guide students in building up a picture which allows them to label the columns, and find that students very quickly analyse the grid pattern and come to the conclusion that a living thing must have all of the characteristics represented by the column headings. The students have in fact been guided to constructing the desired concept for themselves. Beautiful! They might then be invited to test their conclusion by classifying some additional entities.

Forming Student Groups

Student groups can be formed randomly, purposely, or by student choice. Random arrangements can be achieved by:

1. asking students to count off to the number of groups required, with students saying the same numeral forming a group,
2. having students line up in order according to some criterion (e.g. date of birth, height, alphabetically by first name) and dividing the line sequentially into groups, or
3. handing each student a coloured card (or different shape, perhaps) as they enter the room, where the cards have been previously prepared to correspond with the group size desired.

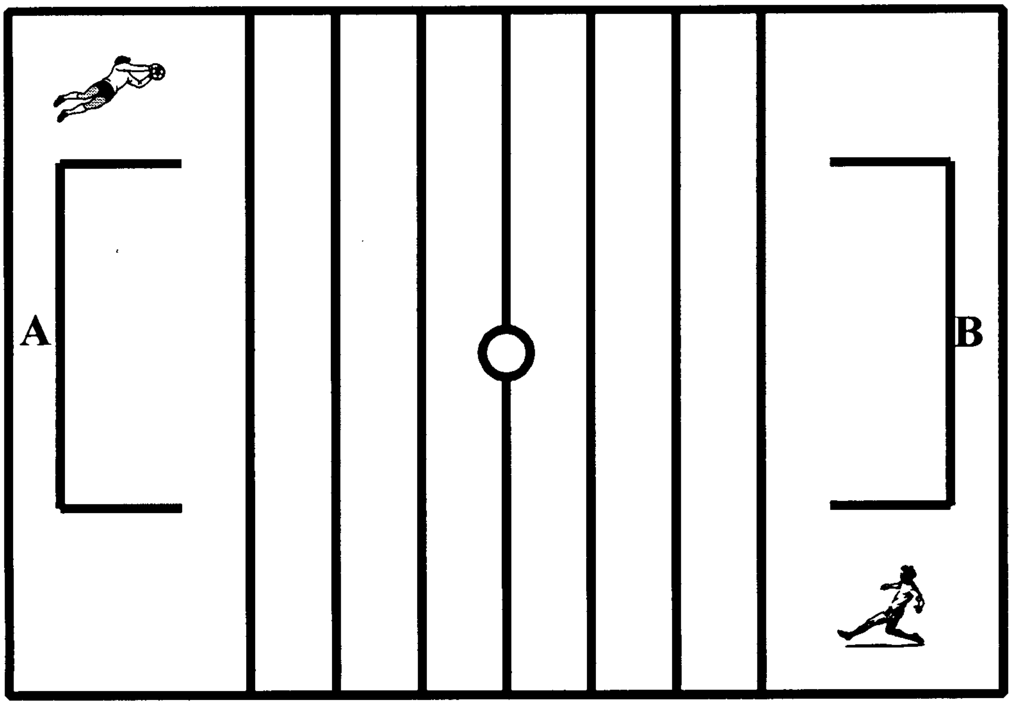
Think: Pair: Share

Pose a question. Ask students to think about the question and possible answers individually, for at least 20 seconds. No speaking or other form of communication is permitted during this time. Then, invite students to discuss their ideas in pairs. Finally, pairs share their deliberations with the whole class.

This is another alternative to whole-class brainstorming, but one that better engages students. One can also consider 1:3:Share or 1:4:Share techniques.

Science Soccer

Games, either home-made or commercial, can assist in achieving various outcomes and add variety and interest to lessons. Science Soccer (see diagram below), for example, can be used as a revision activity. Ask each student to bring to class a number of questions, with answers, about a recent section of class work. Divide the class into two teams that ask questions of the other team alternately. Rotate question-asking through the members of each team, with no one person on a particular team being allowed to answer two questions consecutively. The student asking the question may choose anyone in the other team with a hand up to answer the question. A correct answer results in the “ball” (a marker, like a small washer, on the overhead transparency) being moved one step towards the opposition goal, while an incorrect answer moves the ball towards own goal. The teacher as referee (or a student as referee, if the teacher is the adjudicator only) can award penalties in the form of similar ball movements for any of a range of reasons, such as a student not having a question prepared, or arguing with the referee without raising a hand and being invited to contribute!



Ideas in Brief

Modelling: An Underused Strategy

Rather than simply announcing a task for students and leaving it with them, Holliday (2001) reminds us of the benefits that have been shown to be associated with teacher modelling. This is the process whereby a teacher pretends to be a student and acts out, by describing aloud and questioning students, what he would do if he was asked to perform the assigned task, which might be a reading assignment, solving a problem, or engaging in a minds-on, hands-on activity. The teacher might address the use of various strategies and complete a sample task. Perhaps modelling is underused because teachers consider it to be inconsistent with enquiry learning, but this is not the case. During enquiry learning, good teachers often model the behaviours of skilled investigators. The extent of modelling may be reduced as a course proceeds, thus progressively transferring greater responsibility to students.

Reference

Holliday, W. G. (2001). Modeling in science. *Science Scope*, *25*(2), 56-59.

Chemistry for Scientific Literacy

What chemistry should students learn during their compulsory school years? Holman (2001) suggests five key areas: 1. Atoms and molecules (basic building blocks, size, motion, behaviour of different phases of matter); 2. Chemical compounds (fixed, unvarying composition/formula regardless of how made, ideas of purity and concentration); 3. Chemical change (rearrangement of atoms, products have different properties); 4. Molecular structure (determines properties, shapes of molecules, how they arrange themselves); and 5. Nature of science (how scientists work, power of science, limitations). An understanding of these principles would allow people to: 1. appreciate that scientists do not always agree, that science does not always provide unequivocal answers, and that science cannot provide an answer to some questions; 2. distinguish, for example, chlorine in its various safe or dangerous guises (poisonous gas, table salt, chlorofluorohydrocarbons, and the drying agent potassium ferrocyanide); and 3. make sense of, and participate in, debates about issues like organic foods, genetically modified foods, and taxation on fuels.

In addition, to promote students' enjoyment of chemistry, the course should be built around everyday, interesting, and significant contexts, provide much first-hand experience with common chemicals using practical work over which students have a degree of control, and allow time to discuss chemical discoveries and social issues in science. One model for UK schools is that all students study chemistry for, say, 10% of curriculum time, with optional academic and vocational modules also available.

Reference

Holman, J. (2001). All you need to know about chemistry . . . *Education in Chemistry*, *38*, 10-11.

Knowing Your Students

During the first day of class, Mamola (2000) surveys introductory undergraduate students to collect not only the traditional background and aspirational information but also their places of employment and special activities in which they will be involved during semester. Making the effort to take his family to a restaurant or shop where a student works, attend a particular theatre or musical performance, watch a sporting event, etc. provides both personal and pedagogical benefits. While he can visit only a few students, word about his interest in pupils spreads, with associated improvements in students' interest in the class and the friendliness of the classroom atmosphere.

Reference

Mamola, K. (2000). Students as people. *The Physics Teacher*, *38*, 452.

Why use Cooperative Learning?

Lord (2002) was aware of literature both supporting and repudiating the effectiveness of cooperative learning as a high school and college learning strategy, so he undertook a comprehensive literature review as part of the process of deciding whether or not to trial cooperative learning in his college biology classes. The vast majority of the articles were positive and, after 3 years of implementation and refinement, he became a true believer. This noncompetitive, team learning strategy had enhanced student knowledge and understanding.

Based on his literature review, Lord gives 101 reasons why teachers should consider using cooperative learning in biology, grouped in eleven categories, as follows. Cooperative learning enhances: 1. thinking and learning; 2. the learning environment; 3. attitudes of students; 4. assessment; 5. reading and writing skills; 6. social skills of students; 7. instruction; 8. student values; and 9. understanding of practical relationships. Cooperative learning also: 10. models real life; and 11. supports the learning of both women and men.

A group assignment, in which different members of the group contribute a different section to a final group report, provides an opportunity for students to critique the work of others before the report is submitted, gives students a sense of writing for an audience other than just the teacher, and can be highly motivating. Team members can be asked to proportion the overall mark for such an assignment. For example, if a work by 3 students was awarded a score of 85, students could be asked to divide the total of 85 x 3 = 255 between them according to the contribution each made. Students appreciate this input, and consider the process a fair one. Cooperative learning also provides students with opportunities to learn to challenge ideas and advocate positions without personalising their contributions.

Reference

Lord, T. R. (2001). 101 reasons for using cooperative learning in biology teaching. *The American Biology Teacher, 63*, 30-39.

Out With the Traditional Lecture

Singham (2000) used to laboriously carry a large quantity of previously photocopied homework sheets to each introductory physics lecture, and ask students to copy what were meticulously prepared and very well-received lecture notes. He was concerned, though, that students did not appear to be learning at the depth he desired. He changed to putting most course material (syllabi, lecture outlines, hints, solutions, homework, etc.) on the Web for ready access by students. He was advised that this may result in students not attending class, but that has not been the case. He now uses class, not for filling the heads of passive students, but for group discussions (small group first, then whole class) of prepared questions aimed at facilitating better student understanding.

Reference

Singham, M. (2000). PSST! – Want to buy my lecture notes? *The Physics Teacher*, *38*, 58.

Questioning Techniques

By promoting higher levels of thinking, quality questioning can make a huge contribution to lifelong learning. Questions can seek knowledge, promote understanding (higher levels of Bloom's Taxonomy), and invite reflection. The key to improving questioning is planning, and the type and level of the questions prepared will depend on the nature of the lesson (e.g., is it review, or introducing a new topic?). Other useful techniques include: 1. Using wait time. The longer the pause (3-5 seconds) between question and response, the higher the quality of the response, especially with higher-order questions. 2. Focussing on students' contributions rather than course coverage. 3. Redirecting questions and responses. 4. Analysing and improving questioning by recording instruction (audio or video) and using peer review or a personal survey. Just as a good baseball batter gets a hit three times out of every ten times he bats, teachers should aim for at least three quality questions in ten.

Reference

Harris, R. L. (2000). Batting 1,000: Questioning techniques in student-centered classrooms. *The Clearing House*, *74*, 25-26.

Why Teach Biology Backwards?

Learning cycle, enquiry learning, and constructivist approaches can exemplify how real science is done, and often involve students in using given materials and minimal instructions to investigate a situation, drawing conclusions from their results, and being guided towards the concept being developed. Wivagg (2001) reminds us, though, that much practical biology is taught backwards.

Students begin by reading the introduction in the laboratory manual to gain some understanding of a concept before following a procedure designed to allow them to come up with the "right" answer; i.e. the answer in accord with existing biological understanding. To facilitate better teaching, we can use the same preparation and materials, but vary the order of components in the learning sequence and provide opportunities for discussion.

Reference

Wivagg, D. (2001). We teach biology backwards. *The American Biology Teacher*, *63*, 82.

High School Physics: What Help to College Physics?

Many teachers and college or university professors in the United States have long differed in their opinions about the role of high school science courses in preparing students for success at the undergraduate level (Sadler & Tai, 1997; Yager, 1986). Does taking high school physics facilitate higher achievement at the next stage? According to the findings of Sadler and Tai (1997, 2001), there is a positive relationship between these two variables, although this relationship is modest and very much less strong than students themselves perceive it to be.

There is no consensus in the conclusions of earlier studies of the relationship between high school preparation and introductory undergraduate physics achievement. These studies were based on relatively small student populations in single tertiary institutions, and poor methodology is not uncommon. Some studies used a simple correlation to conclude that students who studied high school physics scored higher in undergraduate physics than students who had not. But what is to say that these same students wouldn't have scored just as highly had they not taken high school physics? Perhaps other variables, such as having highly educated parents or belonging to more affluent communities, better predict higher introductory undergraduate achievement, and it just so happens that these types of students are also the ones who choose to take physics in high school?

Multiple regression is a technique for analysing the collective and separate effects of two or more independent variables on a dependent variable. While the technique cannot claim causal relationships, it can identify key connections, and a small or negative correlation is evidence for a lack of causality. Sadler and Tai (1997, 2001) appear to be the first to have used multiple regression analysis in this physics education context, focussing especially upon demographic explanations and in a broad context. Their sample population was 1933 introductory physics students in 19 courses at 18 colleges and universities around the United States. Ten of these courses were algebra-based college physics courses and nine were calculus-based university courses. About one half took regular physics in high school, with one sixth each having taken advanced placement (AP), honors, or no physics at all. Most students had 1 year of high school physics, with 13% having 2 or more years.

Overall, taking high school physics predicted a 2.4 – 2.8% higher achievement in introductory undergraduate physics than not taking high school physics, a result about one half that found by previous studies and greater than the 1.24% resulting from a preliminary analysis reported in Sadler and Tai's (1997) earlier article. College achievement on this 100-point scale had a mean of 81.8 and a standard deviation of 10. The authors conclude that this casts doubt on any major impact that particulary a 1-year high school physics course is thought to have on undergraduate achievement. However, the result conceals much detail related to demographic and schooling factors, and this is elaborated below. Also, students predicted that taking high school physics would result in a 7.8% increase in undergraduate achievement, an effect three times greater than the observed relationship.

Predictors of higher introductory undergraduate grades include race (being white related to a 3.62% advantage, and Asian 3.37%), taking calculus in high school (+2.58%), 1 year of regular physics (+2.26%), 1 year of honors physics (+3.51%), 1 year of AP coursework (+4.32%), and taking 2 or more years of any high school physics (+2.8%). These values are additive, so a student who studied calculus plus 2 years of regular physics is predicted to score (2.58 + 2.8 + 2.26)% = 7.64% higher in college/university. Institutions that restrict students without high school physics from enrolment in certain undergraduate courses should rethink that policy, since academically stronger students with calculus can do as well as, or even better than, students who have taken physics.

Sadler and Tai (2001) also analysed the data for only those students who had taken high school physics, and found the following predictors of introductory undergraduate achievement: white (+2.41%), Asian (+2.92%), calculus (+2.47%), 2 or more years of high school physics (+3.05%), and college professor being same sex as the student (+3.74%). Men performed 2.01% lower than women with the same background. Interestingly, whether a student took regular, honors, or AP physics in high school was not significant, because variations between students was better explained by differences in the pedagogical approaches adopted in high school courses than by categorisation of these courses on the basis of rigour. Other conclusions were that higher undergraduate grades were related to students whose high school courses had no text (or where the course required them to read it less), and who had high school courses that focussed on fewer topics, concepts, problems, and labs but in greater depth than textbook-centred courses which covered more content. Students from less affluent communities appear to be in greater need of the advantages provided by a strong high school physics preparation.

***SER Asks*: Philip Sadler**

Philip, your and Robert Tai's work has made a welcome contribution to the physics education field. Are there any plans for extending it?

Our work has been well received. This fall we were awarded a 4-year, $3M grant to expand our study to chemistry, biology, and physics preparation for college courses by the Interagency Educational Research Initiative (NSF, NIH, DoED). We are just beginning to set it all up.

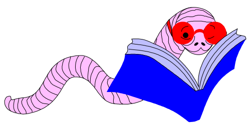
Peter Eastwell

References

Sadler, P. M., & Tai, R. H. (1997). The role of high-school physics in preparing students for college physics. *The Physics Teacher*, *35*, 282-285.

Sadler, P. M., & Tai, R. H. (2001). Success in introductory college physics: The role of high school preparation. *Science Education*, *85*, 111-136.

Yager, R. E. (1986). What kind of school science leads to college success? *The Science Teacher*, *53*(9), 21-25.



Research in Brief

It is perhaps appropriate to remind ourselves of the potential dangers of generalising from the conclusions of a single study, or even a series of studies in limited contexts. Education is a very complicated, dynamic, social process involving many variables, and no instructional panacea exists. Each of us needs to construct our own pedagogical preferences in context, using anything from simple trial and error and reflection to the conclusions of more formal research, and what works well in one context may not necessarily transfer, with the same success, to a different context.

Teaching Diffusion and Osmosis

Students find diffusion and osmosis difficult to understand. Odom and Kelly (2001) compared the effectiveness of four different approaches to teaching these topics to 108 Years 10 and 11 students in the USA; concept mapping (CM), the learning cycle (LC), expository instruction, and a combination of CM and LC (CM/LC). The students were in four different biology classes, and the same teacher taught each class. The Diffusion and Osmosis Diagnostic Test was used to assess students' understanding immediately after instruction and again 7 weeks later.

By actively engaging students in constructing an understanding of diffusion and osmosis, the CM/LC and CM treatments were shown to significantly improve some aspects of learning compared with the expository approach, and further research about the effects of an LC treatment is recommended. Diffusion and osmosis involve a number of complex processes that may be learned using a series of learning cycles, and concept mapping allows students to make connections between these concepts. The combination of CM and LC provided a very successful strategy.

Reference

Odom, A. L., & Kelly, P. V. (2001). Integrating concept mapping and the learning cycle to teach diffusion and osmosis concepts to high school biology students. *Science Education*, *85*, 615-635.

(*Editor*: The Learning Cycle strategy will be described in a forthcoming issue of *SER*.)

Peer Tutoring in Primary Science

Stephenson and Warwick (2001) report the positive outcomes, for all involved, associated with Year 5 students in the UK preparing a lesson on dissolving materials and teaching it to Year 2 pupils. The Year 5's prepared resources and key questions, practised teaching skills, and planned for safety. Four to five older students worked in each group with a similar number of younger students, supervised by 6 student teachers and their 2 regular teachers.

The children enjoyed the experience. The Year 2 students were excited by, and responded well, to the peer-peer interaction. By needing to focus on their own understanding, Year 5 pupils both reinforced and enhanced that understanding and developed their communication and collaborative abilities. While the regular teachers acknowledge the management implications associated with implementing this rarely used strategy without the assistance of the student teachers, they plan to continue with it on a once-per-term basis.

Reference

Stephenson, P., & Warwick, P. (2001). Peer tutoring in the primary science classroom. *Investigating*, *17*(2), 11-13.

Research and the Teacher

Science education research, aimed at better informing practice, has enjoyed a more than 30-year history. But how familiar are teachers with the conclusions of this research? Costa, Marques, and Kempa (2000), in a study of 42 participants in an advanced training program for secondary science teachers at two Portuguese universities, concluded that participants' awareness of research findings was very limited and that, arguably, the gap between teachers' knowledge and research-based knowledge is widening. Teachers' knowledge was based largely on personal experience and "common sense" and could be a barrier to desirable innovation. The authors have begun a research and development program aimed at closing the gap.

Reference

Costa, N., Marques, L., & Kempa, R. (2000). Science teachers' awareness of findings from education research. *Research in Science & Technological Education*, *18*, 37-44.

Effectiveness of Role-Play and Debate

Simonneaux (2001) compared the effects of role-play and a conventional debate on French students' arguments about whether or not to approve the establishment of a fictitious transgenic salmon farm in a seaside village. Neither strategies are familiar to students or teachers, and he advocates the help of humanities teachers. Pre- and post-tests were used to determine students' opinions. He found few differences between outcomes from each approach, but both strategies were accompanied by changes in students' opinions, a result previously not observed in conjunction with other strategies, such as visits to exhibitions, in which oral discussion by students had not been asked for. Rather than increasing the number of arguments, both strategies increased the persuasiveness of students' arguments. Simonneaux hypothesises that people tend to use fewer arguments in informed and committed decision making, on the premise that a few decisive arguments are sufficient. He emphasises the importance of the teacher following up these activities with reflective questioning and considers the identification, evaluation, and forming of their own opinions by students an essential aspect of science education and the development of scientific literacy.

Reference

Simonneaux, L. (2001). Role-play or debate to promote students' argumentation and justification on an issue in animal transgenesis. *International Journal of Science Education*, *23*, 903-927.

Computer Dissections

Predavec (2001) reports improved student outcomes for first-year undergraduate biology students from a web-based, interactive rat dissection compared with a traditional dissection. The improved outcomes applied to each of the three types of questions, and across different grades of student. For both approaches, greater time spent by students resulted in higher marks. He concludes that the computer-based dissection is a viable alternative to the use of animals in the classroom.

Reference

Predavec, M. (2001). Evaluation of E-Rat, a computer-based rat dissection, in terms of student learning outcomes. *Journal of Biological Education*, *35*, 75-80.

Newspapers in the Classroom

How are newspapers used by science teachers? Jarman and McClune (2001) found that only about one third of 50 secondary school Heads of Science in Northern Ireland used them in any systematic way in their courses, and only a few asked students to evaluate newspaper reports. Possible strategies include: designing comprehension activities based on an extract; identifying questions students would like to ask the scientist or journalist, and discussing these in small groups; extended writing, such as a *Letter to the Editor*; writing and presenting a short play; keeping a diary of science issues; given a headline, predicting a story; given a story, writing a broadsheet and a tabloid style headline; writing up science notes in newspaper format, with headline and word limit; looking for errors; and comparing the treatment of the same issue in a tabloid and a broadsheet.

Science reported in newspapers is likely to be science in the making, with a relatively weak evidence base and being somewhat tentative. Students should therefore be aware of the processes of conference presentations and refereed journals as tests for research findings. Also, when evaluating articles, students should appreciate the limitations associated with the production of newspapers, such as tight deadlines, others (and not necessarily science journalists) editing articles and composing headlines, and newspaper priorities like profit.

Reference

Jarman, R., & McClune, B. (2001). Use the news: A study of secondary teachers' use of newspapers in the classroom. *Journal of Biological Education*, *35*, 69-74.

How Much Cheating in Science Fairs?

Syer and Shore (2001) sought to determine the types of help received by students, and information about cheating, associated with participation in a regional science fair. They distributed 266 invitations, to students in the Montreal area, to return two anonymous questionnaires. The low 11% response was likely influenced by cheating behaviours being part of the study. The final sample comprised 24 students, in Grades 7-11 and from six high schools, who had been required to participate in the fair. With a content-driven curriculum and little "spare" time or resources at school, students completed their projects at home.

The World Wide Web, library, parents, and teachers were the highest rated possible sources of help, but students reported not receiving the help they needed from teachers, with only one half of the sample having consulted a teacher. The most frequently reported difficulty associated with the fair was time pressure, followed by deciding on an idea and keeping motivated. Five students reported cheating, in the form of making up data or results.

In addition to receiving more help from teachers, it is recommended that the compulsory involvement of students in a fair be considered with much care. Students need greater support from teachers in the form of monitoring their planning and data collection, and time pressure needs to be minimised. Teachers should not do the actual work, but help with management of the process.

Reference

Syer, C. A., & Shore, B. M. (2001). Science fairs: What are the sources of help for students and how prevalent is cheating? *School Science and Mathematics*, *101*, 206-220.

(*Editor*: Given that 20% of the volunteer respondents admitted cheating, the relatively low response rate, and the research design, one might predict a much higher rate of cheating in the total student population.)

Assessment Task: Choice in Assignments

As part of her effort to cater for students' different learning styles, Warton (2000) uses assignment choices that reflect each of McCarthy's (1996) 4-MAT learning styles. Assignment 1 is typically a discussion, interview, or creative story. Assignment 2 is always a report. A typical Assignment 3 is to build a model, but others include designing a poster or devising a solution to a problem. Assignment 4 could be inventing a new way of doing something, writing and performing a role-play, designing a computer presentation, or creating a way to teach something. During each year, students are required to complete all types of assignments, but not all contribute to their final assessment. This encourages students to take risks and practise their less preferred learning styles. The following example is for a Year 8 ecology task.

The Task

You will be choosing an endangered species and gathering information about where it lives, the reasons why it is endangered, how many are estimated to still be alive, and what can be done to save it from extinction. Your assignment must include a bibliography. Choose from the four types of assignments below to write up your research.

Assignment 1: Interview an endangered species. Imagine that you can talk to a plant or animal that is endangered. Write questions and answers for the interview and include all the information described above. Length: Two A4 pages.

Assignment 2: Report. Write a report about your chosen endangered species. Include all the information described above. Length: Two A4 pages.

Assignment 3: Poster. Create an information poster for use in a science classroom or at a zoo. Your poster should be on cardboard and requires both written information and diagrams and illustrations. Include all the information described above.

Assignment 4: Write a children's book. Write a children's book to teach children about the endangered species you chose. Use simple language they can understand, and include illustrations. Include all the information described above.

Assessment Criteria

Gathering information	
Uses more than one source of information	0 - 2 marks
Uses keywords or technical language	0 - 2
Summarises information	0 - 2
Processing information	
Collated information	0 - 1
Relevant information	0 - 2
Presenting information	
Correct text type and mode of presentation	0 - 3
Well presented	0 - 1
Acknowledges sources of information	0 - 2
Knowledge and understanding	
Identifies factors affecting survival of organisms in ecosystems	
Appropriate organism	0 - 1
Where it lives	0 - 4
Reasons why endangered	0 - 4
How many are alive	0 - 2
What can be done to save it	0 - 4
Total	30 marks

Reference

McCarthy, B. (1996). *About learning*. Barrington: Excel Inc.
Warton, A. (2000). Providing opportunities for choice in science assignments to address learner diversity. *Science Education News*, *49*, 155-157.

(*SER* gratefully acknowledges *Science Education News*, the official journal of the Science Teachers' Association of New South Wales, Australia, for kind permission to modify the above article.)

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

The questions in this section of *SER* have been contributed by subscribers, or have been asked by teachers during Science Teacher Workshops I have conducted.

Would a magnet exist in outer space?

Yes. If one took two bar magnets into outer space, like poles would repel, unlike poles would attract, and the magnets would still attract paper clips; just like on Earth. The property of magnetism does not require being near Earth. In fact, Earth itself behaves like a giant bar magnet, so when a compass needle (which is just a small bar magnet) is near Earth, the north-seeking end of the compass needle is attracted towards the Earth's north pole.

What is the difference between an atom and a molecule?

Atoms are the basic units that make up all matter, and there are only a little over 100 of them. For example, we have copper atoms, oxygen atoms, hydrogen atoms, and uranium atoms. Let's consider how these atoms, or basic building blocks as they are called, make up a few different substances. A copper rod, for example, consists simply of many copper atoms joined together. We give each copper atom the symbol Cu. In water, the atoms are arranged in a very different way. Liquid water consists of many water particles moving around slowly and independently, and each water particle is actually made by joining together two oxygen atoms (O) and one hydrogen atom (H). This is why water has the formula H_2O. When two or more atoms are joined together like this to make particles of a new substance, we call the resulting particle a ***molecule***. Other substances which consist of molecules are ammonia gas (NH_3; one nitrogen atom joined with three hydrogen atoms), oxygen gas (O_2), and sugar ($C_{12}H_{22}O_{11}$; the C stands for a carbon atom).

Why can't Cling Wrap break down?

Cling Wrap, thin plastic sheeting used for wrapping food, is made in yet another way. It consists of many ethylene molecules (an ethylene molecule contains two carbon atoms and four hydrogen atoms) which are themselves joined together to form very long chains, similar to links in an everyday chain, and many of these chains stick together to make the Cling Wrap. Structures like this take a very long time to decompose, or break down into simpler pieces, so disposal is a major environmental concern. Fortunately, Cling Wrap and many other plastics like it can be easily recycled, because they are readily melted and reformed over and over.

During the 1970's, chemists introduced biodegradable plastics. Here, the long chains are separated by molecules of starch or cellulose, which can be attacked and consumed by microorganisms and hence cause the plastic to deteriorate. However, additives can make plastics unfit for recycling, which some argue is a better way to conserve resources.

Why can't a virus be treated with antibiotics?

Antibiotics are drugs that typically damage certain living cells (like those of disease-causing bacteria) but not normal cells in humans. Viruses are different to bacteria. They are not living cells, being so primitive that many scientists consider them both living and non-living. Viruses are much smaller than bacteria, live in cells, and cause disease by damaging those cells. By itself, a virus is a lifeless particle which cannot reproduce. However, inside a living cell it becomes an active organism that can multiply.

In most cases, we cannot use drugs to kill or damage a virus because the drugs that will do this also damage healthy cells, but antiviral drug research continues. The main treatment of a viral disease is controlling the symptoms. Better is immunisation before a virus strikes. These vaccines, as used to prevent influenza, measles, and polio, cause the immune system to produce antibodies that resist a virus when it enters the body.

Why do cold substances, like dry ice, burn the skin?

Like very high temperatures, very low temperatures can destroy body cells. The difference is that in the latter case, the cells are destroyed when the fluid inside them expands upon freezing, just like a sealed glass bottle filled with water and left in a freezer will break when the water expands as it changes to ice. Dry ice has a temperature of -78.5°C, easily low enough to freeze the liquid in living cells. Liquid nitrogen, at -196°C, is even colder and is commonly used by doctors to remove blemishes from our skin. Interestingly, our nerves cannot distinguish between very high and very low temperatures, and simply record the sensation of pain in both cases. The blistering and swelling associated with both hot and cold burns is due to fluid leaking from the damaged area.

How was ice made in the days of only ice boxes?

The "ice man" collected blocks of ice from a manufacturer, such as a Dairy Cooperative, that operated a compression refrigeration system. The refrigeration cycle was brought about by an electrically powered piston compressor that caused the refrigerant, ammonia gas, to change from a liquid to a gas, back to a liquid again, and so on. These plants commonly leaked ammonia, thus presenting a significant occupational health hazard.

Ice boxes, used for domestic cooling purposes before the development of modern refrigerators, had cakes of ice placed in the upper section. The warm air rose, got cooled by the ice, and this cooler air then flowed downwards to the food compartments where it absorbed heat energy from the food (cooling the food), warmed up, and again rose towards the ice. This cycle continued.

The Changing Nature of Science Teacher Education: An Interview With Keith Lucas

Keith Lucas is an Associate Professor in the School of Mathematics, Science and Technology Education at Queensland University of Technology (Locked Bag 2, Red Hill 4059 Australia). His research interests include the construction of science meaning by students, science learning in informal settings such as interactive science centres, and the professional development of teachers and teacher educators, particularly in developing countries. Regular teaching involvement in recent years has included science curriculum for pre-service and graduate students, the design and teaching of Faculty based research methods courses, and supervision of candidates at masters and doctoral levels. He has served as editor of the *Australian Science Teachers' Journal*, Assistant Editor of *Research in Science Education* (the journal of the Australasian Science Education Research Association), a member of the Editorial Board and the International Committee of the National Association for Research in Science Teaching, and as a regular manuscript reviewer for the *Journal of Research in Science Teaching* and *School Science and Mathematics*. In 1991 and again in 2000, he was awarded the Australian Science Teachers Association Distinguished Service Award.

SER*: *Keith, you have been involved in teacher education for over 35 years. What changes have you seen during this time in the ways pre-service teachers are prepared?

***Keith*:** The most obvious change I suppose has been the length of the pre-service course taken by most science teachers. Forty years ago in Australia, a significant proportion of science teachers completed a basic three-year degree in science followed by a one-year diploma in education. Additionally, there were many who chose to attend the teachers' colleges, which were part of the state departments of education, rather than a university and to complete a two-year diploma of teaching course. These were the main entry pathways to a science teaching career although there were some others, notably some private schools employed science graduates without any professional teaching qualification such as a diploma in education. That was how my career as a science educator commenced.

In the intervening years, the two-year diploma courses lengthened, first to three-year diploma courses, then three-year and ultimately to four-year bachelor of education degree courses. The first two years of such courses are predominantly science based and the others predominantly professional studies in education, including science curriculum and practice teaching. The traditional bachelor of science degree remains a three-year course in most Australian universities, but science graduates are increasingly being required to complete a two-year graduate bachelor of education or master of teaching degree before being eligible for registration as a teacher.

So, there has been a significant increase in the duration of pre-service science teacher courses. Another change which I regard as very significant, and detrimental, has been the reduction in the quantity and diversity of science discipline studies required of pre-service science teachers. For example, the traditional bachelor of science course required students to complete at least one full year of study in four distinct branches of science, including mathematics. Today in many Australian universities it appears to be possible to graduate with a degree in one branch of science without any study in one or more of the other major branches of science. While graduates of such courses may be well suited for numerous occupations, science teaching at the junior secondary school level is certainly not one of them.

A related issue is the remarkable changes that have occurred in the number and character of the institutions in Australia that offer pre-service courses for science teachers. Teachers' colleges became colleges of advanced education (CAE) during the seventies, largely independent of the state education departments and increasingly providers of courses in fields other than teacher education. The CAEs generally did not offer post graduate degree course or conduct extensive research but were effective and efficient providers of quality teacher education, due in no small part to the demonstrated expertise and substantial in-classroom teaching experience of the teaching staff. A wave of institutional restructuring that included forced amalgamations of universities and CAEs during the eighties and early nineties, driven by economic rationalism and political centralist policies of the federal government, resulted in the demise of the CAEs. Priorities within teacher education institutions have changed in recent years: lecturers see their careers being advanced more by the award of research grants than by a commitment to promoting excellent teaching; practice teaching increasingly is problematic in respect of cost and availability of suitable placements for students; and the role of the specialist curriculum lecturer is being usurped by so-called generic approaches to curriculum and the proliferation of courses to meet particular political or social agendas.

Have you discerned any changes in the attitudes of pre-service teachers during the years?

This is a difficult question to answer, not the least because any changes I describe may reflect changes in me rather than changes in pre-service teachers! Nevertheless, I believe that the appeal of science teaching as a career option has decreased in recent times in line with a marked decline in the perceived social status of teaching within the community and higher financial rewards elsewhere.

Scholarships for pre-service teachers are now rare in Australia, but twenty years ago they were common, providing tuition and living expenses, and guaranteed employment on completion of the course. Typically scholarship holders were bonded to the state departments of education to teach for several years, often in small schools in rural communities. Acceptance of this condition constituted evidence of a high level of commitment to teaching as a career which is not always evident in contemporary pre-service teachers, especially if they were denied entry to more favoured university faculties such as medicine, engineering, or law. If entry to a pre-service teacher education is perceived by students as a consolation prize, their commitment to a long term career in teaching is not assured. However, it seems to me that in recent years there have been more mature aged entrants to pre-service science teaching courses–engineers and scientists with years of professional practice undertaking a career change. To do so usually requires of them a remarkably high level of commitment to teaching. In my experience, they transform the nature of the typical pre-service science curriculum class and enrich the quality of science education in school classrooms by virtue of their maturity and relevant life experiences.

One thing that puzzles me a little is that, while integrated science courses were introduced into Australian secondary schools well in advance of many similar countries, there appears to be a decreasing proportion of beginning science teachers who envisage themselves as teachers of science as distinct from teachers of a particular science. I suspect that an explanation may be found in the increasingly narrow and specialised nature of first degrees in science in Australian universities, combined with the demise of integrated discipline and curriculum programs characteristic of the teachers' colleges prior to the mid-seventies and CAEs to the early nineties. If I am correct in this, then there is an urgent need for science teacher educators to find ways to attract and retain young teachers who are keen and well prepared to teach broadly based contemporary science curricula across the compulsory years of schooling.

Do you have any suggestions for facilitating the professional development of practicing teachers?

I think that the best professional development programs for science teachers that I have encountered were conceptualised and facilitated by science teachers' associations at state and national levels, i.e., by science teachers themselves, and funded by generous grants from state and national governments. They were excellent because they did not adopt the common "deficit model" of professional development whereby teachers are perceived by others to be lacking in some important knowledge or skill, and these others set out to provide it for them. Unfortunately the provision of funds for in-service professional development programs to non-profit organisations such as science teachers' associations has been severely curtailed in recent years. You will gather from this that I favour professional development programs that are long term, teacher initiated and school based, and designed to address professional development needs that are vital to teachers themselves. Certainly they may involve "outsiders" such as curriculum developers or university based colleagues, but the impetus and control ought to rest with the teachers themselves. I think such programs have the best chance to make a difference to the quality of the science education of kids, which is really the only reason I can think of for supporting professional development for teachers.

In my view, professional development is a personal professional issue and the key is intrinsic motivation to improve one's own professional practice. Individual science teachers who recognise a personal need to enhance their professional competence are now better served than ever through the increased numbers and varieties of tertiary institutions and courses available. Before 1980 there were very few tertiary institutions in Australia offering post graduate courses suitable for science teachers intent on enhancing their classroom practice, and even fewer opportunities to complete them part-time in one or more of the flexible study modes that are now so familiar a part of Australian universities. Teachers can choose from post graduate diploma courses designed to introduce them to new knowledge and skills, masters degree courses in various areas of specialisation, and research degrees at masters and doctoral level.

What impediments do you see here?

Simply cost and time, from the teachers' perspective. Although places in research degree programs at doctoral level generally attract fee subsidies, and even meagre scholarships, these are in my view the least useful professional development avenues for young science teachers. Of course, the financial support offered for such research degree candidates has much more to do with the research profile and federal funding of the universities and supervising staff than the enhancement of the quality of the science education of children in school classrooms. For other degrees and diplomas, teachers are required to pay substantial fees and to squeeze time for classes, reading and assignments into schedules already crammed with the multitudinous responsibilities of teacher, family and community interests.

Please don't misunderstand me here. I have worked with many teachers of science and other disciplines at diploma, masters and doctoral levels who have accepted the costs involved as a normal part of their personal responsibility for their own professional development and somehow have found the time to engage in the courses enthusiastically. They value the outcomes highly in terms of their own professional development. There are many excellent opportunities for professional development through courses designed for, or suitable for practising teachers in Australian universities. My concern is simply that many many more teachers do not avail themselves of these opportunities. I understand that cost and time are major impediments to them doing so.

Any thoughts about ways of better sharing the wisdom of experienced classroom teachers?

I presume that you mean by this, sharing among colleagues who are classroom teachers of science. This is a challenging issue. As you know, the state and territory science teachers' associations in Australia, and the national science teachers' association which is an affiliation of the state and territory associations, have been active for more than 50 years. Membership has waxed and waned over the years, never achieving membership levels inclusive of the majority of science teachers. However, the associations at state and national levels continue to provide wonderful opportunities for the kind of sharing that you refer to. Nevertheless, we live in a changing world, and strategies such as annual conferences and print journals that have served the associations well in the past are being found lacking in meeting the requirements of contemporary teachers. Strategies are needed for revitalising the associations and capitalising on new technologies to establish communities of professional practice.

I am a fan of schemes that enable teachers to visit and work a while in different locations. A few such schemes have operated over the years to enable Australian science teachers to exchange teaching assignments with colleagues from other states or other countries. An example was the UK/Australia Fellowship for Teachers of Science which provided for ten Australian teachers to exchange with UK colleagues between 1990 and 1995. Sadly sponsorship lapsed. In my view, increasing the availability of opportunities for science teachers to travel and work overseas would be an excellent way to share the wisdom of experienced teachers of science among their colleagues, and at the same time to invigorate the professional practice of the travelling teacher, because sharing is a two-way activity.

Occasionally during my career in teacher education we have been able to find funds to enable us to appoint "visiting teachers" to our department for one or two semesters. Their role was not to teach, but to interact with the regular faculty, thus, to use your phrase "sharing their wisdom of experience" with staff and students. We found this to be an extraordinarily beneficial venture for all concerned. Visiting teacher programs should not be confused with an emerging practice in Australian universities of "using" secondary science teachers, and graduate students, as low cost part-time staff to teach undergraduate curriculum courses to pre-service teachers.

What has not changed during the years?

Several things appear not to have changed very much during the past four decades. There is still a serious shortage of well qualified science and mathematics teachers in primary and secondary schools, especially in senior physics and chemistry. Also, I've not noticed much change in the overwhelmingly large proportion of science teacher education students and practicing science teachers who are dedicated to their students and to the promotion of high quality science education in Australian schools. Despite the changing nature of teachers' work, dedicated teachers seem to thrive on the challenge and professional satisfaction associated with teaching science at all levels of the school. Finally and disappointingly from my perspective, there has been little long term change in the low proportion of science teachers who are active members of their state and national science teachers' associations. I have derived much pleasure and a tremendous amount of professional help and direction from my involvement with the state and national science teachers' associations since my early years as a secondary science and mathematics teacher in Sydney. I'd like to think that that will continue for me, and an increasingly large number of my science teaching colleagues well into the twenty first century.

Thankyou, Keith.

Further Useful Resources

Volvo Ocean Adventure http://www.volvooceanadventure.org

An environmental education learning experience using data collected by yachts in the Volvo Ocean Race, a round-the-world yacht race. Sensors monitor plankton levels in the oceans, and satellite imagery from NASA and ESA [European Space Agency] is used. Data will also be available for classroom use after the race finishes. The data may be used by students to develop an understanding of the workings of the oceans and the impacts they make on our climate and food chain, to perform experiments and local environmental investigations, and to devise and share action plans for reducing environmental impact. There are prizes to be won.

Teacher Focus http://www.teacherfocus.com

A forum for teachers across the curriculum, with resources, reviews, and more.

The Learning Revolution http://www.thelearningweb.net

Dryden, G., & Vos, J. (1997). *The learning revolution (Your 21st century passport: For families, students, teachers, managers, trainers)*. Auckland: The Learning Web Ltd.

Content includes trends shaping our world, needs for a 21st century education system, how the brain works, steps to better learning, creative thinking, and learning styles. Also included is a series of Powerpoint presentations (colour slides and audio on CD) suitable for parent evenings and/or inservice. (Also available from Rodin Educational Consultancy www.rodineducation.com.au .)

Experiment of the Week http://www.krampf.com

E-mail Rob Krampf, an experienced science and museum educator, and he will put you on his e-mail list to receive a free student experiment each week.

schoolscience.co.uk http://www.schoolscience.co.uk

A source of information and pictures, with some interactivity, about the latest applications of science, including The Chemistry of Steelmaking, A World of Particles, The Science of Audiosystems, Cancer and its Treatment, The Human Genome Project, Medicine and Drugs, and The Periodic Table.

Concept Cartoons in Science Education http://www.conceptcartoons.com

Concept cartoons, which feature different viewpoints about an issue, may be used in many ways, including providing a stimulus for discussion or investigation, determining students' prior understanding, and an aid to revision of a topic. (Also available on CD from Science Teachers Association of Queensland, Australia www.staq.qld.edu.au .)

Readers are invited to send, to The Editor at editor@ScienceEducationReview.com , details of your favourite science education website or other resource for inclusion, with acknowledgement, in a future issue of *SER*.

Humour

Teamwork

A doctor noticed severe bruising on the shins of her patient. “Are these from playing soccer or hockey?” she asked. “Neither,” said the patient. “Bridge”!

Just not Teamwork

Two hikers look up to see a lion about to charge them. One hurriedly takes off his boots and puts on running shoes. “You’ll never outrun a lion,” says the other, “so why bother putting those on?” “I don’t have to outrun the lion. I just have to outrun you”!

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Contributions are welcome, as are expressions of interest in joining the Editorial Review Board. The latter role requires the periodic review of submitted contributions, and is not onerous. Comments, questions, and article proposals may be sent to The Editor, Dr Peter H. Eastwell, at editor@ScienceEducationReview.com .

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