Volume 1, Number 3 - 2002

THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

It may be far more hygienic to prepare food on a toilet seat than in the kitchen! Some tests have shown microbe levels on sinks, kitchen chopping boards, and taps to be much higher than on toilet seats, which are typically too dry to support large bacterial colonies. A damp dishcloth is a great source of microbes; and just what many of us use to try to clean the kitchen!

Science Story

Beethoven's Ailment

The German, Ludwig van Beethoven (1770-1827), is one of the greatest composers of all time. What makes his work all the more remarkable, though, is that he wrote his amazing music under quite adverse circumstances.

From the age of 20 years, he experienced increasing deafness, as well as abdominal pain, digestive difficulties, and personality changes in the form of depression and irritability. Despite the pain, he also wrote most of his finest music during this time, continuing to compose incredible music to the day he died. No doctor could diagnose the problem, but it appears that the answer came 2 years ago, 173 years after his death. Element 82, lead, may have killed Beethoven early at 57 years.

After his death, a young music student cut a lock of his hair, a custom of the time. This hair passed through various hands and generations (including an auction!) until, in 2000, modern analytical chemistry techniques were used to determine that Beethoven's body contained a level of lead about 100 times greater than that found in an average person today. As an aside, lead poisoning very rarely causes deafness, and the tests also showed no evidence that Beethoven had taken painkillers, suggesting that he had chosen to persevere through the pain. Opiates were the likely painkillers of the day, and these would have affected the clarity of his mind.

Lead is one of the world's oldest known metals. It has been used for thousands of years as a building material, for water piping, and to make pottery and other things. The symbol for lead, Pb, originates from the Latin word for lead, plumbum. In Roman times, a person who worked with lead pipes was called a plumber, a term which we still use today. For more information about lead poisoning, refer to the question in the *Your Questions Answered* section of this issue.

Social Constructivism

How do students best learn in science? The traditional, teacher-centered view was that students, viewed as "empty vessels" waiting to be filled with new knowledge, "received" understanding by absorbing information supplied by teachers and found in written materials. This information included facts, good explanations, and the use of algorithms to solve problems. There appeared an underlying assumption that, after memorising a critical mass of facts, students would interconnect concepts and develop understanding spontaneously.

We have evidence that such an approach has been less effective in developing understanding than is desirable. For example, "many of the most able students (such as university physics majors and engineering students) have as many misconceptions about science as the average high school student" (Yager, 1991, p. 52). Rather than being "blank slates," students bring their own unique experiences and personal beliefs to the science classroom, and some of these intuitively held ideas differ from the ideas accepted by the scientific community. What is more, students' conceptions are resistant to change through traditional teaching strategies, may be context dependent (i.e. a student may apply different, and even conflicting, concepts in different contexts) and, most significantly, students' prior conceptions, by providing the interpretative schema through which new ideas are viewed, highly influence what their new understanding will be like (Osborne & Wittrock, 1983; Palmer, 2001; Tsai, 2000). "Domain-specific preinstructional knowledge has proven to be *the* key factor determining learning and problem solving in research in all science domains" (Duit & Treagust, 1998, p. 19).

Supplying information to students, without accounting for their existing beliefs, often doesn't do much to help ideas "make sense" to them, and learners frequently develop immature, incomplete, or even dual understandings (Ciascai, Chiç, & Pop, 2002; Wandersee, Mintzes, & Novak, 1994). The latter refers to the situation in which a student adopts one perspective in the classroom and yet a different way of understanding away from the classroom, as in the case of the student who understands the reasoning for why both a small and a large dense mass, when dropped simultaneously, will hit the ground at the same time, but not believe it. Information not connected with a student's prior understanding may also be easily forgotten and not readily transferred to similar, or novel, situations.

The prevailing learning theory in science education, social constructivism, is a more student-centered perspective which embodies the notion that learners construct their own knowledge and understandings based on their existing ideas and the socio-cultural context in which they find themselves (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Solomon, 1993). Meaningful learning occurs when new information is integrated within a coherent conceptual framework (rather than stored in an isolated manner), and such integration requires existing knowledge to be extended and/or restructured. This is a highly individual process, as a learner's prior experiences will influence what aspects of a new learning experience are selected and attended to, what links are created to the long-term memory, and what interpretations are made of the language used in the communication (Osborne & Wittrock, 1983).

Now, the idea of students actively constructing knowledge is not new, and many teachers have been constructivists long before they knew it! However, the theory of social constructivism does provide us with some useful recommendations for the classroom, so let's summarise a few of them.

1. Connect learning with everyday contexts. Where possible, organise courses around problems, of local interest and impact, which have been identified by students.

2. Elicit students' existing ideas, including any alternative conceptions.

3. Implement activities which build upon students' current understandings, and which promote conceptual change by challenging these understandings. Discrepant events (an event in which the result is different to that expected by many students) and student predictions (with reasoning), for example, are useful tools for confronting students' misconceptions.

4. Prepare and use higher order questions, questions which ask how and why, rather than what alone. Remember to allow wait time, since challenging questions demand time to think.

5. Encourage students to take responsibility for their own learning, and this includes reflecting on their own thinking and learning processes. "An appropriately metacognitive learner is one who can effectively undertake the constructivist processes of recognition, evaluation and, where needed, reconstruction of existing ideas" (Gunstone, cited in Tsai, 2001, p. 970).

6. Plan for both teacher-student and student-student social interaction (Tobin, Tippins, & Gallard, 1994). While constructing new understanding is a highly individual activity, communicating with others can enhance learning because it allows students to test their ideas and to consider the ideas of others. Small group discussions, cooperative learning, role plays, and simulation games, for example, all have a place.

7. Practical work needs to be an integral part of the learning sequence, rather than a "tack-on" for practical work sake alone. It also needs to be minds-on, as well as hands-on (Skamp, 1998). Rather than restricting hands-on activities to cookbook or confirmation-style experiences only, provide opportunities for more open-ended investigations which better challenge students' thinking.

8. Plan for the fact that, in addition to having different prior experiences, students will also have different preferred learning and working styles (Gardner, 1992) and learn at different rates.

9. Employ formative assessment frequently (Bentley & Watts, cited in Wellington, 2000.)

10. Use a variety of assessment techniques, including authentic assessment which is conducted while students are engaged in non-contrived activities like practical work or other real-life situations. This caters for diversity in the ways students represent their knowledge and understanding.

If this is the path down which we seek to travel, it is probably fair to assume that some of us are further into the journey than others, and that we all would appreciate any help we can get. By sharing classroom practices which reflect social constructivist principles, much of the content of *The Science Education Review* will assist in implementing the above recommendations.

The Constructivist Learning Environment Survey (CLES) (http://surveylearning.com) is a tool for assessing how consistent a particular classroom environment is with a constructivist epistemology. It may be completed on-line by students and/or the teacher, and the results are compiled and reported automatically. The plausibility of the CLES has been established, and its statistical integrity and robustness validated (Taylor, Fraser, & Fisher, 1997).

In accord with findings that students achieve better when their actual learning environment matches their preferred environment (Fraser & Fisher, 1983), the survey provides for responses to perceptions of both the *Actual* environment and the *Preferred* environment. Each survey comprises five scales: *Personal Relevance Scale* (addressing the use of everyday contexts, and the connectiveness between school science and students' out-of-school experiences); *Uncertainty Scale* (assessing the extent to which students experience science knowledge as arising from theory-dependent enquiry involving human experience and values, and hence as evolving and culturally and socially determined); *Critical Voice Scale* (examining the extent to which students feel free to question their teacher's approaches and to share impediments to learning; *Shared Control Scale* (concerned with the involvement of students in sharing planning, implementation, and assessment with the teacher); and *Student Negotiation Scale* (examining the opportunities provided for students to exchange and consider views).

The CLES could be employed in varied ways, and would be a particularly useful tool in action research projects. It could be used, for example:

- to assist teachers to reflect on their epistemological assumptions and to modify their teaching practices;
- to monitor the effectiveness of such attempted changes in practice to a more constructivist approach; and
- to evaluate the impact of constructivist approaches to teaching and learning on student outcomes.

A constructivist view can be a uniting view, because it can include so many strategies, like enquiry learning, cooperative learning, and science/technology/society, which have at times been labelled fads by some. "Far from being faddish, the teaching practices supported by constructivism represent the best practices of science teachers since time immemorial!" (Colburn, 2000, p. 12).

Peter Eastwell

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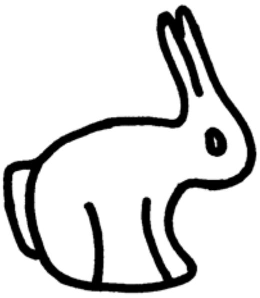
Demonstrations

What do you See?

Look at the sketch below. What do you see? What do others in your class see? A rabbit? Now rotate the image 90º counterclockwise. What do you and others see? A duck? What do you conclude?



In identifying the features of the nature of science (NOS), Eastwell (2002) included that "different scientists can observe the same things, and interpret the same experimental data, differently" (p. 45). This activity might be used to demonstrate this point; and even that the same scientist can interpret data in different ways!

Reference

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The Magic Candle

Needed. A medium-sized candle, "Magic Candle" (a candle which automatically relights after being blown out, and available from party shops and some supermarkets), box of matches, and draft-free room.

Invitation. Can you suggest a way to light the standard candle without touching anything to the wick?

Exploration. Try any student suggestions, as well as the following. Light the candle and, when it is burning with a strong flame, use a short puff to blow the flame out. Immediately, place the flame of a burning match in the trail of smoke coming from the candle, and a few centimetres away from the wick. Surprisingly, the candle bursts into light. Invite students to hypothesise; i.e. to propose possible explanations for why the candle lights.

Concept introduction. Where practicable, test the student hypotheses by testing predictions which follow from them. It is not uncommon for students to believe that the light produced by a candle comes mainly from the burning wick, rather than from the burning wax, which is the fuel.

When a wick is lit, the heat energy produced melts some solid wax. This molten wax moves up the wick by capillary action, vaporises, and burns to produce light and more heat energy.

After the candle is blown out, the wick is still hot and melts some wax. It is this molten wax that produces the smoke trail. The smoke consists of very small particles of wax, which burn readily. Touching a match flame to the smoke trail causes this wax to begin burning, and the flame travels right back to the wick and reignites the candle.

Extension. Demonstrate the operation of a "Magic Candle." Invite students to hypothesise about how it works.

Students will hopefully ponder other ways by which the wax might relight. In this case, the wax has red phosphorus added to it. The burning candle causes the phosphorus particles to spark up and, after the candle flame is blown out, to relight the wax.

Student Experiments

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

Shattering Rocks

Needed. A glass jar with screw-on lid, water, clear plastic bag, and access to a freezer. (Additional optional materials are mentioned below.)

Invitation. Frost can break up rocks. Can you explain how this might happen?

Exploration. As the water in a cup freezes (i.e. changes to ice), does it expand (i.e. take up more space/volume), contract, or not change size? Make a prediction. Design and carry out an experiment to find out. As an extension, students might also be asked to determine how much the volume changes (if at all), and even express the change as a percentage of the original volume.

In addition to other student suggestions, the following approaches might be tried:

1. Fill the glass jar with water, screw on the lid, place it in the plastic bag, tie the bag, and put in the freezer overnight. What has happened to the glass? Why?

   This activity demonstrates the frost shattering of rocks. However, unlike the following procedures, it does not allow for a quantitative determination of the volume change.

2. Partially fill a plastic measuring cylinder with water, record the volume, place in a freezer overnight, and then note the new volume. After freezing, the top surface of the ice may be uneven, so an average reading may be necessary.

3. Use an appropriate glue or sealant to seal the small needle end of a syringe, and half fill the syringe with water. You need to push the plunger down to the water surface. To do this, place a wire down the side of the plunger, thus allowing all the air to escape as the plunger is pushed in. Record the volume of the water. Freeze overnight and record the new volume.

4. Inflate a balloon with water. Tie the top, place it on a desk top, and measure its circumference. Freeze the balloon and measure the new circumference as before.

Concept introduction. As water is cooled below 4°C, it expands. After freezing, it has a volume about 1/11, or 9%, greater than it had at room temperature. In other words, 11 mL of water becomes 12 mL of ice. This occurs not as a result of the water particles (molecules) getting bigger (they stay the same size), but because the water particles slow down as they are cooled and pack together in an arrangement which takes up more space. When water gets into cracks in a rock, the water can freeze, expand, and cause the rock to break into smaller pieces.

Concept application. (1) An empty 200-litre fuel drum is filled with water. By how much will the volume of the water increase if it freezes? (*Answer:* 9% x 200 L = 18 L, which is quite a volume.) (2) In what places in Africa would you more likely find rocks which have been produced by frost shattering? (*Answer:* On mountain tops, where it gets coldest.)

Reaction Time

Needed. Two students and a ruler.

Invitation. Your reaction time is the time between something actually happening (the stimulus) and you reacting (i.e. doing something about it). For example, the stimulus might be seeing a child run onto the road in front of your car, and your reaction could be starting to apply the car brakes. Why is there a time delay between such events? To which type of stimulus do you respond the most quickly; seeing something happen, hearing something, or being touched? Do girls respond quicker than boys? Can you suggest a way to answer the last two questions? Discuss student suggestions.

Exploration. In addition to inviting students to carry out suggested procedures which are feasible, the following might be used. Hold a ruler near the top so it hangs vertically. Ask your partner to hold their thumb and forefinger, with a 4 cm space between them, either side of the 0-cm mark near the bottom of the ruler, and prepare to catch the ruler as quickly as he can after it begins to fall. He is not allowed to chase the ruler by moving his hand downwards; that would be cheating! Without warning, release the ruler and record the measurement on the ruler where his thumb caught it. The smaller the measurement, the quicker his reaction time.

Repeat three more times, varying the time between when your partner’s hand is placed in position and the ruler is released. This helps to prevent the ruler being caught by anticipation. Average the results. Did your partner improve with a little practice? Swap roles and have your partner test you in the same way.

Having tested your partner’s response to a visual stimulus (i.e. to seeing something), repeat the experiment for an auditory stimulus (i.e. hearing something). Ask your partner to close his eyes and to catch the ruler as quickly as he can after he hears you say a chosen word like “Go.” Make sure that you release the ruler at the same instant you say “Go.” Average the four results. Did your partner improve with a little practice? Again, swap roles and have your partner test you in the same way.

Finally, test your partner’s response to a tactual stimulus (i.e. to being touched). Ask your partner to close his eyes and to catch the ruler as quickly as he can after you touch his hand. Make sure that you release the ruler at the instant you actually touch his hand, rather than at the instant you begin to move your hand towards his. Average these four results. Did your partner improve with a little practice this time? Once again, swap roles and have your partner test you.

Are there any major differences between your results for the use of different senses - sight, hearing, and touch? What did other students in the class conclude from their results? How do the average reaction times for girls in the class compare with those for boys? As an option, you could compare the results you obtain from doing this experiment in the morning with those obtained during the evening.

Concept introduction. The delay in your reaction to some event is inevitable. It is due to the fact that it takes time for your eye, ear, or hand to signal your brain that the ruler is falling, for your brain to decide what to do, and for your brain to then send another signal to your hand, causing the muscles to move. The signals are electrical impulses which move along nerves. Your reaction time can be affected by drugs and alcohol.

Alert students to the possibility of a connection between the results of this experiment and their preferred perceptual learning style (visual, auditory, tactual, or kinesthetic) as introduced by Margaret Underwood in the *Catering for Individual Student Needs: Learning Styles (Part 2)* article in this issue.

Extension: More advanced students could be invited to convert the measured reaction distances to reaction times. (*Method:* Use $d = gt^2/2$.)

Science Poetry

Science has the Answers

I wonder why the clouds are white,
I wonder why Pluto is out of sight.

I wonder why volcanoes blow,
I wonder why glow worms glow.

I wonder why the sky is blue,
I wonder why you do what you do.

I wonder why we sadly cry,
I wonder why the sky is so high.

I wonder why the stars are so bright,
I wonder why they shine each night.

Louise Miller
Year 7
Australia

Inventors

Many scientists from lands beyond
Have paved for us our way,
So we can have some luxuries
That we think are things of everyday.

When Bell first made the telephone,
Everyone was overjoyed,
Not only messages could be sent quick,
But more people could be employed.

When Volta made the battery,
Napoleon made him a count,
We use his electricity everyday,
Except how many times, I don’t know the amount.

Boyle challenged Aristotle’s theory,
That earth, air, fire and water compose all matter,
So it was Aristotle (long gone) against Boyle (alive),
Only for modern chemistry to be founded by the latter.

Edison made inventions
That still shape our world today,
Just imagine life without lights!
“Thank goodness he lived!” I say.

These great scientists were really something special,
And I’m sorry if I’ve missed some,
(I’m positive I have)
But I hope there are many more great scientists come!

Now all of these great scientists,
Are long gone buried and dead,
But if you think of the world they lived in back then,
They certainly used their head!

I’ll probably never be as great as them,
But that doesn’t matter,
As long as I can remember
How they made our world much better.

Rebecca English
Year 8
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Catering for Individual Student Needs: Learning Styles

(Part 2)

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Physical Strand

Perceptual. The first element deals with perceptual modalities. These refer to our preferred ways of taking in new information. While there are many ways in which people do this, the Dunn and Dunn model deals with four generally accepted ways: visual, auditory, tactual, and kinaesthetic learning. This is a major element of the model. In brief, visual learners remember most of what they see, auditory learners remember most of what they hear, tactile learners learn through touch (which is completely understandable when you think of the concentration of sensory nerve endings in the palms of the hands), and kinaesthetic learners (a very different group to tactiles, though they are often grouped together) need to be fully involved in the learning process with their whole body. Kinaesthetics learn by doing, not by touching, listening, or watching something.

Interestingly enough, we are all born kinaesthetic learners; we need to move to be able to learn. Then we develop the tactile facility; we touch things, and pick them up. At about 8 to 11 years of age (on average; some do it earlier, some later), about 40% of the population develop the visual faculty. But it is not until 11 to 14 years of age (again, on average) that only 18% to 20% of the population develop the auditory faculty, and this percentage is dropping as we become a more visually oriented society. I have noticed working in New Zealand with Maori groups that a larger proportion of those groups are auditory. My guess is it is because they are closer to being an oral society. I should note here that you will find all variations of learning style in every culture. The cross cultural research shows that while you might see trends in a cultural group, you cannot generalise and say that “all . . . are . . . .”

So, when you are looking at the students in your classroom, the majority are going to be tactile/kinaesthetic learners. Some will have only one perceptual strength; others will have two or more. Some will be so low in certain perceptual modalities that they will find it hard to learn through those modes. An example of this is the research showing that males tend to be low auditory learners and more visually oriented than females. It is not that men have selective hearing; low auditory people simply DO

NOT remember sequences of verbal instruction. Ask them to do something and they will not remember it, not because they don't want to, just because they don't register oral input in the same way. So in the classroom and at home, when dealing with low auditory people, the most important thing to do is to WRITE IT DOWN. I cannot emphasize enough how useful this is. I have so many stories from teachers and parents, and even children, who, realising they were dealing with a low auditory person, have changed their lives and stress levels by writing things down. A white board in the kitchen at home and butcher's paper with instructions on how to do tasks, or what to do in the classroom, can change your life with low auditories.

In addition to the above information about perceptual modes, the Dunn and Dunn research shows that the best way for anyone to learn is when they have a quick introduction to the new material through their perceptual strength. Each of us has all four perceptual modes; the question is, which one(s) are most effective for us? They then need another exposure through their second perceptual mode, a third exposure through yet another mode, and finally a creative activity that challenges them to process and integrate the material.

This is not as difficult as it sounds and teachers working with learning styles have developed a number of wonderful, generic resources that can be used for teaching tactile and kinaesthetic students any subject material in the classroom. Also, once the students have learnt how to use the generic resources, they will often create their own. Schools can run competitions to create more self-correcting resources for classroom use.

Intake. The next element in the physiological strand is intake. Do you only like to eat after you have completed a task, or do you need to snack frequently while studying or learning? Recent research shows that chewing helps to activate the brain. Again, there is a very high concentration of sensory nerve endings in the mouth/jaw area, and over 50% of the brain's connections to the body move through the jaw, so perhaps these explain why eating can help learning. The need for intake while learning is also related to blood sugar levels.

When asked what they thought about when they were at school, a surprising number of children with whom I have worked, and who had problems at school, have told me: "After the first hour, I just keep wondering when the bell is going to ring so I can have something to eat". When blood sugar levels drop in the body, we find children and adults can become irritable and find it difficult to think and focus. Food in the classroom is an issue for many teachers, and is of course impossible, for safety reasons, in rooms such as science laboratories. However, when the novelty wears off after the first week, only those students who really need to eat will continue to do so.

What students eat is also an issue. Foods high in processed sugars and other substances are not helpful for learning. There is quite a body of evidence which links behaviour and learning problems to our Western diet, so I always talk to students about the importance of eating “brain food”. Children who have never eaten a carrot have been known to nibble on and enjoy carrot sticks after being told that this food will help their brain to function better. Those non-conformists often don’t like being told to eat something because it is good for them, but they will welcome choices of food that will support their brain in learning.

Time of Day. Time of day is a major element in this model; it affects around 70% of learners. There is a myth out there that says the best time for learning new material is first thing in the morning. That may be true for 55% of adults, but it is not true for children. For the majority of children, the best time for learning is between 10 am and 2 pm, which is when we give them an hour for lunch. The research all supports teaching and testing students at their preferred time of day; students learn more, and their test scores improve.

By the way, the same is true for staff training. Teachers implement more, and do so more effectively, when they receive training at their preferred time of day. Afternoon is not a good time of day for teaching adults, and this is something to consider about staff meetings which, by often being scheduled after school for convenience, are most likely less effective than they could be. Children have the greatest capacity to use the time of day information in planning when to do their homework. Timetablers also need to consider time of day needs when setting secondary school timetables. Remembering that 13% of high school students are night owls who don’t wake up until late in the day, we might also consider videoing or recording important lessons/key material so these students can study at the best time of day for their learning.

I lived in Argentina for 5 years, and public schools there operate three sessions each day; from 7 am to 1 pm, 1 pm to 6 pm, and from 6 pm till 11 pm. Children were able to choose between morning and afternoon sessions, and the evening sessions were for children who had to work, or for adults who wished to complete their schooling. When you think about it, this is a very efficient use of buildings, and also meets children’s need for different learning times.

A small number of schools in New Zealand have started experimenting with a different daily timetable. They start the school day with a short session from 9.00 am till 9.45 am, break until 10.15 am, work through till 12 noon, and have a 15 or 20 minute recess for eating lunch. The next break is 1.45 pm till 2.15 pm, and the school day finishes at 3.00 pm, which is normal. Teachers have told me they were consistently getting more work done in the final 45 minute period than they had ever seen under the old schedule, and far less disruptive behaviour at the breaks.

According to school personnel with whom I have spoken, most disruptive behaviour in the playground occurs in the final 15 minutes of the lunch hour. Having no breaks longer than 30 minutes eliminated these problems. An additional benefit is that the children are out of the worst of the sun at midday.

Mobility. Finally, there is the element of mobility. Research in this element shows that 50%, yes FIFTY PERCENT, of high school students need to move in order to learn, and that only 25% like to sit still. The remaining 25% can sit still if they are interested; otherwise they need to move. And of course they do move, and get reprimanded. They get up to sharpen their pencil 20 times a day. They get up to tell the student sitting next to them something. They rock on their chairs. They wiggle and tap their feet, and they drive teachers crazy because tradition says we must sit still in order to learn. Dr Paul Dennison says: “Movement is the doorway to learning.” All his research, and over 30 years of experience in classrooms, supports that.

So what can we do about the movers and shakers? Allow them to move, as much as they need to, as long as they don’t disrupt anyone else and their work gets done. Give them benches to stand at in the back of the classroom, and old phone books to jiggle up and down on while they stand there. Use Brain Gym and teach them other SAMs (Socially Acceptable Movements) to help them to be able to be present and learn. Bring mini trampolines, rocking chairs, hammocks, exercycles, and other movement equipment into our classrooms. And don’t ask them to “sit still”, because if they do, they’ll often be doing it at the expense of learning.

There are many reasons for why students might need to move while learning, and this is another reason for the 3-day workshop, but it is interesting to note that 94-96% of children with learning difficulties have had chronic ear infections while young. Resulting damage to the vestibular system, which provides 90% of the electrical charge that the brain needs in order to function, may mean that normal movement is not sufficient to enable adequate brain function; so they move more. Many teachers have been amazed at how allowing children to move in the classroom has improved both their learning and their output of written work, and resolved many behavioural problems. This is one of my areas of interest, and I could write a great deal more about it. However, this article is designed to simply overview the model.

Psychological Strand

The final strand is the psychological strand, and the major element here is the global/analytic one. Analytic learners have had things all their own way in our education system for many years. They like to be given discreet pieces of information, and have no trouble putting these together into the big picture. Facts, statistics, and small hard pieces of data suit them just fine. They find multiple-choice, timed tests easy, and in general do very well in the traditional system.

Global learners, on the other hand, find life in the traditional education system more challenging. Global students need to have the big picture. They need to know how what they are learning is relevant to them and they need a context within which to put the information. Analytic students, on the other hand, are not context dependent. Once the global learner has all of these, they too can take the small pieces of information and put them together to get the big picture. Without them, the global student is often lost. They will often be caught by a piece of information and spend time mulling over why it is relevant, miss several subsequent pieces, and then come back in to get another piece of information which, because they are missing the crucial middle pieces, they really cannot fit together with the first piece. Once you lose a global student you can lose them forever.

It is relatively easy to keep them with you. Start your class or unit of work with a visual overview (a mindmap works well for globals), with plenty of colour and symbols, as well as words. Tell them an anecdote, a story that encapsulates the essence of what they will learn and gives them a personal connection to the material, a reason to pay attention. Finally, set a context for the material and keep making, and reminding them of, the connections between this section of a unit and another; between the work they have previously done, what they are doing, and whatever they have yet to cover. There are other things that global students respond to and need, but this is probably the most important and the easiest to implement, no matter what you teach.

Many teachers have told me that the visual overview using symbols, colour, etc. had been one of the easiest, high-impact tools they have taken away from the workshop. Why? Let’s look at the statistics. In our primary population, only 12% of learners are analytic, 70% are global, and the remainder are integrated; they use both ways of processing information. In the adult population, analytics are still definitely the minority at 28%, with globals being a majority 55%. However, when we look at the teaching population, and I have seen this time and again, especially when working with secondary schools, 65% of teachers are analytic, and maths teachers tend to be the most analytic of all. As our traditional education system is analytic, visual, and auditory, learners with those learning style preferences tend to excel in the system . . . and perpetuate it.

In fact, if you compare the general learning style profiles in Figures 2 and 3, you can see how the traditional education system meets the learning style needs of those children who excel in the system, and how those who do poorly have a different set of needs which are often completely opposed to what they meet in the classroom. I hope you can see how difficult it might be for the latter group of students to learn.

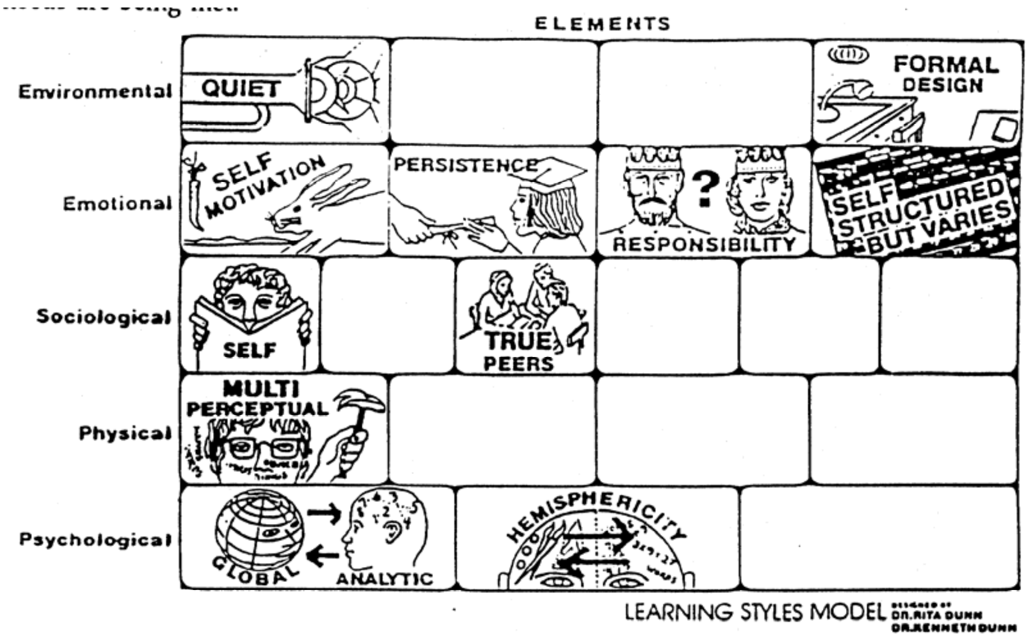

Figure 2. A typical learning style profile for students who are recognised as successful in the traditional school system.

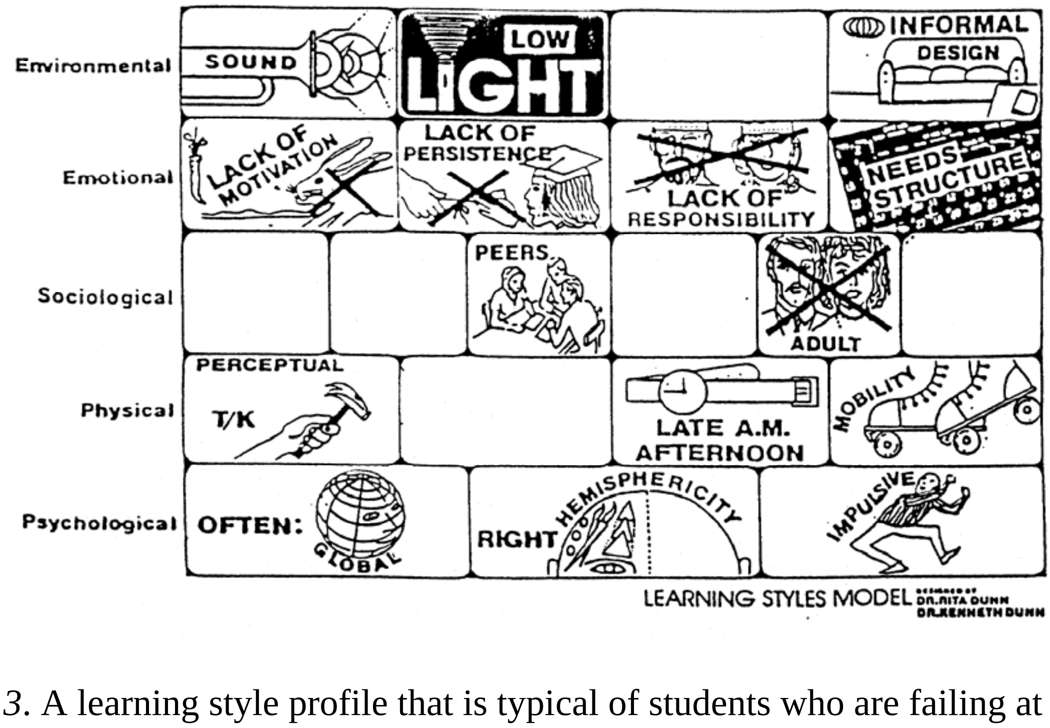

Figure 3. A learning style profile that is typical of students who are failing at school.

The remaining elements in the psychological strand are hemisphericity (which side of the brain do you start processing on first) and impulsive and reflective learners. Educational Kinesiology (http://www.braingym.org) has an excellent course dealing with hemisphericity. It is called Brain Organization Profiles. As far as impulsive and reflective learners are concerned, we all know the impulsive students in our classrooms; they blurt an answer out, often before we have finished asking the question. There is only one way to stop that from happening; physically cover the aperture. “Put your hand over your mouth and write the answer down.”

Reflective students are just that; they need time to think upon something. When they hear the question, an internal committee meets and discusses the question, comes up with several possible answers, chooses one, compares it again to the question - and then they are ready to answer. The trouble is that, by that time, the teacher is usually 6 students past them looking for an answer. So we need to set these students questions in advance so they will be able to answer them at their leisure.

In Conclusion

I hope this has provided a brief overview of the Dunn and Dunn Individual Learning Styles Model and some ideas of how it might look in the classroom. I think the best way to find out about it is to experience it, discover what works for you, and consider how you might use it in the classroom. That is where the workshop is useful. At it you learn through your preferred way of learning. Teachers have often been amazed at how much they effortlessly remember, in the long term, after the workshop; even 3 or 4 years later.

Learning styles teaching and learning is not expensive to implement. Many of the teaching resources can be made very cheaply. Individual learning styles questionnaires can be obtained from Hidden Talents in New Zealand, where the contact person is Aller Spanninga (hidden.talents@clear.net.nz). Cost is only AUD (Australian dollars) 6.55 (for groups of 10 or more), and group reports are included after processing at no extra charge. There are three versions of the questionnaire; for primary students, high school students, and adults. Children are usually re-tested after 3 years, and adults after 5 years. While there may be some initial investment in classroom furniture, there are also cost savings associated with implementation, such as a reduced electricity bill.

If you have any questions for me, or are looking for further information, please feel free to e-mail me at MargaretU@compuserve.com . If you would like more information about workshops in Australia, please contact Jeff Thorpe at jeff.thorpe@woodfordss.qld.edu.au .

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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.

1. A green plant, without any soil on its roots, has a mass of 500 g. It is planted in a pot of soil and watered whenever the soil gets dry. Nothing else is done. After the plant has been growing for 4 years, it is removed from the tub and weighed again. The plant now has a mass of 16 kg.

   During those 4 years, as the plant grew heavier, the soil in the pot:

   a. lost a lot of weight.
   b. stayed about the same weight.
   c. gained a lot of weight.

   Please explain your thinking.

Comment. Choice b is the correct response. The misconception that plants get their food from the soil is probably as old as agriculture itself.

2. If a mouse was placed in a sealed glass box, containing plenty of food and water and positioned in a sunlit position in your classroom, it would soon die. If a green potted plant, also with a plentiful supply of water, was also placed in the box (up high on a special shelf, so the mouse could not reach it), what would happen to the mouse and to the plant?

    a. The mouse would live, but the plant would die.
    b. The mouse would die, but the plant would live.
    c. Both would live.
    d. Both would die.

    Please explain your reasoning.

Comment. Choice c is the appropriate response. The misconception that only animals need to breathe/exchange gases is an ancient one.

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.

Teaching Techniques

The Issue Bin

This is a great aid to monitoring, and dealing with, classroom management issues, because it provides students with a non-threatening way to contribute. When a student has a concern, he may write it on a piece of paper (either with his name, or anonymously) and place it in the Issue Bin, which might be simply a labelled cardboard shoe box.

The submitted issues need to be ones over which students and/or the teacher have some control, and which are not personally hurtful to any member of the class. The teacher checks the bin regularly, considers the issues submitted, and decides on an appropriate course of action. This might be an indivual response, the eliciting of whole-class opinion, and/or providing for class discussion.

PCQ

PCQ stands for pros, cons, and questions. Let’s use it in an example. Forest clearing, which we think is contributing to global warming, results partly from the need of the world’s growing population for more agricultural land. The teacher might propose the following as one way to address the problem: “Limit every woman in the world to having a maximum of two children.”

Students are first invited to list pros, merits, of the proposal. Then, they list cons, as many weaknesses or negative features they can think of. The lists may even be displayed in columns.

These rather convergent thinking tasks are followed by a more divergent one, the listing of questions students have about the proposal, such as: “Has anything like this been already tried somewhere in the world?” “I wonder if people would accept this proposal?” “How could it be enforced?” Encourage students to explore the possibilities broadly. The questions may suggest further library or other research. Students might even propose a hypothesis, a possible explanation, which can be tested (supported or refuted) by ensuing research.

PCQ can also be used as a planning tool for assignments. In this case, it might be an appendix in the submitted assignment.

Ideas in Brief

Senior Citizens in the Classroom

McShane (2002) reminds us that senior citizens, possessing a wealth of experience and talents to share with children, are a great resource in the classroom. A dozen or so visit the school once or twice a week to read with students, and the excellent contribution made by a “rock hound” and a retired engineer is acknowledged.

Some retirees are active yet lonely, perhaps because they live alone or do not have family nearby. Regardless, these school visits are beneficial to both students and the volunteers themselves.

This strategy can also help overcome budgetry constraints associated with obtaining assistance in the classroom. All one needs is people with expertise, time, and the desire to volunteer and work with children.

Reference

McShane, J. B. (2002). Editor's note. *Science and Children, 39*(6), 6.

Benefits From Reviewing Peers

Following her transfer to a new school, Galus (2002) found a practice that was somewhat unusual. During the course of each school year, each teacher was required to select 2 peers, arrange to visit their classrooms, observe, and complete a brief peer review report for each visit. One teacher was to be teaching in the same content area as the reviewer, while the second needed to be working with the same age-level students, but teaching a different subject. The reports needed to be submitted to the curriculum specialist.

Despite initial skepticism, she found the process so rewarding that she now wonders why it is not standard practice in all schools. Regardless of our level of competence, there is scope for all of us to further improve ourselves, and sharing between teachers can facilitate such.

Outcomes from the peer review process may include:

1. reminding us of useful techniques which we may have forgotten;
2. learning new techniques and strategies, including cross-curricular ideas;
3. enhancing one's own teaching in other ways; and
4. development of a positive rapport between teachers, thus facilitating broader discussion, sharing, and collaboration on, for example, activities, discipline, and curriculum.

Reference

Galus, P. (2002). The power of peer reviews. *The Science Teacher, 69*(3), 70-72.

Mentoring and Career Development

Dujari (2001) challenges science educators who are about to retire to consider mentoring young science teachers entering the field. This requires the identification of goals, mutual trust, the sharing of knowledge, and hard work.

It is not necessary for mentors to be top-class achievers in the field, but they do need to be willing to share knowledge and expertise selflessly, have a genuine interest in the task, be a role model, and set high standards. In return, they can gain satisfaction from helping others grow, and the process provides them with an opportunity to reflect on their own career.

Mentees need to recognize the need for, and the benefits that can come from, self-improvement. They will therefore seek guidance willingly, be loyal and respectful, and show faith in the capability of their mentors.

One does not need to be mentored but, as is the case for the sporting elite in our world, a mentor/coach does seem necessary for optimum performance. In many organizations, mentors are formally assigned, although mutual or voluntary selections are more successful (Dalton & Thompson, 1986).

Despite possessing appropriate qualifications, not everyone can be a successful mentor. It is important that the personalities of mentor and mentee match. The mentoring process can also be conducted at a distance, as exemplified by the use of the Internet to connect participants (Dujari, 2000).

Reference

Dalton, G. W., & Thompson, P. H. (1986). *Novations: Strategies for career management*. London: Scott Foresman.

Dujari, A. (2000). Recognizing the achievements of women in science. *Journal of College Science Teaching, 23,* 428-431.

Dujari, A. (2001). Mentoring and career development of science teachers. *Journal of College Science Teaching, XXX,* 278-280.

Current Events Journal

Textbooks date quickly, so Timmerman (2002) requires students to keep a current events journal. She sends an information sheet home to be read and signed by a parent or guardian, encouraging them to work with their child.

Each student is asked to obtain a copy of one science-related article of interest each week from a newspaper or magazine and fix it, together with the source and date of publication, in a bound notebook that also contains a Table of Contents near the front. The article is read and important information highlighted. On the back of the page, the key points are summarised, together with an additional sentence or two explaining why the student has chosen the article and how the issue is important to them or to society. In addition, the definitions of five unfamiliar words (not necessarily scientific), which have been circled in the article, are given. This is aimed at expanding students' vocabulary.

To generate confidence in making presentations, she asks students to present their articles to her alone, to a small group of friends, or to the whole class, and each presentation is followed by discussion. Although it is not required, by the end of the year nearly every student has opted to present to the whole class. To further foster critical thinking and self-expression, at the end of each year students write an essay about the one or two articles which they found most interesting.

This activity serves to demonstrate how personally relevant, and applicable to the real world, science really is. By helping them to choose articles, this task also provides satisfaction for inclusion and learning-disabled students.

Reference

Timmerman, B. (2002). Keeping science current. *Science Scope*, *25*(6), 12-15.

The Term Theory *Misrepresented*

A theory is a "well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypothesis" (National Academy of Sciences, 1998), and referring to evolution as "just a theory" can undervalue the key role of theory in the scientific enterprise. Backhus (2002) says that such a view influenced lay members of the Kansas Board of Education and, as a result, diminished the role of evolution as a unifying theme in the 1999 Kansas decision about the state's science education standards.

While the Kansas decision was reversed in 2001, there is evidence for concern about perceptions associated with the term theory. For example, the Alabama legislature has recently required that all biology textbooks include a disclaimer questioning the validity of evolution as a conceptual theme, various polls show majority public uneasiness with the ideas of evolution, and many science teachers are not clear about their own thinking on evolution (Weld & McNew, 1999).

Further, while theory has a distinctive meaning in science, general use of the term (including some dictionary definitions) doesn't help. It is not uncommon to find the term theory used inappropriately, in newspapers for example, to describe speculation, belief, or conjecture or as a synonym for hypothesis. Even educators err when asking students about their theory on an issue when they are really asking for their opinions.

References

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National Academy of Sciences (1998). *Teaching About Evolution and the Nature of Science*. Washington, D.C.: National Academy Press.
Weld, J., & McNew, J. C. (1999). Attitudes towards evolution. *The Science Teacher*, *66*(9), 27-31.

Relevant Science for Scientific Literacy

Most science courses are largely socially irrelevant. Hobson (2001) has identified five general principles which may be used to change an irrelevant science course, for students not specializing in science, into a socially and culturally relevant one. He suggests that such a change also improves pedagogy and course appeal, while better promoting scientific literacy. His five principles are:

1. *Make the course conceptual and numerate, but not algebraic.* Aim for understanding, using accessible language to express sophisticated science accurately, but without oversimplification. Introduce concepts and their importance before terminology, and only use technical terms if they are vital to describing or understanding an important idea. Include quantitative aspects, such as graphs, percentages, probabilities, efficiencies, and proportionalities, but avoid algebra.

2. *Make classes interactive.* Engage all students, especially those less motivated and/or less confident in expressing themselves. Techniques are available for use in even classes of over 200 students, and include brainstorming, verbal questioning of the class, provocative discussion questions, and the flashcard technique (Meltzer & Manivannan, 1996). In the latter, each student has six flashcards, each with one of the letters A-F printed on it. The presenter prepares several multiple-choice questions for use throughout a class and, after displaying one, asks students to respond by holding up their choice of flashcard. A typical response is 50-90 percent correct, and students are then invited to discuss their reasoning with neighbours. During this time, the presenter might walk around and even join some discussions. The students vote again, and further discussion is requested if more than a few students are still displaying an incorrect answer.

3. *Include only those topics that are highly relevant to the goals of the course, and unify them.* Science courses jam packed with topics often confuse students, because they cannot see the forest (the big ideas) for the trees (the topics). Ask why students need to know a topic, and omit it if you cannot answer the question convincingly. Then unify the topics under the umbrella of a few recurrent themes, like “How do we know?” (scientific methodology) that reflect the course goals.

4. *Ensure the course is modern.* The focus in science literacy courses needs to be on current understanding of our world. Introductory physics courses, for example, often lag far behind modern thinking, such as quantum and relativity physics, and place most emphasis on ideas like Newtonian physics that were drastically modified a long time ago.

5. *Make the course socially relevant,* by integrating a set of social topics (e.g. atmospheric ozone depletion, environmental implications of a method of electric power generation, and transportation), with each topic taking perhaps from 10 minutes to one class period. Such considerations can replace many of the standard problems found in technical courses, impact positively on students in the longer term, foster critical thinking, and make fine projects. Be sure to also examine these topics.

Hobson (2001) gives an example of how a 50-minute class on global warming can be integrated into a general science course. He recommends that all tertiary nonscience students (students of journalism, political science, law, business, etc.) should graduate having completed several socially relevant general science courses, selected from a range of science disciplines. This might be achieved by ensuring that at least 50 percent, say, of all nonscience students on a campus study each course offered by various members of staff in their area of expertise.

Reference

Hobson, A. (2001). Teaching relevant science for scientific literacy. *Journal of College Science Teaching, XXX*, 238-243.

Meltzer, D. E., & Manivannan, K. (1996). Promoting interactivity in physics lecture classes. *The Physics Teacher, 34,* 72-76.

Group Web Page Projects

Traditional written research assignments aim to increase students' knowledge about a topic, and involve researching the topic, synthesizing the findings, reflecting on what has been written, and revising it. Jensen, Moore, and Hatch (2002) suggest that presenting an assignment as a group web page (their students use the "Composer" function in the Netscape navigator program) can not only achieve the same, but also allows students to benefit from critical feedback from other members of their group and to incorporate images, sound, etc. in their report.

While this mode of expression is presently a novelty, it may very well become standard as technology continues to advance and students become increasingly computer literate. For example, word processing programs now include a "Save as a Web Page" option, which makes the construction of web pages very simple.

The approach taken by Jensen, Moore, and Hatch (2002) with college students of human anatomy and physiology has evolved through three main phases. Initially, after the installation of a computer classroom in 1996, students were required to choose a topic and complete an individual web page report. Considerable time was spent acquainting students with how to create web pages, insert links to other sites, and insert graphics. Partially to help students to overcome "computer phobia," this approach was then revised to require students to produce a group web project, where each student in a group of 3-5 students was assigned a specific role such as technology expert, research specialist, or editor.

In an effort to better promote individual accountability, further revision has seen each member of a group required to produce one web page of a group web project, with all pages linked to a common, introductory page. If, for example, the project theme was leprosy, one student might report on the historical significance of leprosy, another on physical symptoms, another on treatment, and so on. Also, a cooperative quiz is used to promote students' skills in using a computer and creating web pages. The emphasis in assessment is on the quality of content (coverage, depth, explanation, synthesis of information from various sources, etc.) as opposed to how attractive the product looks (e.g. animated images and blinking text).

Plagiarism (copying and pasting chunks of information from the World Wide Web) presents a problem, and students find difficulty in correctly referencing sources. A few selected projects are published at http://www.gen.umn.edu/faculty_staff/jensen/1135/example_student_projects/ , with remaining projects available from file servers within the college only.

Reference

Jensen, M., Moore, R., & Hatch, J. (2002). Group web projects for freshman anatomy and physiology students. *The American Biology Teacher, 64,* 272-275.

Some Testing and Assessment Issues

Traditional testing in schools has focussed on rote knowledge and recall. However, in accord with the development of National Science Education Standards (NSES), the trend in the United States of America during the past decade has been towards more authentic, performance-based science assessments and higher-order thinking tasks. Given the differences in culture between countries, there is much debate about the validity of comparative international testing as in the Third International Math and Science Study.

The main concern of teachers is students' understanding of concepts. Both teachers and researchers are agreed about the strengths of performance testing in assessing such, and also acknowledge that performance testing promotes high quality learning in science and is a richer form of assessment than a written exam. However, performance assessments are time-consuming so, for the purposes of accountability, states seek to measure student outcomes and program effectiveness using cheaper, high-stakes, standardised tests.

Such assessments have become the norm in the United States, with 48 of 50 states administering state science exams. Iowa and Nebraska are the exceptions. In addition, though, adopting practices such as not allowing a student to graduate from high school unless they also pass a battery of standardised tests is placing both students and teachers under increased pressure, resulting in the focus being turned back to these tests.

What does passing a test require anyway? As Veronesi (2000) says, a batting average of 0.400 (i.e. managing to get on base 4 times out of every 10 one comes to bat) would command the highest salary for a baseball player today. In school, how much knowledge and understanding is enough? Why 75 percent? Why not 50 percent? What criteria do we use? The answers are not clear.

Many students from socioculturally disadvantaged districts do not pass standardised exams, and many of them simply need more time to develop the required understanding as described in the NSES. “Unfortunately there is still a huge effort to make the child fit the mittens rather than make the mittens to fit the child” (Veronesi, 2000, p. 29). The pressure associated with such high-stakes tests may also be starting to cause a backlash against state-mandated standardised testing.

Veronesi (2000) also asks if such use of the restricted data that can be gleaned from performances on standardised tests has any parallel in the story of soldiers who, a long time ago, were guarding entry to a kingdom. They were required to ask strangers one question, and if the reply was with an unfamiliar or “wrong” accent, the stranger was killed. The native tongue was the only tool used to guard against spies.

The National Science Education Standards have begun to impact on classroom assessments, and a tension will prevail. Some form of standardised testing is sure to continue for the next 10 years or so, while at the same time the merits of performance-based assessment will be increasingly recognised. Like cooperative learning, which is slowing building a base in schools after 20 years of supportive research, it is hoped that authentic science assessment will continue to gain acceptance.

Reference

Veronesi, P. (2000). Testing and assessment in science education: Looking past the scoreboard. *The Clearing House, 74*(1), 27-30.

A Photography Club

McMahon (2002) has found an after-school *Click on Science* photography club to be a rewarding educational experience for K-5 students, teaching them to use a camera and motivating them to learn about science in their everyday lives. Groups of about 20 students, assisted by a couple of parents and some volunteer high school students, participate for 6-week blocks (two 2.5-h sessions each week), although some students choose to stay on to help those in the next group.

The aim is for students to produce a storyboard, in the form of a series of photographs with word-processed captions similar to a comic strip, which tell a story. (Please visit http://www.tricare.osd.mil/hcr/storyboard.html for information on this literary technique.) Content could include erosion in action, identifying native and invasive plants along a creek, documenting birds building a nest, or describing the role of earthworms in promoting healthy soils.

Students are first invited to rank their interest in various areas of science (e.g. animals, weather, or electricity), form groups of 2 or 3 students having a similar interest, think about the science in their lives, and decide on an issue to investigate. The local chamber of commerce is used to identify community experts, who are invited to chat with students, over crackers and juice, about their chosen topic. The parents and high school students join the discussion groups and help by facilitating conversation. Regional libraries and local newspapers could also provide links with suitable guests. Students then do further research in the library or on the World Wide Web, with the high school volunteers assisting to find information, like video clips to provide ideas for the storyboards, and by reading text aloud.

To learn about photography, the students take and analyse practice shots of 5-10 subjects of varying size (from trees to paper clips), using different backgrounds, and under varying lighting conditions. They use digital cameras owned by the school or brought from home, although disposable box cameras would also work. Discounts are received on film processing, and the Parent Teacher Association (PTA) meets other costs. Students then evaluate nine photographs of the same set of three leaves that were taken from various angles under varying light conditions and with different backgrounds. (See Betterphotos.cjb.net for advice on taking photos.)

After designing their storyboard, the required photographs are taken and the storyboards constructed. These are then displayed in museum style on the walls of the school's multipurpose room. Students, parents, and members of the PTA are invited to a showcase, which takes the form of a 15-minute walk, a brief presentation from each group, and a social chat about the club and the projects. The storyboards remain hanging to celebrate the students' achievements and to serve as a marketing tool for the next 6-week block.

Reference

McMahon, M. M. (2002). Picture This! *Science and Children, 39*(7), 42-45.

Teaching Students to Summarise

Summarising science reading requires identifying important ideas and information, connecting them, condensing the ideas, and writing a final product “in your own words.” This requires higher-level thinking that strengthens the links between new information and concepts with which one is already familiar, and also makes information easier to recall and apply.

Friend (2002) has developed a research-based strategy for summarising. There are two key elements to the strategy: repeated references and generalisation. Repeated references refers to the fact that the more important an idea, the more often sentences will refer to it. Generalisation refers to the process of grouping ideas, minus the detail, to form a generality.

The following guidelines are given to students:

Step 1. Read the entire article, chapter, or part thereof and think about what it adds up to as a whole.

Step 2. Determine the main idea of the whole passage, the main message about it, and use you own words to write them in one starting sentence. For example, “Quantum theory assumes that electrons have wavelike properties” (Friend, 2002, p. 42).

Step 3. Determine the major supporting ideas. To do this, group (perhaps by bracketing) consecutive paragraphs which refer to the same aspect of the topic, and use repeated references and generalisation to write the central idea of each group of paragraphs. Some articles will have subtitles, which will help to group paragraphs. When stating a main idea, do not simply select sentences from the passage being summarised. Sometimes the main ideas are not stated explicitly anyway, but in any case synthesising your own expression of the key ideas will strengthen learning.

The central idea in each group of paragraphs should sum up the specifics of the paragraphs, but exclude details, examples, anecdotes, and the like. Do not repeat material in your summary.

Step 4. Revise the above steps.

Reference

Friend, R. (2002). Summing it Up. *The Science Teacher, 69*(4), 40-43.

Science Homework

Is homework good for middle school students? Holliday (2001) concludes that the answer depends on what type of homework it is and on the type of student being asked to do it. Homework can help students develop good study habits, learn “how to learn,” extend material addressed during class, and provide an opportunity for other family members to be involved in facilitating a child’s learning. However, we err by assigning unreasonable amounts of homework and when family members “help” by providing complete solutions to homework problems.

Homework, in general, makes a positive impact on the achievement of older or more mature students, makes little impact on elementary students, and affects the achievement of middle school students only modestly. Assigning middle school students no more than 5-10 hours of homework, in all school subjects, each week (i.e. 1-2 hours each night) appears sufficient. Students assigned twice this amount of homework do not, on average, learn more (Cooper & Valentine, 2001). However, such general findings can hide significant detail. Homework activities, assigned to motivated and adjusted students by a competent teacher, and monitored by informed and thoughtful parents, can have huge learning and motivational effects on students. We fool ourselves, though, if we think that homework can overcome part of the handicap experienced by struggling students living in disadvantaged areas.

Homework should be given in small, frequent amounts rather than as a single large task. In-class, supervised study lessons, with students receiving guidance and support, can help less motivated students achieve, but make less of an impact on more mature students.

Most middle school students desperately need extra help in learning how to study. Teachers could help fill this need by providing guidance in areas such as forming short-term goals, learning study strategies, managing time, monitoring progress, and seeking help.

References

Cooper, H., & Valentine, J. C. (2001). Using research to answer practical questions about homework. *Educational Psychologist*, *36*(3), 143-153.

Holliday, W. G. (2001). Homework in science. *Science Scope*, *25*(3), 58-60.

Individual Variation Brings Science Alive

Understanding the nature of science (NOS) has long been an important outcome in science education. Most images of NOS, though, emphasise norms, conventions, and broad trends. These are important but, by relating only one half of a good story, portray science too narrowly. The human drama and personal significance of the work is often not conveyed (Wong, 2002).

Also, to what degree do the portrayed commonalities correspond with the practice of scientists? Glasson & Bentley's (2000) interviews with scientists showed that they do not seem to think much about NOS, and their viewpoints covered a range that extends outside generally regarded contemporary commonalities. It may be that the commonalities purported to apply to all scientists in general apply to no one in particular.

To bring science alive, there is therefore a need to also describe the variations, the uncommon within the practice of science, as well as the commonalities. Perhaps the most prominent qualities of science education connect with the delight that accompanies insight and discovery, the drama of inquiry, and the pride of accomplishment. Attending to aspects of individual variation like these will foster a better appreciation of science as a creative, motivating, and deeply personal pursuit and reveal the need for judgment and adaptation.

Students need to appreciate what brings life to science, what makes it vibrant, exciting, and fulfilling, qualities which are perhaps least experienced in K-12 science education. The absence of such appreciation can lead to boredom, indifference, and disenfranchisement. The most interesting scientists include those who change or evolve as events unfold. Just as scientists' work transforms them, students can be inspired and transformed in their appreciation of scientists' stories.

To exemplify how we might focus on an understanding of scientists as unique individuals, and on what makes science *their* science, Wong (2002) gives two examples. The first is of Sacks' (1995) anthropological description of Dr Temple Grandin, and the profound connection between her life as an individual and as a scientist. Grandin, a world-renowned animal scientist at the University of Colorado, is autistic, displaying symptoms of impaired movement, social interactions, and verbal and nonverbal communication. She is immensely comforted by physical contact, yet finds being touched by someone else both overwhelming and soothing. She has constructed a large V-shaped trough in her home, lies in her "squeeze machine" every day and, via the use of pressure hoses, gets the padded trough sides to firmly, yet gently, press in on her.

Grandin is remarkably sensitive to the experiences of the animals she works with, and dedicated to comforting livestock as much as possible during their research experiences. She has therefore also designed a corridor into which the confused and distressed animals move for procedures, a corridor in which the side walls move gently and firmly inward, squeezing the animals individually and calming them. Temple Grandin's feeling that the animals need comfort is closely connected with her own way of experiencing the world.

The second example is of Bill, a university professor working on acoustics, and the unmistakable parallels between his scientific work and his life experiences. Bill is extremely sensitive to sound, having spent several months as a boy practically blind and relying heavily on his sense of hearing.

Individuals are not born scientists; they become scientists. There is no typical "science person." Science thrives on individuality, and hence the nature of science is also flexible. Artfully rendered, stories like the above are one technique for sharing the vitality of science with students. They might inspire our students to new thoughts, feelings, and actions.

References

Glasson, G. E., & Bentley, M. L. (2000). Epistemological undercurrents in scientists’ reporting of research to teachers. *Science Education*, *84*(4), 469-485.
Sacks, O. (1995). *An anthropologist from Mars: Seven paradoxical tales*. New York: Knopf.
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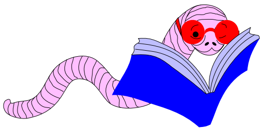

Research in Brief

Students’ Conceptions of Invention

Both invention and discovery are necessary ingredients in the life skill of creative scientific and technological problem-solving. There has been a recent increase given to invention and design education at all levels, where invention refers to the production of something new and useful, and this will provide students with a more complete portrayal of science and technology than they often presently receive.

Plucker (2002) used an open-ended written survey to question 55 Year 6 suburban students in the Midwestern United States about the meaning of invention, the roles of science, art, reflection, and tinkering in inventing things, and knowledge of the patent process. He found that the students generally had simplistic, if any, ideas about the processes of inventing and patenting, and that included both those students who reported having prior instruction in invention and those who said they had invented something.

He recommends that educators consider using the more active, contextual, project, and especially problem-based, learning to better develop students’ understanding of invention, rather than the more popular short-term, cook-book style and Rube Goldberg strategies. The latter refers to “the tendency to teach invention through the use of, for lack of a better term, ‘crazy invention’ contests. In these contests, which are common in post-secondary education, and especially among engineering students, the idea is often to do something simple using the most complex process possible, such as to invent something that toasts bread using at least 20 intermediate steps . . . . These strategies give students the impression that inventing is a wacky, fun exercise, but it doesn't help them see that they can be inventors” (J. A. Plucker, personal communication, September 13, 2002).

(*Editor’s Note*: Please see the *Kid’s Café: PatentCafé’s Space for Young Inventors* website featured in the *Further Useful Resources* section of this issue.)

Reference

Plucker, J. A. (2002). What’s in a name? Young adolescents’ implicit conceptions of invention. *Science Education*, *86*, 149-160.

The Role of Models in Science

Models are used in science to represent abstract concepts and theories, and as learning tools. They help to understand a phenomenon, and may be used to make predictions. Treagust, Chittleborough, and Mamiala (2002) developed a 27-item written questionnaire, *Students’ Understanding of Models in Science* (SUMS), to measure secondary students’ understanding of scientific models and their uses. They administered the instrument, which required Likert-type responses (*Strongly disagree*, *Disagree*, *Not sure*, *Agree*, and *Strongly agree*), to 228 students aged 13-15 years (Years 8-10) in Perth, Western Australia. No special prior teaching about scientific models was provided to the students.

Many students were found to have a sound understanding of the role of models in science. They accept that alternative representations can be used simultaneously, and that models change in response to new data or changes in scientific thinking. However, some other areas that appear to be in need of greater emphasis in science classes were identified.

Many students hold the restricted view of a model as an exact replica of reality as, for example, in the case of a model ear. A realisation that the scientific view of a model also commonly involves an imprecise representation, which may be nothing like the real thing while at the same time providing powerful explanatory insights, will contribute to students’ appreciation of the limitations of scientific models.

While many students recognised that scientific models can take diverse forms (a diagram or picture, map, graph, or photo), a sizeable proportion of students indicated a narrower understanding, more in accord with everyday, and even dictionary, definitions of the term model as a small scale representation or an example for copying. Finally, while many students agreed that models are used for making predictions, developing ideas and theories, and testing them, many did not see any role for models beyond description and explanation.

Reference

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2002). Students’ understanding of the role of scientific models in learning science. *International Journal of Science Education*, *24*, 357-368.

More Active Learning During Lectures

Lectures are a key feature of most science courses, but there is little literature to guide us in improving them. Trimarchi (2002) conducted a 6-month collaborative action research project to first identify, using a science survey, four groups of high school students who struggle with lectures: second language learners, females, low-income students, and students of colour. She then employed some techniques, with four honors biology classes over 6 weeks, aimed at producing interactive lectures, lectures during which students were invited (if not demanded) to participate more actively. Trimachi emphasises the importance of not overdoing any one technique, keeping classes interesting by using a variety of them in conjunction with demonstrations and other activities. To evaluate the impact of these techniques, the students were surveyed both before the techniques were used and again afterwards.

The techniques used are described below. The latter two are general techniques useful for beginning an interactive lecture.

1. *Reflective Response*. Following a question from the lecturer, extend ‘wait time” by giving students 1-3 minutes to write a response. Questions can alternate between simple recall and those requiring more complex analysis. At times, invite students to discuss the question with a neighbour before writing. Then ask a student who does not often contribute verbally in class to share her prepared answer, and invite others to add to it or suggest something different.

2. *Quick Check-Ins*. Hand out blank slips of paper during a lecture, ask a probing question, invite students to respond anonymously in writing, and collect immediately. Read examples aloud, acknowledging correct responses and addressing misconceptions. This technique provides a risk-free way for students to evaluate their understanding.

3. *Teacher Letter*. At the end of a lecture, ask students to write their name, what they thought was the main idea in the lecture, a few important points about this main idea, and what they do not understand from the lecture. Read selected letters the next lesson (without identifying names), answer questions, and address misconceptions. Since they are not anonymous, the letters provide feedback to the teacher about those needing help.

4. *2/3-1/3 Notes*. Divide each notebook page, 2/3 on the left, 1/3 down the right. Students write lecture notes in the former, and questions or comments in the latter. The questions may be written during the lecture, at the end, or for homework. At the beginning of the next class, the instructor addresses the questions.

5. *Review Flash Cards*. To revise a unit, students prepare review questions, either as a small group or for homework, on index cards. One student selects a card, asks the class the question, and comments on the quality of the answer given by a student. The student who answered then asks the next question. Every student asks, and answers, at least one question, with the teacher monitoring the responses given by students, making corrections, and elaborating.

The survey results, together with Trimarchi's (2002) personal observations, showed that the interactive approach did modestly increase the active participation of all students during lectures. She also observed an increase in the number of students lingering after an interactive lecture, or after school, to further discussions started during the lectures.

Reference

Trimarchi, R. (2002). Drawing out the quiet voices. *The Science Teacher*, *69*(1), 30-34.

How Sceptical are our Students?

We appear to live in a superstitious age. For example, a United Kingdom survey reported 63 percent and 67 percent of people believing in the paranormal and clairvoyance, respectively (Toynbee, 1998). Preece and Baxter (2000) feel that, like others, science educators should be concerned about widespread public gullibility concerning superstitions and pseudo-scientific beliefs. Superstitions often relate to good or bad luck, and are passed on by tradition. Pseudo-sciences, like astrology, homeopathy, creationism, feng shui, and reflexology are ideas or theories which, although claimed to be scientific, either have failed tests or cannot be tested. Neither type of belief has any basis in standard science.

Preece and Baxter (2000) used a survey, similar to the following *Beliefs Questionnaire*, to determine the level of such beliefs among 2159 secondary school students, aged 11-18 years, from 22 schools in southwest England. Statements with religious connotations were avoided, although it is noted that item 4 of the questionnaire concerns ghosts, and exorcism services are permitted in established churches.

Beliefs Questionnaire

Please give your opinion about each of the following beliefs by indicating whether you think they are *true*, *probably true*, *probably untrue*, or *untrue*.

1. Breaking a mirror brings bad luck.

2. What happens to people during their lifetime is influenced by the positions of the planets and stars when they are born.
3. Some people have the ability to find missing persons by swinging a pendulum over a map.
4. Ghosts haunt some houses.
5. “Friday the 13th” is an unlucky day, so we need to be very careful on such a day.
6. You can help to keep yourself healthy by wearing jewellery made from certain crystals.
7. The lines on the palms of your hands can tell what will happen to you in the future.
8. Aliens from another planet have landed on earth.

The survey may be scored by assigning one point for a *true* response, two for *probably true*, through to four points for *untrue*. The higher the score on a particular survey form, the more sceptical (less gullible) the respondent. Also, the higher the total score for a class on a particular item, the more sceptical the class is about that item.

Of concern was the finding that many students were very gullible, with only a minority at any age strongly sceptical. In general, females were consistently less sceptical than males at each year level. The exception was in regard to visits by aliens from another planet, where females were the more sceptical. At all levels, the belief that ghosts haunt some houses had the strongest support. For both sexes, the researchers welcomed the finding that students became less gullible with increasing age.

Trainee teachers, all of whom were university science graduates, were also asked to complete the questionnaire, as well as to predict the opinions of 13-year-old students on each item. The lack of scepticism of some pre-service teachers is another concern. They quite accurately predicted the level of scepticism of the girls, but underestimated that of the boys. No relationship was found between trainee teachers’ scores and their predictions about the scores of the 13-year-olds.

Science requires an openness to new ideas, but also demands scepticism. Preece and Baxter (2000) distinguish between well-founded scepticism, such as biologists’ scepticism about reflexology, and scepticism like that displayed by creationists about evolution, which they describe as ill-founded and based on ignorance.

(*Editor’s Note*: Students should be invited to design and carry out experiments to test superstitions and pseudo-scientific beliefs. Forthcoming issues of *The Science Education Review* will contain sample procedures.

The following are suggestions for further items which could be added to the *Beliefs Questionnaire*:

9. Some people possess extrasensory perception (ESP), and can read the minds of other people.
10. Some people can predict the future because they can see events before they occur.
11. Some people can move objects using mental force alone.)

References

Preece, P. F. W., & Baxter, J. H. (2000). Scepticism and gullibility: The superstitious and pseudo-scientific beliefs of secondary school students. *International Journal of Science Education*, *22*, 1147-1156.
Toynbee, P. (1998, May 25). Pope versus the aliens. *The Guardian*, p. 14.

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

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

How does lead from petrol stay in the atmosphere long enough for us to breathe it in? We know lead is toxic, so why was it added to petrol in the first place? Has it been replaced with something else?

If the lead in the air were in the form of lead blocks then, as you imply, it would quickly fall to ground. Much of the lead in the air, though, exists as molecules of lead carbonate or lead sulphate. (For those more scientifically inclined, lead is actually emitted from engines as halides [chlorides and bromides] which, as a result of reactions in the air, become carbonates or sulphates.) Molecules of both lead carbonate ($PbCO_3$) and lead sulphate ($PbSO_4$) contain a single lead (Pb) atom only, and these very small molecules move around in the atmosphere, get bumped by, and bump into, other atoms and molecules in the air, and readily remain suspended.

Lead can be inhaled (e.g. as fumes from the exhausts of cars using leaded petrol), ingested (e.g. by children eating chips of dried leaded paint, as found on many older homes), or absorbed through the skin, and the accumulation of too much lead in the body leads to lead poisoning. The lead interferes with the production of red blood cells and may damage the brain, kidneys, liver, and other organs. Early detection can prevent permanent damage, since drugs can be used to help remove lead in one’s urine.

Lead was first added to petrol, in the form of tetraethyl lead, in the 1920’s. This improved the performance of certain engines by preventing the petrol in the cylinders from beginning to burn too soon or too fast, which would reduce an engine’s power and may damage it. However, it has only been during the last few decades that the dangers of excessive levels of lead in our bodies has been recognised, and this has led to practices such as the banning of leaded paints and the phasing out of leaded petrol in favour of unleaded petrol.

Another reason for the move to unleaded petrol was that lead destroys the effectiveness of catalytic converters, devices installed in the exhaust systems of cars to remove pollutants from exhaust gases. Just when one might think that all our problems have been solved, though, we now find that some of the hydrocarbon compounds used in unleaded petrol are thought to possibly cause cancer!

As an aside, please be assured that students chewing “lead” pencils are not adding lead to their bodies. The core of lead pencils is actually composed of graphite and clay, sometimes combined with wax or other chemicals, but not lead. When these pencils were first introduced, people mistakenly thought they contained lead. It is interesting that they continue to be called lead pencils, and that the graphite mixture in them continues to be called lead.

Further Useful Resources

Kid’s Café: PatentCafé’s Space for Young Inventors

http://kids.patentcafe.com

Encourages primary and middle school students to invent. Includes science lesson plans, scaffolding for how to invent, patent details, and a history of inventors.

The Pathfinder Teaching and Learning Units

http://www.prel.org/products/ms_/pathfinder/pathfinder.htm

Standards-based, multicultural curriculum materials presenting important scientific concepts in cultural contexts meaningful to Pacific Island learners. Produced by Pacific Resources for Education and Learning, based in Hawaii. Units comprise *The Island’s Freshwater and Ecology*, *Our Coral Reef*, *Fish as a Marine Resource*, *Organisms Around Our Island*, *A Field Trip to Nan Madol*, and *Components of Pacific Sand*.

Earthwatch Student Challenge Program

http://www.earthwatch.org/australia/fellstud.html

Earthwatch Institute is the world's oldest, largest, and most respected non-profit organisation directly involving the public in scientific field research. This year, Earthwatch will support more than 130 expeditions in 48 countries and will send some 4,000 members of the public to work with over 200 scientists. The above link describes one of these opportunities, for Year 10 or 11 Australian students to participate in either of two projects, *Echidnas and Goannas on Kangaroo Island* or *Australia's Vanishing Frogs*.

Humour

Some utterances of prominent people of their time provide entertaining reading. Try these.

"Animals, which move, have limbs and muscles. The earth does not have limbs and muscles; therefore it does not move." *Scipio Chiaramonti, Professor of Philosophy and Mathematics, University of Pisa (arguing against the Heliocentric solar system)*

"The abolishment of pain in surgery is a chimera. It is absurd to go on seeking it . . . . Knife and pain are two words in surgery that must forever be associated in the consciousness of the patient." *Dr Alfred Velpeau, French surgeon, 1839*

"That the automobile has practically reached the limit of its development is suggested by the fact that during the past year no improvements of a radical nature have been introduced." *Scientific American, January 2, 1909*

The Science Education Review (ISSN 1446-6120) is published by ***Science Time***, "Willow Downs," M/S 623, Warwick, Queensland 4370 Australia. Comments, questions, and article proposals may be sent to The Editor, Dr Peter H. Eastwell, at editor@ScienceEducationReview.com .

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