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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Of the 6055 million people in the world in the year 2000, less than half (47%, or 2846 million) had access to running water through household piping. Thirty-five percent (2110 million) had access to improved water sources, but 1099 million people (18%) had no such access at all.

The availability of fresh, clean water is being impacted negatively by an increasing demand for it by industry and for irrigation, together with the effects of pollution and changing climate conditions. It has been predicted that, by the year 2025, 3000 million people may be affected by chronic water shortages, especially in Africa and South Asia.

Science Story

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

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

The "First" Artificial Diamond

In 1893, the French chemist Henri Moissan announced success where others had repeatedly failed. He had apparently produced the world's first artificial diamond. The method involved subjecting graphite to high temperature and pressure, and the resulting diamond was flawless and nearly 1 mm in diameter.

However, the result was mystifying, because nobody was able to repeat the feat. In fact, we now know that his method could not have worked anyway. Far greater temperature and pressure are required.

It turned out that an assistant had decided to "help" by planting his own diamond as a prank. Unfortunately, the prank was allowed to go too far, to the extent that owning up to the hoax became considered to be no longer an option. The loss of a valuable diamond must surely have contributed to the lesson learned by this prankster!

Curriculum Reform in Science: Getting Started

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Abstract

In spite of the almost universal call for curriculum reform in science education that began over a decade ago, research indicates that very little change is actually happening in a large majority of schools. Perhaps the reason is that teachers need to see a relatively fast, easy way to get started. This article considers some desirable elements of reform and the role that open-ended investigations might play.

For the past 10 years, many researchers in science education have been calling for change leading to improvement (Anderson, 1995; Anderson et al., 1994; Fensham, Gunstone, & White, 1994; Van Den Akker, 1998; Yager, 1991). Various studies in the USA, UK, and the rest of the world report "an awareness of poor student outcomes in science" (Van Den Akker, 1998, p. 427), indicating that teachers recognise the need for reform. However, the same study goes on to report a "huge gap between improvement ideals in various reform efforts and current classroom practices" (p. 438). The change questions most frequently raised concern first, what should be taught if students are to develop scientific literacy, and second, how the determined programs should be implemented. Overall, I believe, there are two main areas of change required:

1. increased student centredness (or a focus on outcomes or student understanding, as opposed to a focus on content), and

2. trimming down the over-crowded curriculum, in order to maximise understanding.

Student Centred? Doesn't That Mean No Class Control?!!!!

The traditional view of teaching and learning has focused on what is being taught, the content of the lesson. We as teachers have believed that our role is to impart new information, and if students are paying attention or are motivated, they will learn what has been taught. In other words, we have believed that learning is the result of teaching.

Constructivist Learning Theory (Cheek, 1992; Yager, 1991) maintains that learning is not the result of teaching only. Rather, it is the result of what the student does with the new information he/she is presented with. In other words, students are active learners who construct their own knowledge, and not passive recipients of new information, somewhat like a sponge. This theory is the basis of the shift away from a content-focused pedagogy towards a focus on student outcomes or understandings, with some countries describing the outcomes in terms of standards.

Many teachers see this learning theory as just a new way of presenting what we already know: "Okay, doesn't that mean the same as above, that students will construct new knowledge as the result of our teaching, as long as they are motivated or paying attention?" The answer is no. While being motivated and paying attention to our delivery is of course a factor in learning, there is something even more important to be considered, and that is what students already know and bring with them to each new learning experience.

Since Constructivist Learning Theory asserts that students construct their own learning based on what they already know, the ideas they bring with them to the classroom have a profound effect on what they actually learn there. Teachers need to recognise this prior knowledge, appreciating that it will be either a bridge or a barrier to new learning. Where prior knowledge is in fact at odds with what experts currently believe to be true (i.e., where students have alternative conceptions, or misconceptions), teachers need to employ teaching strategies that present the students with conflict between the incorrect knowledge they have and the new information being presented. In this way, students can identify the differences between the two and are given opportunities to construct their own correct concepts so that new learning can occur. Collaborative discourse is one suggested strategy for achieving conceptual change where misconceptions exist in the minds of learners. Cooperative group work on concept-focused tasks, a constructivist teaching strategy, has been found to have a significant effect in helping students overcome misconceptions (Basili & Sanford, 1991).

A student-centred style of learning is therefore the first major focus for change stemming from the constructivist teaching reform. Here, the strategy of teacher as information transmitter with a “chalk and talk” or lecture approach is minimised in favour of the teacher acting as a facilitator, where students “drive” the lessons in order that they will actively construct their own knowledge. Teachers should concentrate not on whether or not they have taught something, but on whether or not the students understand any new information. This does not mean, though, that there is no direct teaching. Some direct inputs are necessary for outcomes to occur. The suggestion is merely that teachers should move away from a predominantly “chalk and talk” teaching style. In a constructivist setting, “activities are student-centered and students are encouraged to ask their own questions, carry out their own experiments, make their own analogies and come to their own conclusions” (Hanley, 1994).

The second change emphasis, trimming the curriculum, emanates from the first. In other words, a starting point in making lessons more student-centred is to reduce the content, since constructivist teaching methods are generally more time-consuming than traditional methods. In many countries, science teachers are being asked to cut back on content in order to maximise opportunities for students to construct their own knowledge, in conjunction with understanding. The emphasis is firmly on the idea that “less is more”. Teachers are required to focus in depth in their treatment of major concepts, rather than covering lots and lots of facts and concepts in minute detail. In this way, we can focus more on what our students are actually learning, rather than on time and deadline aspects that have often in the past dictated our teaching strategies.

You Can’t do That to the Curriculum!

Blasphemy! We can’t possibly leave out the topics we have taught our students since we began teaching! The idea of students passing into post-compulsory chemistry courses without having learned the mole concept is preposterous! Physics students will most definitely need to have done energy calculations before they enter the post-compulsory course! To many, the idea of attacking science content is almost sac religious, like pruning books of the bible, or leaving some books of it out altogether, would be to a religious person!

However, for the sake of appearing progressive and not impossibly conservative, we will agree to look at the idea, and sit around the staff office table with a notion to lightly “prune” the syllabus. Half an hour later, and after much loud and undisciplined debate, we have all failed to agree on any one topic that can be removed. The physical science teachers have, of course, agreed that much of the biological science topics may be removed, and the biological science teachers have unanimously agreed on the scrapping of most of the physical science topics, but no overall consensus has been reached.

Teachers who use traditional pedagogies, as well as more progressive teachers (and not just of science), are very big on pre-requisite learning. Anderson (1995) reports that “the notion of preparing for the next level of schooling …. is so deeply ingrained in the culture of schools that to omit any topic they know will be encountered later makes teachers feel inadequate” (p. 34).

Contrary to popular belief, post-compulsory school students need to have very little pre-requisite factual knowledge. Very little of what is learnt prior to this level is retained anyway (ask any post compulsory teacher!). Students who fail to understand difficult concepts construct incorrect meanings which act as barriers to future understanding which are very difficult to shift by traditional teaching methods (Sewell, 2002). Teachers who use predominantly traditional pedagogies have often failed to take into account the current research that indicates the potentially damaging effect that misconceptions (or wrongly learnt information) can have on student learning of the more difficult concepts. It would be arguably better for many students not to have encountered many concepts at all prior to post-compulsory instruction in them. Re-teaching, to overcome student misconceptions, before new real learning with understanding can occur is much more time-consuming than the education process where students begin with knowing nothing at all about a new concept. Pre-requisite instruction can actually hinder the learning process.

The argument for the inclusion of units of content in a subject purely on the basis that such content has always been “taught” to students of compulsory school age is no longer valid (if it ever was) in the light of current accepted learning theory. Curricula need to be thoroughly audited in light of the fact that in our world of rapidly changing and continually superceded factual information, there is not a lot of information that students need to know. However, there is an awful lot that students increasingly need to know how to do.

Rather than beginning this somewhat daunting task from scratch, though, help is available in pruning the curriculum. Please visit AAAS Project 2061 (2002), “Excerpts From” (2002), “Less is More” (2002), and/or “Benchmarks On-Line” (n.d.) and find out how the American Academy of Science went about the process, and what resources are available to help teachers in this task. Pruning the curriculum is no easy task. Indeed it may take several years to successfully work through the process. Outside agencies and organisations may need to be consulted and worked with before a consensus can be reached. But ultimately the resulting science program will allow more time for student learning, where meaningful learning is the goal.

Reform: A Daunting Task

The pressure to move towards a minimalist approach, or one that focuses on essential concepts, and the shift to student-centredness by teaching systems, is quite daunting to many science teachers, who believe they are faced with the prospect of total disruption to the "business as usual" style they have survived on in the classroom for many years. The new approaches to learning are "a formidable challenge to teachers [as] … to achieve [them] … teachers will have to change almost every aspect of their professional equipment" (Black & Atkin, 1996, p. 63).

With research from the past decade resulting in awareness of poor student learning outcomes in science, many teachers agree in principle with the constructivist approach to learning and can see the need for reform or change. However, as mentioned above, the reform is in many cases not happening. The various worldwide studies reported by Van Den Akker (1998) report the "persistency of traditional teaching practices" (p. 432). The reason is not apathy, or lack of funding, as many commonly believe. I believe that many teachers quite simply don't know how and where to start.

I also believe another difficulty for many of us, as teachers, is not in adapting to different strategies but in shifting our thinking! We often see change as being a threat to our complacency. We are happy with what we're doing and don't want to move out of our "comfort zones." "Besides, it will take lots of time and that's something I don't have," we might say. However, if we can accept that change is desirable (have you considered the possibility that many students are not learning much at all in your classroom?) we really just need to see that change doesn't have to be all that difficult or time-consuming. All we might require is some basic help in how to make our classrooms student-centred and how to reduce the content. How easy is that?

Student Centred/Outcomes Focused: How do I do That?

Once you have trimmed back the content, you are halfway there. You have set the scene for increasing student understanding. You can now focus on things in depth rather than dealing with them superficially, which is often what happens when speed of coverage is an important consideration, as has been the case in the past.

The next step is to allow students to work at their own levels and rates of cognitive development and understanding. The best way of doing this is to give them problems to solve which allow individual entry points and allow them to extend their capabilities as much as they like. Open-ended investigations facilitate this process. An open-ended investigation begins with a problem to solve. A relevant problem is best if it interests and motivates students. Examples for students in the middle years of schooling might be:

1. Peter sits close to the window in his maths class. He notices that the shadow cast by a small tree constantly changes, depending on the time of day.
   How does the length of a shadow and its direction change during the day?

2. Walking through the National Park on the long weekend, Judy notices that different rocks she picks up have different sized crystals in them.
   What factors affect the size of crystals?

3. Kerry has just had her hair acid-permed, and her hairdresser says she should use a very alkaline shampoo when she washes it. She decides to test some herself.
   What type/brand of shampoo has the highest pH?

All of these examples allow students to plan their investigation according to their individual level of ability and readiness. Ideally, they could choose their own equipment to use, but this is sometimes not feasible or possible. Teachers can begin by providing a list of suggested equipment from which students can choose.

How far a student proceeds with the investigation is entirely up to him/her. In the case of the first example above, students can achieve understandings ranging from how the Earth's behaviour affects the different seasons to how the sun affects the behaviour and features of other planets, and is itself influenced by other stars and components of the universe, or move to even higher levels of understanding such as the nature and behaviour of different stars, constellations, and so on.

In the case of the third example above, student understandings can range from determining that acids and bases have particular physical and chemical properties, through understanding that a pH value describes the extent of a relationship between H^+ and OH^- ions, to being able to write simple chemical equations that show how acids and bases produce ions in solution.

Teach Investigative Process Skills During The Investigations

It will obviously be essential for teachers to teach students how to plan - only one variable tested at a time, how to conduct an investigation where repeat trials are necessary, how to present data in tables and graphs, and other investigation skills - so they have some idea of the scientific processes involved. These are skills students can learn as they work through investigations. In this way, teachers are supporting and guiding students in their movement to higher levels of conceptual understandings.

Many students can be very lazy in their thinking and reluctant to begin a task, particularly where they are used to closed investigations that are totally prescriptive and where little self-planning is required. Initially, the majority of students will ask "what do we do?" and moan that they "don't know how to do it." Scaffolding, or frameworks, will be necessary for the majority of students at first, so that they can build their confidence with planning, evaluating, and other aspects of investigating with which they often have had little past experience. This scaffolding can gradually be removed as the students gain in confidence and skill. They will need encouragement and support to take risks and to test out their ideas so that they can extend their thinking each time.

Some students will find this much easier than others, depending on their confidence and thinking skills. Many teachers will find this change more difficult than their students, being required to facilitate and guide students in their efforts rather than give the answers at the outset. Teachers will need to encourage students to elaborate and talk about their initial findings and responses. This evaluation process will lead to students discovering their own mistakes, refining their ideas, and hence developing their understandings further.

Resources for Open Investigations

Sewell and Smith (2002a, 2002b, 2002c, 2002d) have written four books for teachers to guide them in the changes outlined above. Each is a book of investigations that focuses on one of the four main areas of science concepts: Earth and Beyond, Energy and Change, Life and Living, and Natural and Processed Materials. By helping teachers to focus on key conceptual areas, they may play an important part in enabling teachers to cut content effectively. Each book contains 40 open investigations, each with a student page that guides students through the investigation. Appendix A contains an example.

A feature of these resources is a discussion of current research on common student misconceptions associated with every problem, and suggestions for helping students overcome these. Each investigation is also accompanied by a large number of related activities and suggestions for extended research, making it possible for a whole unit of work to be built around the open-ended problem. Finally, a series of judgements enabling teachers to differentiate each student's level of understanding based on their investigation work accompanies each investigation.

These books are designed to not only help students progress in their understandings of the investigative processes and concepts of science, but also to help teachers in their understandings as they develop the skills to be outcomes focused rather than content focused, as may have been the case in the past. It is important to also realise that open investigations are just one way of helping your classroom to become more student centred. Other strategies exist to facilitate this change. Using this strategy and the above resources (or other open-ended investigations) will merely serve to facilitate the change process. Coming to grips with open investigation strategies is merely an effective starting point for teachers who don't know where or how to start.

In Conclusion

Both teachers and students will need to persevere, and resist the temptation to revert to the traditional, closed style of investigation, where planning and method are prescribed in the minutest detail. The important thing is that to take on this new role, teachers will have to forgo their desire to appear all-knowing, and direct students in their efforts to find out for themselves. Developing a Socratic approach – answering a question with a question - to lead students towards their own solutions is vital in today's classroom. In the modern world, it is not always important to know the facts. Rather, it is important to be able to find out the facts. This does not mean that science teachers do not need a strong conceptual understanding. To facilitate students' construction of knowledge, it is desirable that teachers possess an in-depth knowledge of subject material if misconceptions are to be both avoided and overcome. The important thing to keep in mind is that "Rome wasn't built in a day," that change takes time. Where reform is to occur, small steps forward are better than none at all.

Science curriculum reform addresses the premise that science teaching is based not only on what is taught, but also on how it is taught. Students need to be given time to develop a thorough understanding of essential concepts that will provide building blocks for future learning. Reducing the content addresses the time issue, while open investigations allow students to develop their understandings according to their individual readiness. The above suggestions for getting started with curriculum reform are simply that - suggestions. Both of them represent serious challenges to the science teacher. Change is rarely easy, but these thoughts may serve to facilitate change for those teachers who do not know where, or how, to begin.

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Appendix A

CAPTURE COLOURS

STRAND	Level			
	3	4	5	6
EB				
EC				
LL				
NPM				

Susan enjoys looking after her rose garden. She knows that in spring aphids can be a real problem on the new shoots. Quite often their green colour makes them difficult to see. She regularly sees ladybirds because their red colour tends to stand out. She thinks that maybe if aphids were red, wasps and ladybirds would eat more of them.

PROBLEM

Does the colour of an animal affect its survival rate?
Design and carry out an investigation.

Suggested Equipment: Different coloured beads or popsticks, beakers, markers, metre rule, stopwatch.

Planning:

1. What procedure will you use to solve this problem?
2. What equipment will you use?
3. What do you need to do to make it a fair test?
4. How will you record your data?
5. What do you predict will happen?

Conducting/Solving:

6. Carry out some preliminary trials. Were there any problems?
7. Do you need to modify the experiment to fix the problems?
8. Have you used repeated trials in your investigation?

Processing Data:

9. Present your results clearly and accurately (i.e., a table, graph, diagram, oral report, chart, etc.).
10. What do your results show?
11. Are there any patterns or trends in the data?
12. Use some science ideas to explain what happened?

Evaluation:

13. Were your findings what you expected?
14. What dfficulties did you experience in doing this investigation?
15. How would you improve your investigation? (i.e., fairness, accuracy, etc.)
16. What have you learned from this investigation?

Demonstrations

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

Water for Human Consumption

Because water appears abundant to many students, it is easy to understand how they might readily (and incorrectly) assume that there is an unlimited supply of water on Earth available for human consumption.

Needed. Two 1-L vessels, a 50 mL vessel, three small test tubes, an eye dropper, and food colouring.

Ask students to estimate (or guess?) what percentage of all the water on Earth is fairly readily accessible for human consumption. Fill one of the 1-litre vessels with coloured water, and tell the class to imagine that this water represents all the water on Earth. Transfer 28 mL to the other 1-L vessel, label it *Freshwater*, and label the original vessel *Saltwater*. Most of the saltwater on Earth is found in the oceans. Emphasize how relatively small the quantity of freshwater on Earth is. What percentage of all water is freshwater? (*Answer:* About 3%.)

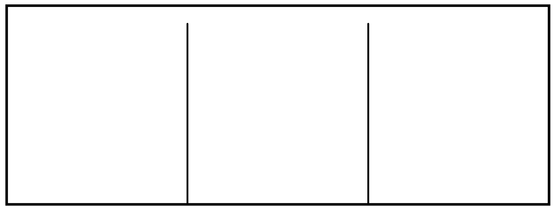
Divide the 28 mL of "freshwater" between the other four containers, using about 23 mL, 4 mL, 2 "drops," and 1 drop to represent *Icecaps and Glaciers*, *Groundwater*, *Surface Water*, and *Atmospheric Water*, respectively. Label the containers.

Invite students to calculate the percentage of each type of water on Earth, and to represent the results graphically. (For the purpose of this exercise, assume the volume of a single drop is 0.2 mL.) Where on Earth is most freshwater found? (*Answer:* Polar icecaps and glaciers.) Approximately what percentage of water on Earth is accessible for human consumption? (*Answer:* Since the water in icecaps and glaciers is not readily accessible, less than 0.5%.)

The Frustrating Tear

Needed. A piece of paper, paper clip, and heavier coin.

Exploration. Tear nearly across the piece of paper in two places, as shown.



Invite a student to hold the paper by the two top corners (one corner in each hand), and pull in such a way that a single pull tears the paper into three pieces. Try as she might (she may even wish to prepare another piece of paper with original tears that go ever so close to the edge), the paper always breaks in just one place only. Isn't that frustrating? Invite other students to try.

Concept introduction. To tear the paper in both places simultaneously, first use the paper clip to attach the coin to the top of the middle section of the paper, and then pull swiftly.

The coin increases the inertia of the middle section, where inertia is the tendency of a body at rest to remain at rest, or the tendency of a moving body to continue moving. A train, for example, has much inertia. A stationary train has a tendency to remain stationary, as evidenced by the quite large forces that are required to get it moving. Similarly, a moving train has a strong tendency to keep moving, as a considerable effort is required to stop it quickly. The greater the mass of an object, the greater its inertia. The coin gives the middle section of paper sufficient tendency to remain stationary (i.e. sufficient inertia) for the tearing forces to succeed in tearing the paper in both places.

Concept application. Invite students to give other examples of inertia at work. Some of the demonstrations in this section of subsequent issues of *SER* will do just that.

Student Experiments

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

Delicious Weathering

Needed. Specimens of granite, and pieces of confectionery, composed of peanuts, caramel, and chocolate. Product names may vary with country, but Snickers and Baby Ruth bars are examples.

Exploration. Check for any allergies that students may have to peanuts, caramel, or chocolate. Provide each of them with a piece of confectionery, asking that they suck it only (no biting allowed) and note what taste/s they experience. After only peanuts remain, invite the students to chew and swallow them. Then list, in order, the ingredients tasted (chocolate, caramel, and then peanuts).

Concept introduction. List the following three minerals, in order of increasing resistance to weathering, commonly found in granite: hornblende, feldspar, and quartz. Draw parallels between the taste experiment and the chemical weathering of granite. For example, the chocolate corresponds with hornblende. When students examine the granite samples, they may therefore find the more quickly weathering dark minerals in depressions on the surface of the rock.

The caramel corresponds with feldspars in granite. Chemical weathering is enhanced in wet, tropical climates. Like the effect of constant surface run-off and groundwater flow, salivation and swallowing provide fresh weathering solution. Both peanuts and quartz are highly resistant to chemical weathering. Just like chewing breaks the peanuts into smaller pieces, physical weathering such as freeze thaw action breaks open rocks, thus increasing the surface area of the rocks.

This experiment might also be used to distinguish between weathering (the dissolving of the chocolate and caramel) and erosion (the swallowing of the peanut pieces). Finally, one might stress the conservation of matter and the fact that weathering can be a formative, as well as a destructive, process. Weathered minerals can form new materials, like clays, just as the confectionery ingredients will form new products in our bodies.

Extension. To examine the effect of temperature on the rate of weathering, place one piece of confectionery in a quantity of water at room temperature, and an equivalent piece in the same volume of warm water. Compare the relative changes in cloudiness of the solutions with time.

Why Does a Breeze Feel Cool?

Needed. A thermometer, fan, and water.

Invitation. When you hold a thermometer, do not hold it by the bulb (at the bottom), because this will cause your fingers to heat the liquid in the thermometer and change its reading. Hold the thermometer and read the temperature. (If it is changing, wait until it stops.)

Predict what will happen to the reading on the thermometer if you hold it so that its bulb is in the breeze from a fan. Try it. Did your prediction come true?

Exploration. Most students think the breeze will cool the thermometer, and are surprised to find that the breeze makes no difference. To investigate further, immerse the bulb of the thermometer in water and read the temperature of the water. Then remove the thermometer from the water and hold the wet bulb in the breeze of the fan. What happens to the temperature of the bulb this time? Does it get lower?

Concept introduction. The breeze alone did not cool the thermometer. In the other case, though, the moving air from the fan caused water on the bulb to evaporate more quickly than it would without the fan. Heat energy is needed to evaporate this water, and this heat energy comes from the bulb itself. Hence, with heat energy leaving the bulb, the temperature of the bulb decreased.

A similar thing happens to us when we stand in a breeze. The moving air evaporates moisture (water/perspiration) from our skin, removing heat energy from the skin and thus making us feel colder than it really is. We sometimes speak of the wind chill temperature. The faster the wind blows, the faster the moisture on our skin evaporates and the colder we feel. When, for example, the temperature is 12°C and the wind speed is 16 km/h, the wind chill temperature is -23°C. This means that, under these circumstances, a person would feel as cold as they would if the temperature was -23°C and there was no wind.

Evolution, Creationism, and the Courts: 20 Questions

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Abstract

The teaching of evolution and creationism is controversial to many people in the United States. Knowledge of the many important court-decisions about the teaching of evolution and creationism in the United States can be used not only to resist anti-evolution activities of creationists, but also to help teachers address questions about the teaching of evolution and creationism.

To read the full text of this article (12 pages), please **click here**.

Science Poetry

The article "Poetry: Adding Passion to the Science Curriculum" (Volume 1, p. 52-56) contains a rationale for including poetic learning experiences in the science curriculum during especially the compulsory school years, as well as associated practical classroom techniques and resources. Reading and/or listening to poems that have been composed by other children their own age can inspire and reassure students as to their ability to understand, and write, poetry, and the science poems in this regular section of *SER* may be used for this purpose. Please find information about the *International Science Poetry Competition* at http://www.ScienceEducationReview.com/poetcomp.html .

Describing Antarctica

Antarctica
Antarctica has amazing features,
It also has its wonderful creatures.
In its waters it has whale, penguin, seal,
So what you may think? Big deal?

Sometimes the wind scoured snowdrifts into huge waves,
The action of the wind formed iceberg caves.
Clumsy explorers fell down crevasses,
It's so snowy and white you'll need directive compasses.
Casey Station has been designed like an aircraft wing,
It has snow sculptures, blizzards, glaciers, that sort of thing.

Some icebergs are old and capsized,
If we were under there we'd be squashed like flies!
Mount Erebus pours out boiling hot steam,
If you were thinking of trees and horses,
You must have had a bad dream!
Snowflakes that fall there are never the same shape,
They also have ice that forms like pancakes.

If you visit Antarctica the land of snow and ice,
Watch out for crevasses and icebergs,
And you'll find it very nice!

Jessica Cameron, Year 5
Matthew Pearce Public School
New South Wales, Australia

The Circulatory System

The circulatory system has a role,
Of transporting blood towards its goal.

The heart is the biggest organ there,
It pumps out blood so we live and breathe air.

The heart has four chambers which help with transportation,
Left and right ventricles and left and right atrium.

The left and right atria collect blood that is old,
The ventricles pump warm blood so you don't get cold.

Blood goes from ventricles to arteries and then –
To capillaries, which are so small you can't really see them.

Capillaries distribute food and gases,
To surrounding tissues, which exist in masses.

Because blood carries nutrients everywhere,
It connects to all the systems where the goodness is shared.

The blood in the arteries is bright red in colour,
But blood in the veins is darker and duller.

Oxygen makes the blood bright red,
When it's dark it means cells have been fed.

Katherine Truong & Katie Stenzel
St. Aidan's Anglican Girls' School
Queensland, Australia

Students' Alternative Conceptions

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

While the tasks will reveal misconceptions, not all of them are designed to reveal the reasons behind the misconceptions. Some strategies for achieving the latter may be found in the *Catering for Individual Student Needs* article (Volume 1, p. 14), as well as the *Teaching Techniques* section of issues of this periodical.

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

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

1. Please respond to each of the following statements with *true*, *false*, or *not sure*.

   a. Atoms are in the nucleus of cells.
   b. Cells are inside atoms.
   c. Both atoms and cells have a nucleus.
   d. Cells are living things, but atoms are not.
   e. Cells are made up of atoms.
   f. There is no relationship between atoms and cells. These are two separate parts of science.
   g. Atoms are made of cells.
   h. Atoms make up all living things.
   i. Atoms are the smallest parts of non-living matter, while cells are the smallest parts of living matter.
   j. Atoms are made up of molecules.
   k. Atoms are lots of cells joined together.
   l. Molecules are lots of cells joined together.
   m. Both atoms and cells are found in blood.

n. Atoms are made up of three types of cells; protons, neutrons, and electrons.
o. Cells are made up of a nucleus, protons, neutrons, and electrons.
p. Both atoms and cells are visible using a microscope.
q. Cells are found only in human bodies.
r. Cells are living things, but atoms are not.

Comment. This task addresses the relationship between cells and atoms, and is based on the findings of action research conducted by Sewell (2002). Statements a, c, d, e, h, m, and r are true, although it would be important to also explore students' reasoning behind their responses to especially statements i and o before drawing conclusions about their understanding.

Cells and atoms are often the topics of different units in a science course, being taught separately without any relationships being made explicit. Students also learn that both cells and atoms have a nucleus. It is perhaps not surprising, then, that students may not make any connection at all between the concepts of cells and atoms, and that those who do try might easily get it wrong.

Reference

Sewell, A. (2002). Cells and atoms: Are they related? *Australian Science Teachers' Journal*, *48*(2), 26-30.

2. Please respond to each of the following statements with *true*, *false*, or *not sure*.

a. The Sun will burn out.
b. We have seasons because the distance between the Earth and the Sun changes.
c. Meteors are falling stars.
d. The shadow of the Earth on the Moon causes the phases of the moon.
e. Continents move.
f. All stars are the same size.
g. The brightness of all stars is the same.
h. Magnets attract all metals.
i. Batteries have electricity, like the electricity you find in wires, stored inside them.
j. The pupil of the human eye is a black mark, or object, on the surface of the eye.

Comment. These items point to the most common alternative conceptions identified, from a given list, by students of the general-education course *Introduction to Physical Science* at Arkansas Tech University (Gonzalez-Espada, 2003). Items a and e are reversed so as to produce the only true statements. The most prevalent reported misconception was b, followed by c.

I have chosen to omit one further item included by Gonzalez-Espada (2003): "God and angels cause thunder and lightning" (p. 37) on the basis that, because it involves notions that cannot be tested, such an explanation lies outside the province of the way of knowing called science (Eastwell, 2002). In addition, science deals with the natural rather than the supernatural. Please do submit your thoughts on this matter, as they will make a useful contribution to the forthcoming *Readers' Forum* section of *SER*.

In addition, students identified the media (and cartoons in particular), religion, parents, and elementary teachers as the most common sources of their alternative conceptions. Not one of them mentioned internal factors, such as misunderstanding an explanation in school, or the faulty construction of understanding, as possible contributors!

References

Eastwell, P. H. (2002). The nature of science. *The Science Education Review*, *1*, 43-48.
Gonzalez-Espada, W. J. (2003). A last chance for getting it right: Addressing alternative conceptions in the physical sciences. *The Physics Teacher*, *41*, 36-38.

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

Teaching Techniques

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

1:4:P:C:R

This is a very powerful technique for facilitating the creation of a new product, such as a solution to a problem (e.g. the clearing of forests), an experimental design, a mission statement, a slogan, or the definition of a term (e.g. sustainable development).

1. Students devise a solution, mission statement, or whatever individually.

2. They then share this work with other members of their groups of 4, discuss the various ideas presented, devise a single group product, and ***P***ublish it on a sheet of paper.

3. With the sheets located on desks or walls around the classroom, groups ***C***ircle the room, discussing the content of each sheet and making notes. As an option, one member of each group can remain behind to act as an Explainer by responding to

questions from members of visiting groups. Each group should visit the work of at least four other groups although, time permitting, the more visits the better.

4. Each group returns to their original place, discusses new ideas, and ***R***efines either the group or individual products. These are then shared with the whole class.

Student Mobility

This is the first of the regular contributions being made to this section of *SER* by Margaret Underwood (MargaretU@compuserve.com), International Consultant and author of the two-part article *Catering for Individual Differences: Learning Styles* that featured in Volume 1. Thankyou, Margaret.

One of the easier learning style elements to cater for in the science classroom is the need for mobility. Students who need to move in order to learn will create a multitude of strategies to satisfy that need, from swinging on chairs to getting up to tell the student sitting next to them something. Some strategies may be very disruptive. However, if we acknowledge and cater for the need, we find that we can allow students to move without causing too much disruption in the classroom. Many teachers have found that catering to this element has completely changed the outcomes for some of their most challenging students.

The following are some ideas for catering for the need for mobility:

- Allow students to change their place of work as often as they need to during a lesson, as long as they don't disrupt other students and all of their work is completed satisfactorily.
- Create space, preferably at the back of the room, where students can stand and work, and move as needed. Movers and Shakers are best located at the back of a classroom, where they naturally congregate. However, teachers often try to stop their movement by placing them at the front of the class, where they cause even more disruption.
- Put partly inflated beach balls on the seats, so students are kept moving while seated. This movement helps to stimulate the vestibular system, and hence brain function.
- Introduce role plays into your lessons. Get students to act out, or become the parts of, anything you are teaching, from the parts of a cell (the difference between animal and plant, for example) to a chemical equation. You will be amazed at how much they learn and retain by being involved.
- Place copies of old, thick phone books on the floor for students to stand on and jiggle up and down. This may sound weird, but again it keeps them moving, and also more or less in one place.

- Use Brain Gym (http://www.braingym.org) movements at the start of each class to get students' brains ready to learn.

The initial research that identified this element was done by Joan Della Valle PhD, New York. She found that 50% of the high school students she studied needed to move in order to learn. Only 25% were passive learners, who liked to sit still while learning. The remaining 25% could sit still if they were interested, but if not they needed to move.

As movement stimulates the vestibular system in the inner ear, which in turn provides 90% of the electrical potential the brain needs in order to function (Tomatis, 1991), we can see why some students, perhaps with damaged vestibular systems from early childhood ear infections, need more movement than the traditional classroom allows in order to learn.

Give it a go and see what happens. You may be very surprised by the results!

Reference

Tomatis, A. (1991). *The conscious ear*. New York: Station Press.

Ideas in Brief

Plagiarism: Prevention and Detection

Plagiarism involves the copying, or paraphrasing (i.e. restating the ideas), of someone else’s work without acknowledgement, and the Internet has made it easier. Our aim should be to prevent plagiarism, and Galus (2002) suggests the following:

- Provide students with scaffolding for assignment writing. This should include familiarization with library resources and using a series of exercises to develop their ability to conduct library research (including using electronic sources), to take notes and synthesize them, and to cite sources in-text and reference them. When there is a need to copy, quotes should be enclosed within quotation marks and appropriately cited and referenced.
- Check students’ note-taking and preliminary drafts.
- Spot check citations.
- Ask students to provide a copy of the page (from a book or the Internet) they are citing.
- Require students to sign a Plagiarism Form that defines plagiarism, that acknowledges they have received instruction on locating and using library

resources and on writing a research paper, and that makes the consequences of plagiarism (e.g. a mark of zero) clear.

To detect plagiarism, one might:

- Type a sentence or two from a passage into a search engine such as Google (http://www.google.com) or Yahoo (http://www.yahoo.com).
- Check the content of books a student has recently borrowed on the topic.

Plagiarism is very addictive, and denies students the opportunity to experience the sense of satisfaction that follows sound work. This can result in them losing confidence in their ability to write. Since writing is such an important skill in all professions, students who plagiarize may in turn be robbing themselves of future success.

Reference

Galus, P. (2002). Detecting preventing plagiarism. *The Science Teacher*, *69*(8), 35-37.

Cultivate Interest Early

Following interviews with many scientists, Rubin (2002) found that for most, their interest in their profession was sparked by a person, place, or thing at a rather young age, leading her to use the term *magic "seven"* (years of age). None of them mentioned discovering a professional interest as a middle or high school student, although they may have "rediscovered" their interests during these years. Why then, she asks, are most science education programs aimed at these older groups?

She advocates the need for science and mathematics exploration and other activities at preschool and kindergarten, and provides the following suggestions:

- Invite scientists to visit the classroom and demonstrate their tools of trade.
- Encourage students to pursue a hobby, to access associated library resources, and to share their work via show-and-tell experiences.
- Provide career-oriented learning centres in the classroom. Possibilities include kitchen chemistry, nutrition/botany, zoology, oceanography, earth science, and paleontology, and Rubin (2002) offers examples of the materials and activities for each, referring to the STUFF (***S***timulating ***T***ools ***U***seful for ***F***un and ***F***undamentals) provided.

Reference

Rubin, P. (2002). Start young. *Science and Children*, *40*(2), 25-27.

Science Teachers and Terrorism

Terrorist weapons include radiological, biological, chemical, and nuclear devices. Some experts and government officials in the United States have expressed the view that there is no point in informing the public about the nature of such weapons and how one might best respond to the use of them in order to minimise injury. Reasons given for such a position include that members of the public cannot be expected to understand the issues involved, and that they are not capable of responding rationally.

Paldy (2002) disagrees with such a stance, suggesting that an education about such devices would contribute greatly to allaying unnecessary fear about them and provide the public with a basis for responding appropriately. All members of Congress have emergency evacuation plans, and all towns should also. He calls for citizens to tell legislators they are not sheep and to demand public information programs, and suggests that science teachers can contribute both in classes and in broader forums.

For example, a radioactive dispersion device (RDD) contains a conventional high explosive, together with a quantity of radioactive material. When it explodes, it is only people close to the explosion that will likely be injured or killed. However, the explosion, as well as any wind, will also spread the radioactive material in the air. While populations may need to be evacuated to avoid exposure to the plume, panic flight through the plume is not a preferred response.

Anthrax is not contagious, and is readily treated with antibiotics. It would be difficult to spread the spores so as to affect people over any large area. Also, without special vehicles, aircraft, or missiles, nerve gases and other chemical agents are not easily spread so as to cause mass casualties.

Reference

Paldy, L. G. (2002). Science teachers and the war against terrorism. *Journal of College Science Teaching*, *XXX11*, 90.

Adding Interest to the Physics Classroom

DePino (2002) provides the following suggestions for brightening up the physics classroom:

- Invite students to donate unwanted CD’s. Use them to cover a door by drilling a hole in each and nailing them to the door so that they overlap significantly. Reflected sunlight will produce colourful diffraction patterns, and photographs taken with a flash camera also make an impressive display.

- Take photographs of students participating in class activities, and display them on the walls or noticeboard. Refer to the photographs while revising for a test (e.g., "Remember when . . . ?"), and later give them to students as mementos.
- Use toys for displays and activities. For example, a mannequin, doll, or "Lego man" (or woman) might display the topic being studied and any required assignments, while plastic people donated by students add interest to motion, energy, and collision demonstrations.
- Invite students to paint physics equations on the classroom walls. The teacher might refer to them during class, and students might use them during tests.
- Dress as a character, scientist or otherwise, to edutain (i.e., to educate and entertain) while performing demonstrations.

Reference

DePino, A. (2002). Easy ways to add interest to your physics classroom. *The Physics Teacher*, *40*, 508-509.

Misconduct in Science

Fakery is rare in science, so it is most newsworthy when it does occur. Moore (2002) cites two examples of scientific misconduct that have recently been reported in the media. The first involved the 32-year-old Bell Labs physicist, J. Hendrik Schön. Moore says his "discoveries" in molecular electronics and superconductivity may have been of Nobel Prize-winning merit – if only they had been true! He says that, in retrospect, the lack of deviation from a straight line of some of the graphs Schön and his team members published looks far too good to be true. Also, uncritical acceptance of the results by colleagues may have been facilitated by the fact that the results confirmed an idea that had been previously proposed by one of them. For further information, please visit "Bell Labs Announces" (2002) and "Results of Inquiry" (2003).

The second was the withdrawal, by Lawrence Berkeley National Laboratory researchers, of the claim that element 118 had been discovered. This conclusion was based on Victor Ninov's computer analysis of raw data from cyclotron experiments. None of his other team members knew how to run the program, and it was only after other laboratories could not reproduce the results that another person learned to use the computer program and found that the published results were not there. (As is standard practice, the raw data were not published.) Further, analysis of a computer log file showed that data had been cut, pasted, and changed. However, as Ninov pointed out in defending his innocence, many people had access to the computer files.

Both cases involved collaborative research projects, and work was published without other team members, journal referees, or journal editors detecting a problem.

Collaboration does not necessarily reduce the likelihood of misconduct, because different scientists often complete different pieces of work. While trust is required, there is presently no clear, broadly accepted ethical standards in relation to the responsibilities of individuals in collaborative projects (Chang, 2002).

Teachers need to address scientific ethics with students, not just as an issue in general, but because students themselves are becoming increasingly involved in cooperative or collaborative work. Cases such as the two mentioned above might be used to facilitate discussion.

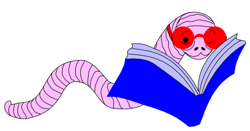
References

Bell Labs announces results of inquiry into research misconduct. (2002). Retrieved February 20, 2003, from http://www.lucent.com/press/0902/020925.bla.html .

Chang, K. (2002, October 15). On scientific fakery and the systems to catch it. *New York Times*, p. D1.

Moore, J. W. (2002). Scientific misconduct. *Journal of Chemical Education*, *79*, 1391.

Results of inquiry into the validity of certain physics research papers from Bell Labs. (2003). Retrieved February 20, 2003, from http://www.lucent.com/news_events/researchreview.html .



Research in Brief

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

Resistance to New Ideas by Students and Scientists: Any Parallels?

The resistance displayed by students to conceptual change is well known, and Campanario (2002) wondered if an understanding of the resistance of scientists to new ideas and discoveries might help us address such student resistance. The resistance by scientists to scientific discoveries being considered, though, is that which goes further than the desirable, and genuine, scepticism that is a key feature of the nature of science. Such instances are not easy to research, because the history of science is dominated by success stories, and the other stories tend to get lost.

Campanario (2002) identifies two main types of resistance by scientists:

1. *Active resistance*. This often comprises the refusal by a journal to publish a manuscript, and he provides 12 examples of scientists who won the Nobel prize for work that was originally rejected by journals. These include H. Michell (on the topic of photosynthesis), H. Taubes (inorganic complex), and M. Gell-Mann (quarks). He also refers to a further 23 cases of Nobel Prize recipients who experienced difficulties with journal referees and editors.

In addition, he lists 14 examples of scientists who experienced unusual difficulties with publishing papers that eventually became highly cited and/or very influential in their fields. They include J. Messig (DNA, 1981, a classic originally rejected for being too trivial), T. Maiman (describing the first laser, 1960, but rejected for not making any significant contribution to basic physics), B. P. Belusov (oscillating chemical reactions, 1959, considered to conflict with the First Law of Thermodynamics), and M. Maruyama (feedback in diverse processes, 1963, another classic that was rejected by 10 journals).

2. *Delayed recognition*, where the value of a paper is not recognised till well after publication. For example, T. F. Anderson (electron microscope techniques, 1951, a paper very rarely cited during the 19 years following publication), Mendel's genetics studies, J. G. Oldroyd (polymers, 1950), and Da Rios' hydrodynamic equations that were rediscovered on three separate occasions during the 20th Century.

Further miscellaneous examples of resistance are:

- Mayer's first version of the First law of Thermodynamics, now universally accepted, was initially rejected by a prestigious journal. The ensuing indifference he had to endure depressed him greatly.
- Lord Kelvin would not admit that helium could be a product of the disintegration of radium.
- Kauffman believed very strongly that Bartlett's report of the synthesis of a compound involving a noble gas was a prank.
- Contrary to what textbooks often portray, Newton's Universal Law of Gravitation was not immediately accepted.
- Waterson's manuscript about a molecular theory of gases was firmly rejected by a referee. The theory was put back on the agenda by Lord Raleigh 45 years later.
- Wegener experienced much animosity from geologists over his idea of continental drift, a theory that now features commonly in basic science courses.
- A paper, published in the *Journal of the American Chemical Society* in 1957, that had been rejected in 1932 – 25 years earlier.

He also provides seven causes of such resistance by scientists:

1. *Error of judgement*. Scientists are only human, and can make mistakes (although this simply describes the cause without explaining the reasons for errors).

2. *Conceptual conservatism*, or “new idea” syndrome. This describes resistance to change beyond the logic of scepticism, and is also alive and well in everyday life and other areas, such as the business world and political history.

3. *Influence of religious and metaphysical concepts*. Examples are the threat, to Christian convictions, of geological findings about the age of the earth, and bias towards a particular basic idea antagonising many scientists in regard to concepts dealing with the continuity or discontinuity of matter.

4. *Beliefs about how research should be done* (e.g., the criticism directed at Williams for conducting research into vitamins using yeast, when animal studies were the norm at the time).

5. *The persistence of simplistic ideas*. For example, it was believed that proteins must be the genetic material, since the diversity in organisms could be explained by the diversity of proteins. All DNA molecules were thought to be the same.

6. *Rivalries* (e.g., the threat, perceived by experts in a field, to new ideas proposed by a foreigner, such as the concept of microbes proposed by Pasteur, a chemist, and the physics explored by Joule, a brewer).

7. *The emotional threat*. It can be very difficult, for example, for scientists to abandon an idea that they have long promoted and that may have effectively become a part of their image. Cecilia Payne, probably the first to propose that hydrogen was the most abundant element in the stellar atmosphere, was repeatedly asked, by the great astronomer Henry Norris Russell, to change her PhD research conclusions.

Companario (2002) concludes that there are parallels between the resistance to new ideas by students and scientists. He recommends that knowledge of the resistance displayed by scientists be included in all science courses. It will contribute to scientific literacy, and counter the simplistic, inadequate view of how science progresses (linear, truth always prevailing, etc.) so commonly portrayed in textbooks. In addition, accepting that one has misconceptions can be threatening. After recognizing that even well-known scientists can be mistaken, students are likely to more willingly address their own misconceptions.

Reference

Campanario, J. M. (2002). The parallelism between scientists’ and students’ resistance to new scientific ideas. *International Journal of Science Education, 24*, 1095-1110.

Understanding in Primary Science

Newton, Newton, and Blake (2002) observed 50 teachers in science lessons, in England, with children aged 7+ to 10+ years. The teachers asked many questions about words, facts, and descriptions, but few questions probed understanding, even during hands-on practical activities. “Why” questions were more likely in lessons with older pupils having a teacher with a stronger science background.

Activities were a part of the lessons of 39 teachers. More than one half of these were written tasks like labelling parts or listing examples. The others were hands-on, but largely focussed on creating an awareness of phenomena than on any form of knowing why. While knowing names and being able to describe things are important, ignoring understanding creates a distorted view of the nature of science and reduces the value of what is learnt.

The following reasons are postulated for teachers neglecting understanding:

- A lack of science background knowledge and understanding correlates with low confidence in teaching science, an increased emphasis on process as opposed to conceptual understanding, greater use of activity and text, and avoidance of questioning and discussion (Harlen & Holroyd, 1997).
- Teachers with little science background view science as being more about facts and descriptions than about explaining.
- Perhaps some teachers regard knowing why in science to be too much to ask of younger students.
- Primary students in England sit tests of their knowledge in core subjects, including science. Some feel that rote learning helps to produce better scores on such tests, scores that in turn reflect on the quality of teachers and institutions. On this basis, understanding becomes a secondary concern.

Primary classrooms often contain science books, and scrutiny of those written for this age group showed that, like the teachers, the emphasis was on facts and descriptions. However, at least one book could be found, for each topic commonly taught, which took things further, so the teacher who recognised the value of knowing why could, with some effort, get support by selecting wisely.

References

Harlen, W., & Holroyd, C. (1997). Primary teachers’ understanding of concepts of science: Impact on confidence and teaching. *Science Education*, *19*, 93-105.

Newton, L., Newton, D., & Blake, A. (2002). Understanding and primary science teaching. *Investigating*, *18*(1), 11-13.

How Effective is Problem-Solving in Developing Physics Concepts?

Solving traditional exercises and problems is an integral component of most physics courses. How effective, though, is this process in overcoming conceptual difficulties reported in the literature?

In preparation for the very highly competitive university entrance exam, 27 first-year physics education students at Seoul National University, Korea, in 1994 (9 females and 18 males) reported solving between 300 and 2900 (average 1500) physics workbook problems during high school physics (Kim & Pak, 2002). The researchers used qualitative questions about basic mechanics, based on research, to assess the students' conceptual understanding.

These students demonstrated the ability to readily use physics formulae and mathematics. However, many of the conceptual difficulties reported by researchers elsewhere persisted, and these were categorised as (a) a lack of differentiation among force, acceleration, and velocity, (b) misunderstanding Newton's third law, and (c) a gap between the use of algebraic expressions and the associated physics concepts. There was little relationship between the number of problems solved and level of conceptual understanding.

While traditional problem-solving plays an important role in developing physics understanding, it is limited in its impact. Other techniques appear necessary for developing some aspects of conceptual understanding.

Reference

Kim, E., & Pak, S. (2002). Students do not overcome conceptual difficulties after solving 1000 traditional problems. *American Journal of Physics*, *70*, 759-765.

Longer-Term Impact of an Inquiry-Based Program on Attitudes Toward Science

Following a review of the literature, Gibson and Chase (2002) concluded that "students who learn science using an inquiry approach score higher on science achievement tests, have improved science process skills, and have more positive attitudes towards science, when compared to students taught using a traditional approach" (p. 694). However, these were short-term influences, observed 2 weeks to 1 year following inquiry science activities, and little (if anything) has been reported about the longer-term outcomes of inquiry-based instruction.

These researchers used surveys and interviews to study the effect, on the attitudes of successful middle school applicants during 1996/7 (several years later), of participation in 2-week inquiry-based summer science camps conducted at

Hampshire College, Amherst, Massachusetts during 1992 to 1994. The results suggest that the programs may have helped students, with a high level of interest in science, maintain that interest (including interest in a science career) during their high school years.

The program students sustained more positive attitudes than students who applied to participate but were not selected, with the attitudes of the latter decreasing over time. Gibson and Chase (2002) conclude that actually increasing students' attitudes between middle and high school "is very difficult to do and may be an unrealistic goal" (p. 704). Attitudes toward science appear to be developed early and to be difficult to change once students reach middle school.

Reference

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education*, *86*, 693-705.

Problem-Based Learning: Features and Barriers

The 21st century demands a curriculum that fosters students' higher-order thinking, including problem-solving, critical thinking, and decision-making, and Problem-Based Learning (PBL) can contribute. PBL challenges students to address a problematic real-life situation, and is one of the best examples of a constructivist learning environment. It aims to be student-centered, to allow all students to achieve something, and to promote collaboration, reflection, self-directed learning and life-long learning, and requires mediation and scaffolding of students' learning by the teacher.

Angeli (2002) interviewed 10 teachers (5 males and 5 females) in the United States (personal communication, April 10, 2003) to identify recommended design considerations for PBL, together with barriers to implementation. The teachers spanned the K-12 range, and were all experienced in using PBL. Rather than using it solely, though, all used PBL as a complement only to traditional instruction.

The results include the following advice for implementing PBL:

- If possible, observe PBL in action before trying to use it yourself.
- Inform the school community (administration, staff, and parents) prior to implementation.
- The most challenging part is perhaps choosing, or generating, problems to be addressed. Problems need to be complex, with alternative solutions, and accessible to students of all abilities, and students need to be motivated by the problems.
- Introduce students to PBL using simpler problems before demanding more.

- Use interesting ways to introduce a problem to students, such as a visiting expert, drama, or a well-written narrative.
- Group students heterogeneously by sex, ability, and race, pairing low-ability students with more capable students within groups.
- Use a variety of strategies, including lectures, self-directed learning, discussions, journals, cooperative learning, and group presentations.

The following barriers to the implementation of PBL were offered:

- While PBL is widely used in adult and professional education (e.g., medical students diagnosing and recommending treatment for a patient), an incompatibility with the current beliefs and culture of schooling (including the structure and/or management of the classroom, the role of the teacher, and the question of what to teach) may be restricting its use in K-12.
- While teachers do provide guidance and support, it is difficult for them to transfer control for learning to students. Factors like standardized testing, accountability, and parents' expectations don't help.
- Concerns about the associated need to reduce content coverage, and how such may affect student's performances on standardized tests.
- The complexity of PBL, including the need for additional preparation time, makes it difficult to use on a daily basis.
- The implementation of both a new curriculum and a new pedagogy requires a major leap for most teachers.
- Adverse reactions by parents.

Reference

Angeli, C. (2002). Teachers' practical theories for the design and implementation of problem-based learning. *Science Education International*, *13*(3), 9-15.

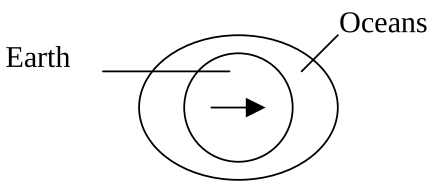
"There is a difference between knowing the name of something and knowing something." *Richard Feynman*

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

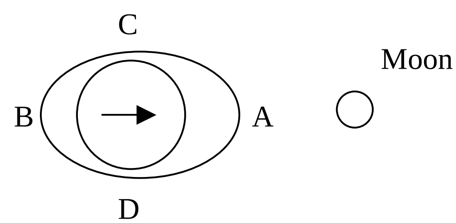
This section of *SER* is intended to cater primarily for the needs of science non-specialists, so please submit your question. Have that long-standing query resolved; hopefully.

If the pull of the Moon causes a high tide, and we rotate past the moon once daily, why don't we experience just one high tide each day?

Yes, you are correct in identifying the gravitational attraction of the moon on the water in our oceans as the major cause of tides, but the effect of the Earth's rotation on this water also needs to be considered.



Earth spinning, no moon



When, for example, the spin-dryer in a washing machine spins, the water tends to move to the outside of the spinner. The same thing happens to the water in our oceans as the earth spins. As shown in the first diagram (not to scale), in the absence of the moon this would result in a bulge (high water levels) around equatorial regions and lower water levels towards the poles.

If we now introduce the influence of the moon (second diagram), we can understand why tides arise. The water at point A is closest to the moon and gets pulled out (bulges) even more, with some water moving from regions around C and D to contribute to this bulge. The water level at B is only slightly reduced, because it is further away from the Moon (less gravitational attraction by the moon on the water).

The overall result is a large bulge (high tide) at A, a smaller bulge at B (a smaller high tide), quite low water levels at C and D, and low tides on each side of the Earth half-way between A and B. As the earth rotates, then, a typical location on its surface experiences two high and two low tides each full rotation (i.e., each day).

Further Useful Resources

Inventions and *Albert Einstein: A Life of Genius*

http://www.kidscanpress.com

These two books are among the new children's book titles published by Kids Can Press. *Inventions* adopts the popular Frequently Asked Questions (FAQ) format often used on the Internet. How do inventors invent? Why were blue jeans invented? Who invented canned food? When was the compass invented? Who invented Band-Aids? Can kids invent? How do you keep people from stealing your invention? Also included are activities, fascinating facts, and an invention time-line.

Many of us are aware of the brilliance of Albert Einstein, and how his theories about time, light, and gravity changed the way we think about the world and resulted in many new inventions. But how many of us also realise that he was so absentminded that he once forgot where he lived, or that even though he was an advocate for world peace, his work led to the production of the atomic bomb? *Albert Einstein: A Life of Genius* is a biography that introduces young readers to this great thinker. In addition to photographs, maps, quotes, letters, and drawings, one will find a time-line of his life and a list of places to visit to learn more about him.

Other new titles include *Tornado!*, *Otters,* and *Animals and Their Young: How Animals Produce and Care for Their Babies*. Visit the Web site to find a full book list, sample pages from books, educator resources, author and illustrator biographies, and downloadable activities.

Common Errors in English

http://www.wsu.edu/~brians/errors/

Clarifies a wide range of issues that arise when writing in English, including the use of apostrophes, hyphens and dashes, and quotation marks and writing numbers.

Boil, Boil, Toil, and Trouble: The International Boiling Point Project

http://www.k12science.org/curriculum/boilproj/

This collaborative experiment represents one type of Web-based inquiry (WBI) activity. Students from different geographical locations collect and share data to investigate which of several factors has the greatest effect on the boiling point of water.

Evolution

http://www.pbs.org/wgbh/evolution

Update your teaching of evolution. Seven key areas are explored: Darwin, Change, Extinction, Survival, Sex, Humans, and Religion. Includes inquiry-based lesson plans and an on-line, professional development course.

The Periodic Table of Poetry

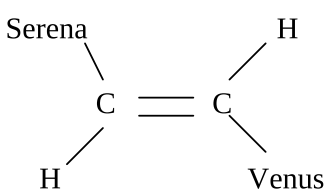
http://www.superdeluxe.com/elemental/

Contains poems for many of the chemical elements. Selected poems might be displayed in the classroom or laboratory.

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

Humour

Read the following chemical word.



Answer: trans-sisters (“transistors”)

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