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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Despite any impressions Hollywood may give, cave people did not have to battle dinosaurs. Dinosaurs first appeared on Earth more than 200 million years ago, and became extinct about 60 million years ago. While Homo sapiens, the species to which we belong, may have first appeared on Earth up to 400,000 years ago, modern humans have been on Earth for less than 100,000 years.

Science Story

The stories in this regular section of *SER* may be used to enrich lessons and make them more interesting.

Murphy's Law

"If anything can go wrong, it will." This saying may be attributed to Captain Edward A. Murphy, an engineer at Edwards Air Force Base, United States, who in 1949 was working on an investigation into how great a deceleration a person can withstand in a crash. Cursing a technician who had wired a transducer incorrectly, he said: "If there is any way to do it wrong, he'll find it."

During a press conference after pulling 40 Gs on the deceleration track, the Air Force doctor John Paul Stapp attributed the projects fine safety record to a firm belief in Murphy's law, and the need to get around it. After being picked up on by aerospace manufacturers, the saying spread throughout the world.

(*Editor:* Please see the *Student Experiments* section of this issue for examples of using Murphy's law statements to initiate inquiry science activities.)

Going Beyond STS: Towards a Curriculum for Sociopolitical Action

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Abstract

This article asserts that STS-oriented curricula, while of value in presenting a more authentic view of scientific practice and its cultural context, are too timid in their approach towards the political interests and social values that underpin scientific and technological developments. A case is made for politicizing students through an issues-based, technology-oriented curriculum aimed at social critique, values clarification, and preparation for sociopolitical action. (This paper is a summary of Hodson, 2003)

Introduction

Regrettably, science is often regarded as a body of knowledge that can be transmitted by teachers, memorized by students, and reproduced on demand in examinations. Regrettably, too, science is often portrayed as the de-personalized and disinterested pursuit of objective truth, independent of the society in which it is practised and untouched by ordinary human emotions, values, and conventions. Although the science-technology-society movement (STS education) has done much to shift the emphasis of science education in some educational jurisdictions towards a more authentic representation of scientific knowledge and scientific practice (Kumar & Chubin, 2000; Solomon & Aikenhead, 1994; Yager, 1996), the reforms do not go nearly far enough. Although some curricula draw on elements of the history, philosophy, and sociology of science to show students how scientific inquiry is influenced by the sociocultural context in which it is located, this insight is not used to politicize students. Too often, teachers avoid confronting the political interests and social values underlying the scientific and technological practices they teach about, and seek to avoid making judgements about them or influencing students' views. Two points are worth making. First, curriculum cannot be value-free. Values are promoted as much by what is omitted as by what is included. Second, the so-called “value-free” approach diverts attention away from what I consider to be the major purpose of science education: preparation for responsible citizenship.

It almost goes without saying that science education should lay the foundation for further study and for a potential career as a scientist, engineer, or technician, but it should also be concerned with enabling young citizens to look critically at the society we have, and the values that sustain it, and to ask what can and should be changed in order to achieve a more socially just democracy and to ensure more environmentally sustainable lifestyles. This view of science education is overtly and unashamedly political. It takes the Advisory Group on Education for Citizenship and the Teaching of Democracy in Schools (Qualifications and Curriculum Authority [QCA], 1998) at its word--not just education about citizenship, but education for citizenship: "Citizenship education is education *for* citizenship, *behaving and acting as a citizen*, therefore it is not just knowledge of citizenship and civic society; it also implies developing values, skills and understanding" (p. 13, emphasis added).

Politicizing the Curriculum

My view is that politicization of science education is best approached via an issues-based and technology-oriented curriculum. In the modern world, technology pervades everything we do; its social and environmental impact is clear; its disconcerting social implications and disturbing moral-ethical dilemmas are made apparent in the media almost every day. Consequently, it is much easier to see how technology is determined by the sociocultural context in which it is located than to see how science is driven by such factors, and it is much easier to see the environmental and societal impact of technology than science. This is not an argument against teaching science; rather, it is an argument for using technology as a means of contextualizing science in a way that makes it more accessible to students.

In Hodson (2003), I outline my proposal for a curriculum focused on seven areas of concern: human health; food and agriculture; land, water, and mineral resources; energy resources and consumption; industry (including manufacturing industry, the leisure and service industries, biotechnology, and so on); information transfer and transportation; freedom and control in science and technology (ethics and social responsibility). Within such a curriculum, a judicious mix of local, regional, national, and global concerns can be addressed in terms of four levels of sophistication.

- *Level 1*: Appreciating the societal impact of scientific and technological change, and recognizing that science and technology are, to some extent, culturally determined.
- *Level 2*: Recognizing that decisions about scientific and technological development are taken in pursuit of particular interests, and that benefits accruing to some may be at the expense of others. Recognizing that scientific and technological developments are inextricably linked with the distribution of wealth and power.
- *Level 3*: Developing one's own views and establishing one's own underlying value positions.
- *Level 4*: Preparing for, and taking, action.

Level 1 is about the complex interactions among science, technology, society, and environment. Technology is not shaped by scientific knowledge alone; rather, it is the product of particular sociopolitical, cultural, and economic circumstances. In turn, technologies such as the printing press and the computer, or the steam engine and the internal combustion engine, shape the lives of people and impact on both the natural and built environments in quite dramatic ways. Level One awareness includes recognition that the benefits of scientific and technological innovations are often accompanied by problems: hazards to human health, challenging and sometimes disconcerting social changes, environmental degradation, and major moral-ethical dilemmas.

Although there are STS-oriented curricula that identify problematic features of scientific and technological development, many regard decision-making in science and technology as a relatively simple matter of reaching consensus or effecting a compromise. In contrast, the intention at Level Two is to assist students in recognizing that decisions are usually taken in pursuit of particular interests, justified by particular values, and sometimes implemented by those with sufficient economic or political power to override the needs and interests of others. In consequence, the advantages and disadvantages of scientific and technological developments often impact differentially on society. In other words, science and technology may serve the rich and the powerful in ways that are prejudicial to the interests and well-being of the poor and powerless, sometimes giving rise to further inequalities and injustices. In many ways, the material benefits of the industrialized world are achieved at the expense of those living in the Developing World. The intention of Level 2 is twofold. First, students recognize that critical consideration of scientific and technological development is inextricably linked with questions about the distribution of wealth and power. Second, they begin to see that problems of environmental degradation are rooted in societal practices and in the values and interests that sustain and legitimate them.

Level Three is concerned primarily with supporting students in formulating their own opinions on important issues. Its focus is values clarification, developing strong feelings about issues, and actively thinking about what it means to act wisely, justly, and honourably in particular social, political, and environmental contexts. Like global education (Selby, 1995), with which it has much in common, it begins with the fostering of self-esteem and personal well-being, and extends to respect for the rights of others, mutual trust, the pursuit of justice, cooperative decision-making, and creative resolution of conflict between individuals, within and between communities, and throughout the world. It is driven by commitment to the principle that alternative voices can and should be heard in order that decisions in science and technology reflect wisdom and justice, rather than powerful sectional interests (Maxwell, 1992).

The fourth level of sophistication is where the radical character of this curriculum is principally located: helping students to prepare for, and to take, responsible action. Socially and environmentally responsible behaviour will not necessarily follow from knowledge of key concepts or even from the possession of the “right attitudes.” Almost every one of us has personal experience illustrating that it is much easier to proclaim that one cares about an issue than to do something about it. What translates knowledge into action is ownership and empowerment. Those who act are those who have a deep personal understanding of the issues (especially their human and environmental implications) and feel a personal investment in addressing and solving the problems. Those who act are those who feel personally empowered to effect change, who feel that they can make a difference and, crucially, know how to do so. Thus, a prerequisite for action is a clear understanding of how decisions are made within local, regional, and national government, and within industry, commerce, and the military. Without knowledge of where, and with whom, power of decision-making is located, and awareness of the mechanisms by which decisions are reached, intervention is not possible. In other words, the kind of scientific and technological literacy that this curriculum proposal is designed to achieve is inextricably linked with education for political literacy. The likelihood that students will deploy their knowledge of political structures and mechanisms in significant sociopolitical action in adult life will be much greater if they are given opportunities to take action as part of the curriculum experience. Examples of such action include conducting surveys of dump sites, public footpaths, and environmentally sensitive areas, generating data for community groups such as birdwatchers and ramblers, making public statements and writing letters, organizing petitions and consumer boycotts of environmentally unsafe products, publishing newsletters, lobbying local government officials, working on environmental clean-up projects, creating nature trails, assuming responsibility for environmental enhancement of the school grounds, monitoring the school's consumption of energy and material resources in order to formulate more appropriate practices, and so on. It is not enough for students to learn that science and technology are influenced by social, political, and economic forces. They need to learn how to participate, and they need to experience participation. It is not enough for students to be armchair critics! As Kyle (1996) put it: "Education must be transformed from the passive, technical, and apolitical orientation that is reflective of most students' school-based experiences to an active, critical, and politicized life-long endeavour that transcends the boundaries of classrooms and schools" (p. 1).

The curriculum proposals outlined here are unashamedly intended to produce activists: people who will fight for what is right, good, and just; people who will work to re-fashion society along more socially-just lines; people who will work vigorously in the best interests of the biosphere. It is here that the curriculum deviates sharply from STS courses currently in use.

Changing Values and Changing Lifestyle

The gist of my argument is that science and technology education has the responsibility of showing students the complex but intimate relationships among the technological products we consume, the processes that produce them, the values that underpin them, and the biosphere that sustains us. Within an issues-based curriculum oriented towards sociopolitical action, it is not acceptable to regard environmental problems as an inevitable consequence of technological development or to imply that science itself can solve the problems by simple technical means. Projecting such messages depoliticizes the issues, thereby removing them from the "realm of possibility" within which ordinary people see themselves as capable of intervention. As a consequence, dealing with environmental problems is left to experts and officials, and ordinary citizens are disempowered. Education for sociopolitical action entails recognizing that the environment is not just a "given," but a social construct. It is a social construct in the sense that we act upon and change the natural environment, and so construct and reconstruct it through our social actions. It is a social construct in the sense that we perceive it in a way that reflects the prevailing sociocultural framework. In consequence, environmental problems are not problems "out there" in our surroundings, but problems "in here" (in our heads), in the way we choose to make sense of the world. They are pre-eminently social problems--problems of people, their lifestyles, and their relations with the natural world.

By adopting this position, we can challenge the notion that environmental problems are inevitable. If environment is a social construct, environmental problems are social problems, caused by societal practices and structures, and justified by society's current values. It follows that solving environmental problems is a matter of addressing and changing the social conditions that give rise to them and the values that sustain them. It follows that science education for sociopolitical action is inescapably an exercise in values clarification and values change. Hence Level 3 in the scheme outlined above. Environmental problems will not just "go away," nor will they be solved by a quick "technical fix" while we blithely maintain our profligate lifestyle. We have to change the way we live; the planet can no longer sustain our present way of life.

It is a well-worn cliché to say that we live in a global village, and that what we do in our own backyard can impact quite significantly on people living elsewhere in the world. It is also the case that our actions now impact on the lives of future citizens. The ethics of previous generations have dealt almost exclusively with relations among people alive at the same time. In startling contrast, the impact of contemporary technology makes an urgent issue of relations with those as yet unborn. In recognizing this new reality, we would do well to heed the wisdom of the First Nations people of North America: "Treat the Earth well. It was not given to you by your parents; it was loaned to you by your children. We do not inherit the Earth from our ancestors, we borrow it from our children" (oral tradition). It is not too much of an exaggeration to say that the degree to which young citizens incorporate sustainable practices into their professional and personal lives will determine the quality of life for future generations. It is my contention that the science curriculum has a crucial role to play in teaching students how to exercise the enormous power of technology responsibly, carefully, and compassionately, and in the interests of all living creatures.

The most fundamental element in this values shift is the rejection of anthropocentrism (and the objectification and exploitation of nature that follow from it) in favour of biocentrism: having respect for the intrinsic value of all livings things, cultivating a sense of compassion and caring towards both human and non-human species, having a concern for maintaining the existence of biological and cultural diversity, challenging and rejecting all forms of discrimination, and making choices that are designed to maintain an ecologically sound and humane lifestyle. Laszlo (2001) describes the inculcation of this clutch of values as developing a "planetary ethic"--an ethic which "respects the conditions under which all people in the world community can live in dignity and freedom, without destroying each other's chances of livelihood, culture, society and environment" (p. 78). He goes to some length to reassure readers that abiding by a planetary ethic does not necessarily entail major sacrifices or self-denying behaviour. Striving for excellence, beauty, personal growth, enjoyment, even comfort and luxury, is still possible, provided that we keep in mind the consequences of our actions on the life and activity of others by asking:

- Is the way I live compatible with the rights of others?
- Does it take basic resources from them?
- Does it impact adversely on the environment?

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Demonstrations

While the activities in this section of *SER* have been designated demonstrations, they might easily be structured as hands-on student learning experiences. Although some sample lesson sequences may be 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.

Using the Paranormal to Teach Scientific Habits of Mind

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"Why are you teaching biology instead of making millions on television?" This is the question I was asked by a student convinced that I had psychic abilities. We were about 2 weeks into *Alien Abductions, Crop Circles, and Psychics,* a seminar course that uses paranormalism as a hook for teaching skeptical inquiry. I now adapt activities from that nonscience course for my biology classes in order to illustrate how valuable scientific thinking can be in everyday life outside the classroom.

Unfortunately, I have found a great need for activities of this type, even among potential science majors. On surveys I administer listing 13 paranormal beliefs, freshmen at my institution (typically 18-19 years old) admit to believing in roughly 30%. Add to that another 20% of beliefs that fall in the *not sure* category, and I began to realize that students in my classes were open to perhaps half of the common paranormal beliefs (Dougherty, in press). I suspect my classes have not been unique. Worse yet, I have yet to survey a class where even a single student chose *do not believe* for every paranormal phenomenon listed. Examining your own students in this way may illustrate how polling organizations consistently come up with their disturbingly high percentages of adults (in the United States, at least) who profess to believe in unsubstantiated phenomena such as ESP (extrasensory perception), astrology, and psychic ability (e.g., Gallup & Newport, 1991; Gallup, 1997).

Paranormal, as defined by Goode (2000), encompasses both phenomena and cognitive approaches to understanding phenomena. Of course, novel observations or phenomena initially may have unknown causes, but they may yield to naturalistic explanations once they have been investigated with the methods of science. Thus, tentative acceptance of a variety of scientific explanations for an inexplicable phenomenon is reasonable. This is why we develop competing hypotheses in science.

Acceptance of paranormal investigative approaches, however, is problematic because it runs counter to the methods of science. For example, accepting the claim of a ghost sighting based on a psychic's "special sensory intuition" is an explanatory dead-end. There is nothing to test; only a claim from authority. As Goode (2000) writes: "Paranormalism is a non- or extra-scientific approach to a phenomenon--a scientifically implausible event is believed to be valid and literally and completely true" (pp. 19-20). If our high school graduates accept the validity of explanations that are explicitly nonscientific (e.g., non-naturalistic, non-rational, non-evidence based), then we have failed to provide them with important skeptical thinking abilities. They will be vulnerable to exploitation by crank medical practitioners, marketers, politicians, and anyone else who might profit from their gullibility.

Meet the students where they are. The student quoted above questioned my career choice because he had participated in activities that exploited his desire to believe paranormal abilities are real. My teaching approach was essentially constructivist in that I initially engaged my students in an exploration of psychic abilities rather than offering an explanation or a debunking. This tactic is fun for the students, and it gives the instructor the opportunity to establish common experiences that everyone in the class shares.

I believe a particularly powerful driver of belief in the paranormal is the widespread, albeit unique, experiences that each of us has had with strange phenomena, which some people ascribe as paranormal. For example, I once had a vivid but bizarre vision, which I attribute to an hallucination brought on by hypothermia and sleep deprivation. It was so real and powerful that I still remember the details some 20 years later. Someone not so inclined, or less experienced in skeptical thinking, might attribute the same vision to ghosts or angels.

How should we deal with students who have had similar, seemingly inexplicable experiences? We could jump right in and help each student analyze his or her own beliefs as a scientist might, but I believe this is the wrong approach, for several reasons. First, you will alienate the student because he or she feels a deep and personal connection to the event that you are trying to discredit. Second, it is impractical to dissect each belief individually; there are too many, varied experiences in the class and too little detailed information is known about each. Effective skeptical analysis requires that a great many details be known. Third, I believe that effective debunking of an apparently paranormal phenomenon is best accomplished using shared, common experiences. Thus, I endeavor to provide a set of seemingly paranormal experiences that may be embraced by all (or most) students and that then may serve as common substrates for skeptical analysis.

The in-class exercises described below also have the effect of creating some cognitive dissonance for most students. Students generally don't think of their professor as a palm reader or a telekineticist, and so they may feel somewhat uneasy if their own observations challenge that perception. If a professor can come off as a convincing paranormalist--only to be revealed as a charlatan later on--then perhaps the paranormalists on television are worthy of a little skepticism as well.

What to do. I usually start with a mind-reading activity. “Pick a number 1 to 10, but keep it a secret. Now, multiply your number by 2; add 6; cut that number in half. Now, subtract your original number.” I peer intently at the student and confidently announce the number that is now in his head. After repeating this two more times (but no more!), the students are generally amazed. Some may suspect chicanery, but they probably will not be able to articulate what you did to trick the answer out of them. If someone questions all the numerical manipulations, simply respond that the power of their mental processing strengthens the signal you receive. Students seem willing to accept that supposed mental powers are not foolproof and might require special circumstances. (By the way, I routinely perform this trick on science teachers at workshops; although they are skeptical, they also cannot identify how it works.)

The entire ruse is merely a means of talking someone through the algebraic equation $\{(2x + y)/2\} - x$. This reduces to $y/2$, where y is the number you tell the student to add to whatever figure he has in his head after doubling the original, secret number. If performed only a small number of times, your audience will not notice the pattern. To be convincing, practice a few variations on the wording, which you will alternate as you move from one subject to the next. For example, if you ask the first person to “double your secret number,” you might ask the next person to “multiply your number by two.” Similarly, you can say “divide by two” or “cut your new number in half.” The solution seems obvious, but even sharp skeptics who immediately suspect the mathematics usually can’t figure it out if only performed two or three times. And this exercise really amazes anyone with a desire to believe in psychic abilities.

Another exercise that is simple to perform involves the hooey stick, a pair of short sticks with notches and a small propeller. The details of how to make these simple devices (or to purchase them) can be found at Banister-Marx (n.d.). The basic idea is that the direction of propeller rotation can be reversed with a subtle--and with practice, undetectable--sleight of hand.

I set students up by telling them I have telekinetic powers. They watch closely as I rub the sticks together and cause the propeller to rotate. At this point I tell them I am going to cause the propeller to reverse direction using only the power of my mind. By shifting my finger position ever so slightly, the propeller direction does indeed reverse. (For added theatrical flair, I often fail the first time and announce that doubters are disrupting my extrasensory abilities with their negative energy. When I encourage everyone to think positively, I achieve success.) If students immediately suspect trickery, hand them the sticks and ask them to duplicate your performance. In my experience, students are unfamiliar with hooey sticks. They can get the propeller moving, but cannot reverse the direction at will.

Leading the students to skepticism. The elegance of both these tricks for a nature-of-science demonstration is that you need only careful observation and repetition to reveal them for what they are. When the students are ready to move from the engagement/exploration phase of their lesson on skeptical thinking to the explanatory phase (again within a constructivist framework), remind them that in science explanations must be naturalistic and empirical (i.e., must adhere to natural laws and be based on logic and evidence, such as observation and/or experiment). With these strictures in place, allow them to watch your hands very closely as you repeat your demonstration with the hooey sticks. Ask them to generate hypotheses. Each hypothesis should lead to a prediction, which you can allow the students to test for themselves and verify with independent testers. Similarly, you can challenge the students to debunk your mind-reading ability by carefully recording the sequence of statements you make each time you reveal someone's number.

By the end of such activities, students are more willing to examine their previously "off-limits" experiences and consider ascribing natural explanations to them. In my expanded course on skepticism, which includes many other paranormal phenomena and alternative scientific explanations for each, I generally assign a paper that asks students to critique a personal paranormal experience as a scientist would. (This builds on an earlier paper in which they merely described their experience.) Notice that with this wording, even students who have not fully relinquished their hold on the paranormal can be successful by explaining how scientists analyze a phenomenon (for example, with appeals to naturalistic arguments that are evidence-based and logical). With luck (!), your students will actively question what they see and hear in the future.

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Gallup, G. (1997). *Public opinion 1996*. Wilmington, DE: Scholarly Resources.

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Student Experiments

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

Murphy's Laws

Murphy's laws are statements that reinforce the notion that if something can go wrong, it will go wrong. For example, Murphy's Law of Toast goes something like this: "If a piece of toast falls, it will make the maximum mess by landing buttered-side down.” They can provide excellent stimuli for inquiry science activities, while also showing the relevance of the methods of science to everyday-life experiences. Students need to first ask if the statement is testable and, if so, design an experiment to test it. This will involve identifying variables and investigating any effects these may have on the outcomes.

Returning to the example of Murphy’s Law of toast, the variables will include how the toast is dropped, from what height, and the amount of butter used. Matthews (2001) concluded that, for toast that slides off a tilted plate from waist height, Murphy’s law is indeed valid and is not simply the product of a selective memory for unfortunate outcomes. There is a substantial bias towards the toast landing buttered-side down, and the effect should be noticeable after a dozen or so trials. This conclusion was unaffected by the amount of butter used (determined by the use of both buttered and unbuttered, but marked, toast).

However, toast similarly dropped from a height of 2.5-3.0 m was shown to spin so as to be somewhat more likely (i.e., better than a 50:50 rate) to land buttered-side up. So, to increase the chances of avoiding a messy, unwanted outcome, one might move with the plate held above the head!

Other well-known myths that might be examined experimentally include:

- Placing a spoon in the neck of a bottle of fizzy drink will make the fizz last longer.
- The neighbouring supermarket queue usually moves quicker.
- Adding cold milk immediately, rather than later, to a hot drink keeps it warmer for longer.
- Watering plants on a hot day burns them, because the water droplets act as lenses.
- If you are looking for a location on a map, it will usually lie in an awkward part of the map (i.e., close to the edges, or across the central crease).

Reference

Matthews, R. A. J. (2001). Testing Murphy’s law: Urban myths as a source of school science projects. *School Science Review*, *83*(302), 23-28.

For Further Reading

Murphy’s Laws and Corollaries   http://dmawww.epfl.ch/roso.mosaic/dm/murphy.html .
Murphy’s Laws Site   http://www.murphys-laws.com .
The Ultimate Collection of Murphy’s Laws   http://www.cpuidle.de/murphy.shtml .

Critical Incident

The stimulus for this new, regular section in *The Science Education Review* was correspondence received from Gary Simpson, Woodleigh School, Victoria, Australia, a strong supporter of this journal and a regular contributor. A critical incident "is an event or situation that marks a significant turning point or change (Tripp, 1993)" (Gary Simpson, personal communication, October 9, 2002). Gary went on to say:

> the majority of critical incidents are not dramatic or obvious, but are rendered critical through the analysis of the teacher. In the tradition of autobiography in education, Tripp suggests that these incidents tell us something about whom and where we are, and where we might be going. He claims that, by working on our professional practice, we are working on our values in this practice, and that professional autobiography is about recognising, articulating, critiquing, and modifying, our professional values.

An Invitation

Below you will find a report of a critical incident which might serve as an example for contributions to this section of *SER*. Readers are invited to send, to the Editor at editor@ScienceEducationReview.com , a summary of a critical incident in which you have been involved. You might describe the educational context and the incident (please use pseudonyms), analyse the incident (e.g., provide reasons to explain your observations), and reflect on the impact the incident made on your views about the learning and teaching process. Upon request, authors may remain anonymous.

We have undoubtedly all done things about which we were very pleased, and perhaps done other things about which we did not feel so pleased, and we all need to remain reflexive of our practice. While teachers will view an incident through the lenses of their own professional experiences, and may therefore explain it differently, this does not detract from the potential benefits to be gained from our willingness to share our experiences and thus better inform the practice of other teachers. Please find the following example of a critical incident.

Reference

Tripp, D. (1993*). Critical incidents in teaching: Developing professional judgement*. London: Routledge.

"Miss, may I Please Explain to you About Radioactive Isotopes?"

Contributed by: Gary Simpson, Woodleigh School, Victoria, Australia, on behalf of Marni Sellens simpg@woodleigh.vic.edu.au

My second teaching round [Marni was a fourth-year teacher education student] was at a country Victorian (Australia) high school with around 800 students. I taught three of the eight Year 8 classes, one with each supervisor. In my first observation of 8B, a class of 25 students with equal numbers of girls and boys, I was surprised for the first of many times over the 5 weeks. The students came in, took out their work, and immediately began asking for help. Then "1…2…3" and silence. There was no pulling kids from the ceiling, "please sit down," "take out your books," or "turn to page 37" (that would come later in another class).

Five minutes of talk from the teacher and they were away. My supervisor had only just introduced me and already I had students lining up to talk to me, not about where I got my shoes, but about convection and the difference between series and parallel circuits. No, they didn't want me to explain it to them; I was to listen and question them, while they explained it to me. I was out of my comfort zone and had to adapt--fast.

Being a little rusty on the topic at hand, I was a little nervous, but after some diagrams on the board, explanation and clarification of terms, demonstrations, and the encouragement of the other students, I was beginning to really understand. But hang on, wasn't I supposed to be teaching them? "Well done, yes that's it." The waiting students were happy with the responses given. "Just sign here Miss S," as a paper was handed over--my first capacity matrix.

Thus began my education in student-centered learning. Affinity, interrelationship, and fishbone diagrams, dissecting (or padding out!) the CSF (Curriculum Standards and Framework, Years P-10, Victorian Curriculum and Assessment Authority), appointment times with the teacher for one-on-one time, Chris and Ben explaining radioactive isotopes to me, and how the decay of carbon allows us to determine the age of rocks. Beth and Lucy happily staying after school on a Friday. David coming to see me at recess to get more items signed off, explaining and drawing the rock cycle, and making up songs about it, and students designing their own experiments (one involving the use of acid, boiling water, and a large drill).

Students who claim they won't do homework, yet turn up to class with a beautifully presented flow chart, a Power Point presentation, or a new way to demonstrate something to me. Students who share information, and respect each other's opinion and the opinion of their teacher. You couldn't get the smile off my face the day one of my "cool" students reprimanded another student for calling me over by yelling out

“Hey!” Thankyou Drew for responding icily: “Her name . . . is Miss Sellens.”

I never once heard “this is useless, why are we doing this, we’ll never use it again” from 8B. Why? Because they owned their work, their grade, and therefore the responsibility of their education. Now that may all sound sappy to some, but I didn’t know if I really wanted to be a teacher at the start of my round and these students and my supervisor managed to give me the inspiration I needed. Hopefully, I will be able to train (I mean encourage) my own classes to be independent learners.

Each student went about completing his or her matrix in a different way. Some admittedly struggled to begin researching a new item, but were often helped along by their peers rather than myself. Some students also tried coasting along until the end of the topic, as they knew they could get it all done in a couple of weeks if they tried hard. They were tripped up, though, by report writing and missed a lot of their work being recognised--a mistake they said they would not repeat again.

This class was important to me because I realized that I enjoyed each student’s success. I got to know each of them and appreciate each of their differences. Some worked as teams, and I saw them change as different members learned who worked best with whom. They worked through problems at the end of the topic and figured out ways to best utilize their time. Now, I could have thought that this class was a one-off, but my supervisor had another class that was working in the same manner. They worked differently, but still successfully. There were problems, like students wasting time and unmotivated students falling behind, but there wasn’t one discipline issue, and the other issues happen in all classes anyway. Show me a perfect class and I’ll show you a unicorn. What these students were doing was gaining skills vital for the rest of their school career: research, explanation, problem-solving tools, and cooperation. They may not have covered as many topics, but they learned to value education, and I think that is more important.

Unfortunately, not all the teachers at this school shared the opinion of my supervisor, or appreciated his style. I had four “extras” teachers supervise me, and I watched amused as they would at first try and control the class or stop kids from doing something I had given permission for. My favorite comment was from an extra who arrived late and came in when we were already underway: “Is this Mr S’s science class?” “Yes,” I assured her. “Are they doing something?”

Many of the older teachers thought this teaching approach wasted time, or didn’t cover enough of the curriculum. There was an obvious line drawn in the staff room, and you could tell who stood on which side. I believe the current trend in education is towards student-centered learning. Universities are teaching it, and professional development sessions are addressing it. I look forward to the future.

Science Poetry

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 .

Science

Science is the study of what's around
We can find science in the ground
It is there when we go to space
We use it all over the place
We need it to understand the stars
And even when we design cars
A scientist is not a fool
So I will work hard at school

Ayrton Gugenberger, 9 years
Australia

Theories of Matter

Earth, fire, water and air,
That is all that matter that is here and there.
Empedocles said that matter is made of all four,
Then Aristotle came and added some more.
Hot, cold, dry and wet,
"That's what it is," the ancient Greeks bet.
Leucippus and his pupil Democritus then thought of more,
To add to the qualities and elements all four.
All matter is particles of differing size and shape,
Whether in wood, clothes or sticky tape.
Anaxagoras, however, said they were wrong,
And that matter was one whole all along.
Galileo then came and had a new reason,
That particles were held together by something called cohesion.
That there were an infinite number of particles so small,
Held together by infinite vacua and that was all.
Descartes then said that matter had mass,
That it was infinitely divisible whether in solid, liquid or gas.

Empedocles, Aristotle, and Leucippus were right,
But not Anaxagoras whom judged by sight.
Democritus and Galileo--they were right too,
But Descartes was wrong with his point of view.
In 1808 John Dalton then put forward a theory,
To see if he could solve the atomic query.
He said that all matter had tiny particles, atoms they were named,
And that atoms of the same element were alike he claimed.
He also said that you couldn't divide atoms into smaller particles,
But to prove this he could not,
So then the English scientist Sir J. J. Thompson gave it a shot.
He said that negatively charged particles are what atoms contained,
He called these particles "electrons," so that is what they were named.
He made a model to prove his point of view,
As he believed his explanation was true.
That atoms were positively charged, his model had shown,
And that these atoms even had a shape of their own.
Like spheres they were round,
And in them negatively charged electrons were found.
Then Lord Rutherford had an idea or a thought you could say,
And the model he made back then is similar to today.
It showed the atom with mostly empty space,
And with charged protons inside this empty place.
Negatively charged electrons orbited round,
Orbiting the nucleus is where they were found.
Though there was a problem that grabbed his attention,
The one thing that left a blank in his model-invention.
It was that the orbiting electrons would eventually give in,
And that towards the nucleus they would spiral and spin.
He couldn't explain or fix this, so that was his flaw,
So to solve this problem Niels Bohr gave it his all.
He modified the model by making a significant change,
It was that the orbiting electrons had an energy range.
To be on a level the electrons and the energy had to be the same,
And when it came to moving levels it was just about loss or gain.
And although a reason for the orbiting, the model had involved,
An explanation was needed for the properties, so still it was unsolved.
Sir James Chadwick made a discovery in 1932,
To explain the unsolved query with his scientific point of view.
An explanation for the nucleus was needed to solve the question that remained,
So he said the positively charged protons and neutrons are what the nucleus contained.
Neutrons had no electric charge and though in this way they were distinct,

“The proton and neutron have something similar,” is what he began to think.
The neutrons are the same as the protons when it comes to mass,
And all of this explains the theories of solid, liquid and gas.
Many scientists have tried some were right and some were wrong,
But they have all contributed to the answer that has puzzled for so long.
Now that all of this is explained, the issue can now rest,
Until yet again science comes along and puts their theory to the test.
All of this writing may seem like “scientific chatter,”
But in the end it always is “the many theories of matter.”

Anna Karen Gonzales, 13 years
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.

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

a. When you give a disease to another person, it means that you don’t have it anymore yourself.
b. Dirt causes illness.
c. Tiny living things cause illness. These may be found in dirt.
d. Cooking food will prevent food poisoning.

Comment: Statement c is the only true one. Statement a equates “giving a disease to another person” with literally giving it away. While cooking will kill bacteria, it does not necessarily prevent food poisoning, because some bacteria produce toxins that linger and cause illness.

2. Explain why people often don’t become ill till a day or two after infection.

Comment: This item explores understanding related to the concept of microbes multiplying over time.

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 in this task.

Teaching Techniques

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

Press Conference

To teach the kind of issues-based curriculum advocated by Hodson in his article *Going Beyond STS: Towards a Curriculum for Sociopolitical Action* found earlier in this issue, science teachers will need to further develop teaching techniques more commonly associated with the humanities and language arts. You may therefore expect to see such included in this section of *The Science Education Review*.

A press conference role-play provides an opportunity for students to explore aspects of a socioscientific issue (e.g., the building of a facility in your town to manufacture radioactive medicine, or the use of animals in certain experiments), while also exemplifying that science does have limitations. While science can contribute to a debate, science cannot answer all questions. Science cannot answer, for example, moral or ethical questions, and hence the need for politics. Politicians need the ability to tradeoff between different points of view in cases where no natural tradeoffs exist.

Divide the class into groups, with each group representing a different party concerned with the issue. These might include the city mayor, a leading scientific researcher, doctor, father, mother, child, engineer, environmentalist, worker, zookeeper, company executive, or whatever--even an animal or plant. Each group researches and discusses the issue from their standpoint, and one person from each group then volunteers to represent that group as a panel member in a simulated press conference. During the conference, those students who are not on the panel act as journalists in an audience that questions the panelists. During questioning of the panel, other members of a student's group may help a panelist respond. If appropriate, the activity could culminate with a student vote on the issue.

Element Bingo

To reinforce the symbols for elements, provide each student with a card featuring different element symbols in each position of a grid. The symbols should be in different positions on different cards, and the symbols on each card need not be the same. The teacher (or a student) has a set of flashcards, with a different element name printed on each card. He chooses a flashcard at random, displays it to the class while saying the element name, and students who have the matching symbol on their cards mark the symbol, possibly by placing a small piece of paper in that position.

This process continues until a student's card is filled, until a column or row is completed, or whatever, and this student then announces "Bingo!" (or something similar). A check is made of the match between the student's symbols and the names called by the teacher and, if correct, that student wins that game.

Ideas in Brief

Questions to Avoid Asking

Brovey (2003) suggests that teachers should refrain from asking students questions to which the teacher already knows the answer. Rather, the teacher should simply tell them the information she wishes to emphasize. So, for example, instead of asking what the scale of a map is, she might tell them that the scale of the map is 1: 2000 and that this means one unit on the map is equal to 2000 units on the ground, and then ask if there are any questions about this. His criterion for an effective class is that students find it interesting enough to want to ask questions.

This approach to questioning has several associated advantages. The crisp, energetic flow of information makes for very efficient use of classroom time, and students are not distracted by the wrong answers of peers that take time to correct. For teachers who find this too difficult, Brovey (2003) suggests the use of rhetorical questions which they answer themselves.

Reference

Brovey, D. J. (2003). Questioning questioning. *Journal of College Science Teaching*, *33*(2), 5.

Editor: The rationale for Brovey's suggestion comes from his reflections on his own learning as a student and his observations as an observer of other teachers and presenters (personal communication, March 23, 2004). In this communication, he also said that he thinks the idea applies to learners of any age, acknowledging though that his personal experience has been with Grades 5 to graduate school and that he therefore cannot comment about the Early Childhood area.

As I was reading the article, I found myself doubting the proposal, and look forward to what others may have to say via, for example, a contribution to the Reader's Forum of this journal. My following reactions are restricted to personal experience, as I haven't yet had the opportunity to investigate what the literature may have to say on the topic.

First, aren't wrong answers from students to be welcomed in class, because they elicit alternative conceptions and thereby provide opportunities for addressing them? Perhaps a criterion for an effective class is also that students feel comfortable to contribute freely, regardless of whether their contributions are correct or not? Also, doesn't the use of questions to which students already know the answer aid in keeping students cognitively active during class, and often model metacognition?

Second, allow me to be pragmatic and share two personal experiences that suggest how difficult it may be to introduce Brovey's idea into teaching culture. When I began teaching some 27 years ago, I was a lecturer/demonstrator who made frequent use of rhetorical questioning. I had been told by students, teacher education supervisors, and senior school staff that I was doing a good job, and then I had my only visit by a school inspector (we no longer have such personnel in Queensland [Australia] schools). He told me that I had made a sound start to teaching, but that my questioning technique needed refinement. He said the students should be answering the questions I was asking (questions to which I knew the answer), and then proceeded to describe how he had been praised during his teaching career for his questioning ability, including his ability to conduct an entire lesson using questions alone. What was needed to progress within this educational system became very clear!

During the past 10 years, I have also been visiting schools to present science shows. A typical audience comprises anything from a class group up to about 150 students, and I use questions (to which I know the answer) in much the same way I would in a normal classroom situation, and feedback from attending teachers indicates that this involves students in a positive way. One day I found myself at the front of a long, narrow hall seating over 300 students--and, to make things worse, I had to be on stage some distance from even the closest students in the front row. I use a microphone, so I knew the students at the back would be able to hear, and my props were large enough to be able to be seen from the back. However, how was I going to question this group? I would not be able to hear a response from the back of the room, and I thought that restricting my questioning to close students may alienate the others, so I chose to use more rhetorical questioning during the show than I usually would. Teacher feedback from the show was critical of my use of rhetorical questioning and the associated lack of audience participation.

Please do let me know if you have any thoughts or research-based conclusions to inform deliberations about Daniel Brovey's think-piece. I know Daniel will also welcome the feedback. Perhaps there is a research project here?

PBL Need not be Difficult

Problem-based learning (PBL) uses real-life problems, to which students relate, to stimulate self-directed investigation. It has been shown to be an effective strategy, improving students' understanding of scientific concepts and problem-solving processes, and also develops skills like critical thinking and teamwork. However, contrary to the view expressed by some commentators, Grow and Plucker (2003) suggest that implementing PBL does not need to involve a lot of work, nor necessarily the redesign of an entire curriculum. Rather, PBL activities can be embedded into existing lessons.

PBL begins by presenting students with a problem. Ideally, the problem should be from recent news or school or everyday life, thereby being of interest to students and thus motivating them, while also demonstrating the applicability of their studies to students' lives. The problem need not lend itself to being solved via a single process, nor does it necessarily need to have a "correct" answer. Problems of variable length (e.g., a homework or single lesson activity through to a full term or semester project) and complexity should be used. To familiarise students with the process of PBL and working in small groups, a relatively simple problem might be used at the beginning of the school year--for example, a Fermi question, like : "Estimate the total number of sheets of A4 paper used by all students in your school in a year." Further examples of problems include "How do drinking straws work?," "Build an inexpensive, portable device to detect acceleration (i.e., a change in motion) in a situation, such as in a car, on an amusement ride, or in an elevator," and "Find a junk electronic device and dissect and analyse it."

Working in small groups, students analyse the problem and brainstorm what they know and what they need to learn. They then split into smaller groups and produce action plans (i.e., what is to be done, and how to do it) for investigating their subtopic. Early in the year, the teacher might provide resources, such as websites and library titles, but reduce this help as the year progresses. Such group work has many advantages: the interactions between students encourages reflection, which helps learning, it develops an appreciation of the value of delegating, and students come to appreciate that the diversity of characteristics among team members facilitates effective problem-solving.

The teacher works as a coach, guiding students gently but without telling them their ideas are right or wrong. While guiding questions are used, students must discover concepts on their own. From time to time, minilectures may be needed, perhaps to individual groups only. There may also be a need for students to be taught certain technical skills needed for investigating. Parents and other members of the community can be useful resources. For example, a lawyer could be invited to speak on how to make a convincing argument.

Students then return to their original groups and discuss the results. A solution to the problem may arise, or new learning issues, requiring further investigation, may be identified. These groups may also interact. The activity culminates with the group presenting their findings/product to the class.

Assessment needs to match the nature of the problem, so might well be a product or a performance. Formative, as well as summative, assessment will be used, and this should include self-assessment (e.g., rubric or journal writing) which might increase as students become more familiar with the process. Journal writing should include evidence of contributions made by every group member.

Reference

Grow, P. L., & Plucker, J. A. (2003). Good problems to have. *The Science Teacher*, *70*(9), 31-35.

Critical Constructivism, Neo-Relativism, and the Place of Values in Science Education

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Abstract

In this paper, the author considers the role of teaching values in science education as part of a move from teacher-centred pedagogy to student-centred pedagogy. Taking a constructivist-inspired position, he argues that, as part of their study of the use of scientific knowledge by society, students need to be given opportunities to make value judgements. A practice of teaching and learning that is centred on the unique individual needs of each student is outlined as a manner in which this vision for the future can be achieved.

Introduction

Does the teaching of values have a place in science education? If so, whose values? Which ethics? Many philosophers of science and of science education would argue that humans have constructed the body of knowledge we call science and used it to explain the natural world. This is certainly so of indigenous peoples and their constructions of science. If we accept that knowledge is constructed (a relativist position[1]) and we accept that the role of science is to serve the needs of the society, then we must ask about values and ethics (which has not been an explicit relativist concern, as to make a choice between two or more values is to privilege one over the others--something relativists are loath to do). How do we want the knowledge and technologies that result from the scientific endeavour to be utilized by our society? Who should benefit from this knowledge? When are some ideas just too dangerous and unpalatable? Why?

As for education, the educational philosopher Henri Giroux (1987) stated:

> Teachers are asked once again to promote character development in

> students, to teach them a clear sense of right and wrong, to promote skills of individual achievement, which translates into the virtues of hard work, self-discipline, perseverance, industry, respect for family, for learning and for country. (p. 113)

Giroux suggested four theoretical considerations for developing what he calls "pedagogy of critical citizenship" (p. 119). The first is a curriculum that challenges the issues of whose knowledge, history, language, visions, culture, and authority prevail as legitimate objects of learning and analysis? The second is a classroom that allows different student voices to be heard and legitimated. Third, the teacher must provide students with the opportunity to investigate a diversity of discourse about a subject from as many different sources as possible. Finally, Giroux argues for the teaching of values. Students need to be assisted to learn how to critique the information they receive and to evaluate that information and make their own decisions about it. I argue that this must be done through moral and ethical filters.

In this paper, I would like to consider a pedagogical approach to science education that attempts to answer these questions. It applies Critical Constructivism[2] (Lewin, 2000; Taylor, 1998), which by extension suggests Neo-Relativism, to the teaching and learning of science. Neo-Relativism is a term I use to describe a new form of Relativism that is concerned with valuing in the more pragmatic field of education. Using a Neo-Relativistic viewpoint, one is able to accept a variety of constructions of reality, but lead students to the position valued by society (such as a concept like the cellular basis of life) or question the position valued by society (such as globalisation) and suggest a new solution. This way, one is able to accept each student's construction of the concept, but teach them about the concept valued by society and assist them to reconstruct their own knowledge and understanding. It is a highly pragmatic application of relativism to the teaching and learning of science by adolescents.

Student-Centred Teaching and Learning

Radical Constructivism developed as an epistemological[3] response to standard transmissionist epistemologies for science and mathematics education. Ernst von Glasersfeld (1995) suggested that there are two basic tenets of constructivism:

> a) Knowledge is not passively received but built up by the cognising subject.
> b) The function of cognition is adaptive and serves the organisation of the experiential world, not the discovery of ontological reality. (p. 18)

This means that a learner will actively build knowledge to explain his or her experiences with the natural and social world of which the learner is a part. These two basic tenets of constructivism can be expanded to four general characteristics:

1. All knowledge is constructed.
2. There exist cognitive structures that are activated in the process of construction.
3. Cognitive structures are under development that can be transformed through purposive activity or from environmental or social pressure.
4. Acknowledgement of constructivism as a cognitive position leads to the adoption of a constructivist methodology.

Von Glasersfeld did not envisage that Radical Constructivism would deal with the issue of values (von Glasersfeld, 2000), particularly as it took a relativist position in relation to ontology[4] that does not privilege or value one knowledge claim over another. This neutral ontology led to many critical attacks upon the practice of Radical Constructivism and the development of many other versions of constructivism to answer those critics.

Critical Constructivism accepts the general tenets as outlined by von Glasersfeld above, but suggests that the knowledge claims most appropriate to the society are those that are privileged over others. With the move toward Critical Constructivism, this has become an important concern (Lewin, 2000). This suggests a new position for relativism (Neo-Relativism) that develops an axiological[5] approach to answer the question of what is taught? Which knowledge claims are valued? For practicing teachers this is an important development, for we must pragmatically deal with the students in our care. We must privilege western constructions of knowledge, in my case science, but need to do so in a way that is sensitive to “others.” Thus I have developed a student-centred approach to teaching and learning science that accepts von Glasersfeld’s basic characteristics, but also accepts that students must make judgements about the value of different knowledge claims.

My approach comprises three main features:

1. Discovering what the students already know, and what they feel, about a topic.
2. Having discovered what the students know and feel about the topic, and what (mis)conceptions they have, I negotiate meaningful tasks to address the identified needs of the students. That is, we find ways together to (re)inform their knowledge and understanding of phenomena so that they are either accultured (Aikenhead, 2000) or encultured (Driver, Asoko, Leach, Mortimer, & Scott, 1994) to the western tradition of science.
3. Sharing. An obligation of student-centred approaches to teaching that I place on learners is the need to share what they have learnt.

To achieve these three features, I developed six pedagogical characteristics of a critical constructivist epistemology. They are:

1. the measurement of prior knowledge and understanding,
2. the intervention by the teacher to mediate the learning of students with purposive activity,
3. establishing social situations in which students can make sense of experiences in terms of what is already known, and discuss issues of which knowledge claims should be privileged,
4. a diversity of opportunities for students to represent their knowledge,
5. constant monitoring of student activity to recognise signs of difficulty, disengagement, and depth of understanding, and
6. reporting that recognises the learner as a unique individual.

I believe that students enter my classroom with prior conceptions that explain phenomena. These prior conceptions are deeply held by the student because they have developed over time in response to various experiences and the student's unique enculturation that reflects the values of their family and community. To reframe these (mis)conceptions[6] requires the student to actively question what they believe to be true.

A student-centred approach shares the knowledge and power of the teacher with the student, and has the potential to empower all students. Having been empowered to share in the learning process, the students invest personal energy in exploring phenomena, are caused to question their prior conceptions, explain their beliefs to their peers, renegotiate what they believe to be true, and value knowledge claims over other knowledge claims. The requirement to share these new constructions of knowledge with a larger audience causes the learners to prepare these new constructions carefully. Students also need to be prepared to have their knowledge claims challenged by the audience. As learning is a life-long process, this approach recognises that learners need to revisit and revise their understanding frequently in order to enrich and deepen their understanding from their new experiences. Therefore, the ability to describe what knowledge and understanding students in one's class have when a unit of study begins, and then compare that level of knowledge and understanding for each student when the unit of study has been completed, is very important. It is then possible to assess growth in knowledge and understanding and to report success for all learners. However, a cautionary note should be made. One needs to develop this new way of approaching teaching and learning slowly and with sensitivity, understanding that the students' construction of pedagogy is also being challenged.

Having a classroom that is operating under student-centred pedagogy is not an easier way of teaching. It requires the teacher to act as:

- a facilitator, finding information or resources,

- a critical friend, questioning and assessing work in progress in a positive and meaningful manner, and asking questions to cause students to reflect on the values implicit in their knowledge claims,
- a referee, settling squabbles within and between groups of students over who did what, etc.,
- a police officer, maintaining good patterns of student and work behaviours, and
- a seer. The teacher still needs to have a strong knowledge of their subject area in order that they be able to ask the right questions of the students, suggest appropriate lines of inquiry, and construct successful investigations with the students.

Reflection

The WebQuest approach (Simpson, 2003b) published previously in this journal is one example of this approach to teaching and learning. Essentially, I attempt to create a classroom environment that accepts my learners as unique individuals. Like most teachers, I have tasks prepared for my classes. I will plot a sequence of lessons with my learning outcomes in mind, but rather than doggedly demanding all my students to complete it in the way that I had in my mind, I allow students to negotiate all aspects of each activity. The outcome is a diverse set of products responding to the same stimuli. By having the students share these products with the rest of the class, the experience is enriched for all students. Interestingly, the majority of students are usually happy to work with the materials supplied to them, making only minor alterations. In my experience, it is generally the higher achievers who are able to negotiate and radically alter tasks to suit their own needs (Simpson, 2003a). For those students with learning difficulties, I am able to collaboratively create structured tasks that are meaningful and achievable for them. This approach to teaching values each individual, applies an ethic of care to my students (Taylor, 1998), and assists me to build rich relationships with my students.

This approach has important ramifications for assessment and reporting of student success. I wish to report on student growth, so I first need to assess student knowledge, understanding, and scientific literacy prior to the study of a unit. During, and following, the unit of study, I am to assess how students' knowledge and understanding of important concepts have changed. I can therefore report on those changes in a descriptive manner. But I also use rubrics for my individual tasks. These are written to address issues of scientific literacy, practical skill, and knowledge outcomes (Simpson, 2003b), and are given and explained to students with their task. In this way, the purpose of the task is clear, the manner in which it will be assessed is clear, and students are free to negotiate the various parameters of the task within that framework. With students regularly presenting their work to other students, peer assessment is also a common feature of my assessment.

Teaching in this way is often exhausting, sometimes frustrating, often exhilarating and, as a partner in learning, personally educative. A student-centred classroom looks the same as any other classroom, but there is a great deal of difference in how it operates. The students move freely about the classroom, and the whiteboard is often bare--or at least has half a dozen different notes to different groups, notes the students may have written themselves. The teacher moves freely about the classroom, engaging with students. There can be a significant amount of noise, and often very few students are in the classroom proper. They have moved to other parts of the school that have the equipment or expertise required for the work they have negotiated.

Notes

[1] Relativism holds that all knowledge is constructed by cognition and then various forms of relativism argue about the manner in which social pressures mediate that knowledge and its application. The search for an absolute truth by western science is therefore viewed, by relativism, as futile.
[2] Critical Constructivism is a later form of Radical Constructivism. It does not apply the strongly held relativist position of Radical Constructivism, but accepts that choices between knowledge claims need to be made within the social setting of the individuals (Ernst, 1995).
[3] Epistemology is the study of the way we come to know things.
[4] Ontology is the study of ways of being or ways of becoming, and has to do with what we believe to be true.
[5] Axiology is the study of ways of valuing, or how we establish truths.
[6] I use this term here to acknowledge that my students will all have conceptions, but that some are not as sophisticated as others, or in line with current western scientific thinking. The purpose of science education is therefore to acculture (Aikenhead, 2000) or enculture (Driver et al., 1994) our students into the western tradition of science.

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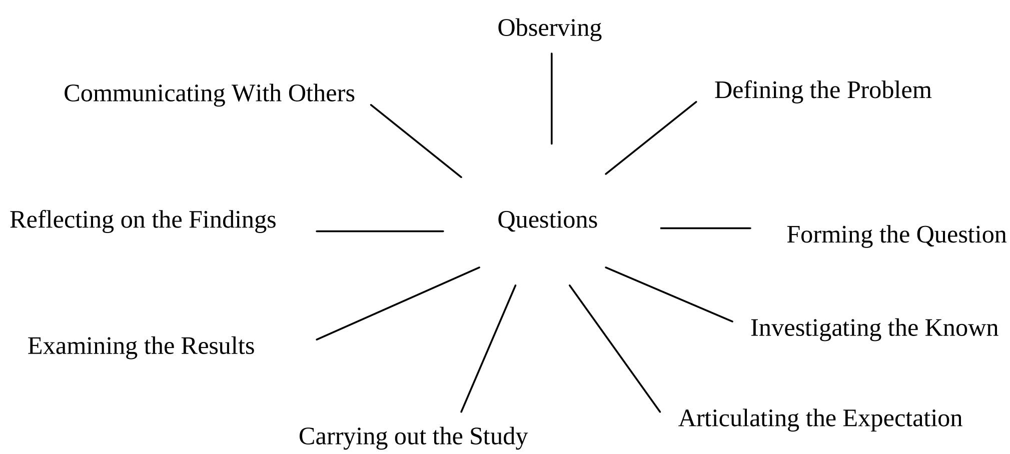
Research in Brief

The Activity Model for Scientific Inquiry

The shortcomings of the typical “Scientific Method” commonly portrayed in textbooks have been long acknowledged. Harwood (2004) used interviews with over 50 research scientists, representing a broad range of fields, to propose an improved model for how science is done. His Activity Model for Scientific Inquiry comprises 10 main activities, as shown in the diagram. During the scientific process, scientists engage in as many of these activities, and in whatever order, as is needed. A particular activity may be used more than once.



Activity Model for Scientific Inquiry

Questions is at the centre of the figure, reflecting the central role of asking questions in any scientific inquiry. *Investigating the Known* might include the use of books, journals, and experts. *Articulating the Expectation* may involve making a prediction or hypothesizing. *Carrying out the Study* includes choosing a methodology, and can include other activities in the model. *Examining the Results* will need to address the validity of the results. *Reflecting on the Findings* requires asking what the results mean (i.e., what conclusions may be reached?). *Communicating With Others* will include collaboration during the inquiry, as well as formal oral or written reports.

The model might be used in a variety of ways. It could serve as a framework for open, guided, or structured inquiry lessons. For example, in the case of the former, the activities could be used to determine if students are using appropriate thinking.

Rather than having students engage in a complete inquiry project, there could be a focus on a particular activity (or combination of activities) alone. For example, addressing *Investigating the Known* could require students to search the World Wide Web and learn how to access and read journals and contact experts. Or, students might be provided with information from a case study and asked to *Examine the Results* and *Reflect on the Findings*.

Reference

Harwood, W. (2004). An activity model for scientific inquiry. *The Science Teacher, 71*(1), 44-46.

Using Drug-Related Topics to Teach Biology and Chemistry

Schwartz-Bloom and Halpin (2003) developed four pharmacology modules to help teach high school students (Years 9-12) basic biology and chemistry principles. The modules were titled *Acids, Bases, and Cocaine Addicts*, *Drug Testing: A Hair-Brained Idea*, *How Drugs Kill Neurons: It's Radical*, and *Military Pharmacology: It Takes Nerves*. After June 2004, these modules, plus two additional ones, will be available at http://www.thepepproject.net .

The 50 experienced teachers initially selected for the study (there was some attrition) were divided equally into an experimental and a control group. Before using the modules in their classes for 12 months, the experimental teachers participated in a 5-day workshop dealing with how to integrate the modules into lessons. They also developed some related classroom activities. During this 12-month period, the control teachers taught as usual. They then experienced the workshop at the end of this period, and used the modules in their classes during the next 12-month period.

The modules were not standalone instructional units, and the teachers were not instructed to use them in any prescribed way. Rather, teachers were encouraged to incorporate aspects of the modules into lessons in any way they considered appropriate, and to use as many of the modules as possible.

At the end of the first 12-month period, both experimental and control classes were given an unannounced, 20-item multiple choice test of knowledge of standard biology and chemistry facts and concepts, as well as reasoning skills. The same test was administered to students, of the control teachers, at the end of the second 12-month period (during which time they had experienced lessons in which module material had been used).

After using a statistical analysis that accounts for various factors that may affect student scores, the data from over 4000 students indicate that the use of these modules, having content of real-world relevance, resulted in significantly higher scores on the test questions. The greater the number of modules used, the greater the increase in achievement. The effects were particularly large when more than two modules were used. Because the way aspects of the modules were implemented in lessons was unique to each teacher, this study can provide no recommendation for a preferred implementation style.

It appears that using topics that are interesting and relevant to students can improve achievement substantially. Another interpretation, though, is that the positive outcomes were due not to the use of the pharmacology topics, but to the fact that the biology and chemistry concepts were repeated within any one module. In any case, the use of the topics provides a way to facilitate repetition without boring students.

Reference

Schwartz-Bloom, R. D., & Halpin, M. J. (2003). Integrating pharmacology topics in high school biology and chemistry classes improves performance. *Journal of Research in Science Teaching*, *40*, 922-938.

Effect of Inquiry Learning on Physical Science Standardized Scores

In contrast to the recommendations of present reforms in science education which advocate student-centered classrooms, teachers provide various reasons for not using inquiry approaches. These include that it requires too much time and energy, that content coverage is too slow, and that teachers feel pressured to use lecture to prepare students for standardized tests.

Tretter and Jones (2003) used urban high school classes taught by one of them to explore the effect of inquiry-based instruction on student performance on North Carolina's (United States) end-of-course (EOC), standardized, multiple-choice test in physical science, and on other classroom measures. During the first 2 years, 161 students in seven physical science classes experienced a traditional, low-inquiry approach. During the next 2 years, the teacher used an inquiry approach with 94 students in four physical science classes. Compared with the traditional emphasis on terminology, definitions, other facts, and the use of formulae, the inquiry approach saw students spending more time on laboratory-based work, and a greater emphasis was given during assessment to the processes related to such.

The inquiry approach did not impact dramatically on students' achievement on the EOC standardized test. However, some other welcome outcomes were observed. Student achievement, both in the classroom and on the standardized test, was more uniform (i.e., more tightly clustered), higher classroom grades were awarded, and there was an improvement in the attitudes of students, with a better classroom atmosphere and much improved participation. Class attendance increased, and fewer students "gave up" on completing tasks and/or sitting the EOC standardized test.

The authors suggest that the nature and format of the questions on the EOC standardized test are a concern. The present test focuses mainly on objective knowledge, and there are better techniques than the use of multiple choice questions to test the skills and concepts learned during inquiry. The North Carolina Department of Public Instruction advocates an inquiry approach, yet the present style of EOC standardized test may not be appropriate for measuring the outcomes associated with such.

Reference

Tretter, T. R., & Jones, M. G. (2003). Relationships between inquiry-based teaching and physical science standardized scores. *School Science and Mathematics*, *103*(7), 345-350.

How Jeff Gordon and NASCAR Helped to Develop a High School Science Curriculum and Educate Future Teachers

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Abstract

The focus of this article is the development of future science teachers. A research project, involving Cornell University, the Cornell Center for Materials Research, and NASCAR Champion Jeff Gordon is described. All research was conducted in association with faculty and staff at Cornell University and resulted in the development of a science education lesson that became part of the SCT BOCES New Visions Education Program.

The Challenge

Imagine the following scenario. You are the teacher in a special program that recruits high school seniors who want to be teachers. You have been told by regional educational administrators that there is a definite need for science teachers at all levels. Your students have already taken most of the available science courses available to them, so they need something different to study. They need something challenging. Keep in mind that these future teachers will need motivating science activities to take into the regular classrooms when they do their student teaching rotations. Your challenge is to create a hands-on science curriculum that can create a love of science. This is your challenge.

This article recounts such a challenge. It is a story that involves a teacher training program, a major research institution, and a world champion NASCAR driver. More importantly, this is a story about building future science teachers. Here is that story.

Defining the New Visions Mission

The SCT BOCES (Schuyler-Chemung-Tioga tri-county area in New York: Board of Cooperative Educational Services) New Visions Education Program is designed to attract the best and brightest high school seniors and prepare them for careers in education. In schools where integrated curriculums are the norm, science education can be used to build critical thinking skills with all students. In New York State, the Department of Education has mandated that all K-12 science curriculums be aligned with the learning standards in Math, Science, and Technology. Since the SCT BOCES New Visions program is designed around the philosophy of technical education, students also build teaching skills under the heading of Career Development Occupational Standards. The mission of the New Visions Education program is simple: Educating our best with the mission to educate others.

Building Future Science Teachers

In this era of advanced technology, preparing future science teachers requires a component that looks at the real-life application of science content. Gone are the days where the science teacher lectures for the full period and then assigns the appropriate chapter on which a test will be constructed. Students in the New Visions program come into the field with a solid background of both math and science. The challenge for the New Visions student is to use this acquired knowledge to construct hands-on classroom activities that excite students about science. Knowing about various aspects of any area of science or math is crucial but, for prospective teachers, it is the delivery of this information that is crucial. Gone are the days where the science test is the only way to evaluate student performance. This is true especially for students who plan to enter the field of science education. It is the interaction between student and teacher that defines successful teaching. More specifically, for the prospective teacher, it goes well beyond the acquiring of knowledge. It becomes a challenge to make science meaningful and relevant to both the student and, more importantly, the teacher.

Enter Cornell University and the RET Experience

Cornell University and the Cornell Center for Materials Research (CCMR) understand how important it is for teachers to expand their knowledge through self-directed project research. The Research Experience for Teachers (RET) program is designed for such a purpose. The RET program is funded by Cornell University and the National Science Foundation. Teachers spend up to 6 weeks at the Center for Materials Research conducting research on a project that they have designed.

The Cornell Center for Materials research is headed by Dr Frank DiSalvo. Dr Helene Schember is the Associate Director and Nevjinder Singhota is the Director of

Educational Programs and the person who oversees the RET program participants. The Cornell Center links teachers with Cornell University professors and offers unlimited access to the research facilities on campus. The NASCAR/Tribology (the science of interacting metals) project came under the review of Dr Brad Anton, Professor of Chemical and Biomolecular Engineering. This connection was especially beneficial because Dr Anton brought road racing experience to the table. An avid road racer, Anton has driven many times at Watkins Glen International. This constant interaction with Cornell faculty and staff lead to the opportunity to develop hands-on technology skills leading to the end result of a science curriculum. Designing a science curriculum to supplement the New Visions Education curriculum that was already in place kept the research project focused throughout the summer of 2002.

The NASCAR/RET Project Proposal

During the summer of 2001, a series of contacts developed with Hendrick Motor Sports. Hendrick Motor Sports is the organization that fields the #24 car driven by World Champion Jeff Gordon. Through the efforts of public relations representative Jon Edwards, crew chief Robbie Gordon agreed to discuss a research proposal where an analysis of Gordon's brake pads and brake rotors would take place at Cornell University. The meeting took place at Watkins Glen International Raceway and an agreement was made to provide brake pads and brake rotors for analysis. This RET project proposal would seek to understand how metals interact on a NASACAR racer when the brakes on the driver's car reach a temperature of over 1600°F. At Watkins Glen International, brakes will undergo in excess of 250 heat cycles during a race. The amount of heat energy that is produced during a race is the key to analyzing how particles transfer from the brake pad to the brake rotor.

The RET Research Focus

The RET project was called the NASCAR/Tribology Project. As rotors and pads arrived from the #24 car, they were sent to Cornell University, where the analysis process would begin. Under the supervision of John Sinnott, supervisor of the CCMR materials facility, rotors and pads were sectioned off into a number of sizes and made ready for microscope analysis. John Hunt, supervisor of the CCMR light microscope and the scanning electron microscope labs, offered guidance on what could be learned by using microscopy to analyze metal samples under high magnification. As the summer progressed, the research project was expanded to include the hardness testing and the surface analysis of Jeff Gordon's rotor samples.

There was even a late entry to the project, as cryogenics became an issue. Cryogenics is the study of extremely low temperatures, and in this project involved the process of hardening metals by subjecting samples to extremely cold temperatures. It is a controversial subject, and many involved with the project wondered what effect the process would have on race car rotors. Cryogenics was of special interest to the #24 team, including Rich Hubbs, the team's coordinator of brake pad/rotor setup.

The RET Project Research Results

At the end of the 2002 summer, in addition to building skills in the area of microscopy, surface area analysis, and hardness testing, a number of discoveries were presented to members of the Cornell University faculty and those who composed the RET program staff at the Cornell Center for Materials Research.

- Through light microscope analysis and surface area testing, it was discovered that the brake rotors used at the NASCAR race at Watkins Glen International had suffered a great deal of surface fad compared with the brake rotors used in the California race. In the case of the rotors used in California, microscopy analysis and surface area analysis revealed less surface fade under similar race conditions. In both cases, rotors reached a temperature of 1600°F throughout the race.

- Using a Rockwell Hardness Tester, it was learned that the process of cryogenics improved the cast iron surface structure of a racecar brake rotor. This was a surprise to many members in the presentation audience, who questioned how cryogenics would change a cast iron rotor.

- Using a profilomiter (a surface area detector), it was learned that the rotors used at the NASCAR race at Watkins Glen suffered much more surface damage than the rotors used in the California race. This was the evidence, in light of the fact that both products underwent similar race conditions (i.e., heat temperatures, heat cycles, number of laps, etc.).

The main cause of rotor failure is the intense heat that builds up during the course of a NASCAR race. The challenge for the engineering staff is therefore simple: How can air be used to lower the temperature of a NASCAR brake system during competition?

Writing a NASCAR/Tribology Curriculum

Research from the 2002 RET experience went directly into the New Visions curriculum under the heading of science education. With the help of a SCT BOCES mini-grant, all New Visions students were provided with a Radio Shack hand-held microscope for use in class. The microscopes have a magnification power of 30X and are battery operated. To begin the unit on science education, students were provided with a review of the research that resulted from the NASCAR/Tribology project. Students then had an opportunity to use a microscope to examine the surface areas of a variety of brake rotors used by NASCAR champion Jeff Gordon, and this piqued students' interest. One benefit from the program was that some of the rotor fragments came from a race at nearby Watkins Glen International Raceway, only 30 miles away from class.

The NASCAR/Tribology curriculum was also used by the New Visions Engineering students who made a field trip to Cornell University to visit the microscopy lab and the materials preparation department. Students even visited the SEM (scanning electron microscope) lab where they examined one of Jeff Gordon's rotor fragments. The visit was covered by the local media and featured on the front page of the Corning Leader in Corning, New York. The publicity from this project has stirred a great deal of interest from other teachers in the area. These rotor fragments have been stored in the New Visions classroom and have been used by entering New Visions students. Students are constantly amazed that they are examining a piece of Jeff Gordon's car. That's the exciting part of the experience and one that motivates these students to teach science through the local community.

Aftermath

Research reports from the RET NASCAR/Tribology project were delivered to Jeff Gordon and the #24 team. Research results and findings were also burned into a CD and sent to the National Science Foundation. The NSF report included curriculum activities that have been integrated into the New Visions Education Program. As a result of the report, other NASCAR teams have shown interest in becoming part of the project. Since the project, other discoveries and revelations have been made concerning the physics of tribology. The bottom line to the project is that, as a result of the summer of 2002, the students of the SCT BOCES New Visions program are learning how microscopy can unlock the secrets of a world not visible to the human eye. Now, the mission of these students is to teach and inspire other students interested in science.

An Update

Since the development of this RET/Cornell University curriculum, students have had an opportunity to take many of the lessons that have been developed and to try them out in regular classrooms in the Elmira, New York area. The results have been spectacular. Since the implementation of this curriculum, the New Visions program has been awarded grants from the SCT BOCES Teacher Center and the Twin Tier Coalition for learning. Monies from these grants were used to purchase more science equipment for use during student teaching rotations.

The highlight of the New Visions Program occurred during September of 2003, when the first graduate of the program was hired as a full-time teacher for a local school district. It is strongly believed that the success of the New Visions Education Program is in its curriculum. The impact of the science activities developed as a result of this research has strengthened the mission statement of the SCT BOCES New Visions Education Program:

"Educating our Best with a Mission to Educate Others."

Further information on the Cornell University CCMR Educational Outreach Program may be obtained from Outreach@ccmr.cornell.edu (phone 607-255-9547). For more information on the SCT BOCES New Visions Program, contact the author.

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

This section of *SER* responds to readers' queries, so please submit your question to The Editor at editor@ScienceEducationReview.com . Have that long-standing query resolved; hopefully!

How is the molecular structure of substances identified?

Whole books could be written about this topic, and probably have. The earliest structural determinations were made by inference from a variety of clues. An example is benzene, which Kekule figured out in a dream. Today, structure is determined primarily through x-ray diffraction, a technique that Nobel laureate Linus Pauling used extensively in studying the structure of matter, especially crystalline substances. The techniques used vary depending on the nature of the molecules being determined.

Harry Keller, USA

How long is a DNA strand?

How long is a piece of string? In the normal human cell there is approximately 1 metre of DNA molecule, but this is divided into 46 chromosomes (strands) of different lengths. Other species have more or less chromosomes than humans and therefore we presume more or less total DNA. How long is a single strand? Which strand do you mean?

Gary Simpson, Australia

What is the difference between inquiry learning and discovery learning?
(The use of discovery learning seems to have been popular some decades ago, but subsequently declined, yet inquiry learning is presently being very strongly advocated.)

According to Victor and Kellough (2003), a fundamental difference between these terms is that discovery learning is a teacher-centered approach, while inquiry is more of a student-centered approach. When using discovery learning, the teacher identifies what science problems are relevant for the students and decides what strategy is the most appropriate to collect and analyze data. All the students have to do is follow the teacher's instruction and they will discover the correct concepts or relationship between variables.

Inquiry, on the other hand, requires students to be in control. Students identify what science problems are relevant for them, students decide what methodology is the best to collect and analyze the data, and students identify a tentative solution to the problem. In this case, the teacher is a facilitator of learning, not an overcontrolling entity.

Both approaches have advantages and disadvantages. Discovery learning might help students focus on what is important in the solution of a problem, rather than going around the branches and meeting dead ends. On the other hand, those dead ends will help students identify what does not work and they will learn from the experience. Inquiry learning might not work as smoothly if students are not used to being in control of their own learning.

In my opinion, if your classroom is lecture-oriented and you want to help students learn more, you should start the transition with discovery learning activities and finalize with truly inquiry experiences. Research suggests that if you implement inquiry lessons overnight, students might become frustrated and tune-out. The transition should be as smooth as possible and should span several grade levels.

Reference

Victor, E., & Kellough, R. D. (2003). *Science K-8: An integrated approach* (10th ed.). Upper Saddle River, NJ: Prentice Hall.

Wilson J. Gonzalez-Espada, Arkansas Tech University, USA

What things should I consider if I am trying to meet the individual learning needs of so many different children in class?

Editor: Please see Margaret Underwood's two-part article, *Catering for Individual Student Needs: Learning Styles*, in Volume 1 of this journal.

I suggest reading *How to Differentiate Instruction in Mixed-Ability Classrooms* (Tomlinson, 2001). It addresses this question directly with a wealth of teacher-friendly ideas.

Reference

Tomlinson, C. (2001). *How to differentiate instruction in mixed-ability classrooms*. Virgina, ASCD.

Adrienne Fong, USA

With constructivism as a referent to my relationship with each individual child I teach, I wish to know their preferred learning style, preferred intelligence, level of learning ability, prior experiences, enculturation, emotional needs, and personal learning needs. From that I then try to develop meaningful and purposeful activities to connect the science of my classroom with the real world lives of my children--all within the constraints of externally set learning outcomes and local school administrative and reporting requirements. Life in its full rich tapestry!

Gary Simpson, Australia

It is important to remember the different backgrounds, learning styles, and personalities of students in order to cater to their learning needs. For teachers with a large number of students and a lot of rules to enforce, this process is diminished. If teachers are allowed to interpret the needs of their students and meet those needs, the classroom environment is more conducive to learning.

Nicole Harvey, USA

Individual needs are a huge consideration. In science at Bremer State High School, we see it like this:

1. Students are working at different conceptual levels in each Strand of the Science syllabus. We know this because we keep track of every CLO (Conceptual Level Outcome) that they demonstrate successfully. So at the very least, we consider the different conceptual development of each student in each strand.

2. While developing their specific concepts through the levels, we also need to take account of their literacy and numeracy needs and learning styles. We therefore try as much as is possible to allow them to work within their preferred learning styles,

while helping to broaden each of these areas by scaffolding. There are a lot more issues really, but we feel we can make a reasonable fist of managing individual difference in these parameters at the least.

Mark Gould, Bremer State High School, Australia

All good teachers struggle with this question in one form or another. At the college level, it oftentimes must be dealt with in terms of the large, rather impersonal lecture hall. Colleges and universities do not often have fixed, upper limits on their student enrolment in freshman-level classes, so faculty must try to meet the needs of sometimes hundreds of students at once. My comments then focus on the large, freshman, general chemistry classes, which I have taught for the past decade.

The "smart" ones. This rather blunt, and partially incorrect, term is used to describe the students who are good visual and aural learners, those who can sit, watch, listen, and learn. These students "get" and process most types of material rather quickly, solve problems well, and generally have few difficulties with math (and certainly have no math phobia). Many teachers find these to be the type of students they want to teach. After all, you simply have to present a logical lecture, talk your way through the concepts, and work out a few example problems for these students to understand. It's a passive form of learning, but one with which these students themselves are comfortable.

So, what must a teacher consider when teaching these students? Consider how to keep them interested! This is the sub-set of students who can end up bored and disinterested, because other students need information presented to them more slowly or repeatedly. This group of students is almost always mixed in with others who learn less quickly, and thus they have to be kept interested. One way is to identify them early, and to involve them in classes, whether it is by answering questions at their seats, getting them to help in solving problems, or finding some other way to get them to interact. By all means, keep them involved and keep their attention!

The "slower" ones. If the first term was blunt, this term--"slower"--is just barely acceptable among educators any longer. It's now considered mildly derogatory, and is in fact untrue in many cases because it reflects only a student's ability to grasp information in a passive setting. But these are the students who are not visual or aural learners, who at best need the information presented to them multiple times, who need detailed, step-by-step problem solving, and who may be acutely math phobic. Most teachers are quite used to teaching such students, but find it more work to do.

The considerations one must make with such students don't necessarily need to be considered a burden. When a new concept is presented, explain to the class that you will be going through it once in its entirety, then again, one piece at a time. Ask, at each point, if everyone understands. One of my favorite comments is to remark: "It's perfectly okay to admit you don't know what's going on right now, but you start losing points when you have to admit it on the test." That usually gets both a laugh and a couple of hands in the air.

Coax these students out of their fears of problem solving by breaking each question into small steps, and having one of these students deal with just one or perhaps two of those steps. Intersperse one of the "smart" ones in such a problem solving exercise to keep them involved and active as well. Have pairs of the "slower" ones double-check each other when solving problems, and working through the math in such problems. It eases student fears, and involves more students in any portion of the class.

One surprise such students may hold is that they do very well in a lab setting. That's when you as the faculty member need to realize that a particular student is a hands-on learner. When you find those students, point out to them in the lectures where such material has been utilized in the lab, or where it will be in the future. Make this sort of connection repeatedly. This keeps their attention.

Using the strengths of all. In many large classes, the faculty members try to break up hours of straight lecturing with some type of group learning. While such group work takes different forms, one continued problem with this is that the "smart" ones don't like to pull along the "slower" ones. The "smart" ones like the passive learning setting that culminates in tests where they can compete with, and usually beat, the "slower" ones. The key consideration, then, in getting students to work together in small groups is to use the strengths of all. Get the "smart" ones involved by using them to explain and further reinforce concepts and ideas to their group members. Get the "slower" ones involved by having them break information into smaller pieces, assemble it into some presentable format, or be the group member who reports back to the larger class. This final idea, of getting a student from each group who is not a quick one on the uptake to report back to the class, is key. You can see a student's confidence grow when he or she "gets it" and presents an idea, concept, or answer back to his or her classmates. By taking into consideration the strengths of each student and their learning style, and using those strengths whenever possible, everyone learns more.

Mark Benvenuto, USA

Further Useful Resources

Children's Books

http://www.kidscanpress.com

Kids Can Press, in association with the Denver Museum of Nature and Science, are introducing a new series of children's books. The first two, *Bees* and *Ants*, are now available. *Bees*, for example, is designed to allow children to find out how bees live and work together, to learn about the bee life cycle, to discover how bees "talk" to one another, and to make honeycomb prints and a model bee.

Other new titles include *Aha! The Most Interesting Book You'll Ever Read About Intelligence*, *The Kids Book of the Night Sky*, and *Animal Groups: How Animals Live Together*. Visit the Web site to find a full book list, sample pages from books, educator resources, author and illustrator biographies, and downloadable activities.

Cognitive Support for Learning: Imagining the Unknown

http://www.iospress.nl

This book, edited by Piet Kommers and published by IOS Press, Nieuwe Hemweg 6B, 1013 BG Amsterdam, The Netherlands, asks the question how learners may become more effective learners while using the highly graphical computer systems that now dominate almost every desk. Its basic paradigm is that learning skills only evolve once the learner experiences more consciously what happens during learning.

Chapters include *Concepts in the World of the Mind* (by Piet Kommers), *Mapping for the Constructivist Acquisition of Concepts?* (Jan Gulmans), *Everything you Always Wanted to Know About . . . Concept Mapping* (Jan Lanzing), *Learning Inquiry and Structural Knowledge Through Epistemic Games* (Chee-Kit Looi), *Concept Mapping in the Teaching of Biology* (Jutta Lumer & Manfred Hesse), *Evaluating Structural Knowledge with Concept Mapping* (Susanne Weber), *Conceptual Tools for Designing and Learning* (David M. Kennedy, Carmel McNaught, & Paul Fritze), *Concept Mapping for Performance Assessment in Physics* (Costas Constantinou), *Conceptual Representations for In-Depth Learning* (Heredina Fernandez, Piet Kommers, and Michael Asensio), and *Knowledge-Based Methodology for Inventive Problem Solving* (Valeri Souchkov & Piet Kommers).

Time Lapse Photography

http://members.ozemail.com.au/~cumulus/lapse2.htm

Use a digital camera to show action at a faster, or slower, rate than in real life. Examples include flower opening, clouds, brain tissue loss in Alzheimer’s disease, aging bananas, and plants-in-motion.

Physics Demonstrations: A Sourcebook for Teachers of Physics

http://sprott.physics.wisc.edu/demobook/intro.htm

Topic areas comprise Motion, Heat, Sound, Electricity, Magnetism, and Light. Also includes vendors of equipment and other materials.

Calculate Your Eco-Footprint

http://www.epa.vic.gov.au/eco-footprint/EF_calculators.asp

The calculators, for households, offices, and schools, use questionnaires to estimate how much productive land and water is needed to support what is used and discarded.

Virtual Skies http://virtualskies.arc.nasa.gov/

On-line activities, complemented by downloadable print materials, to allow students to acquire and employ decision-making and collaborative skills while applying principles. Activities comprise Evolution of Flight, Physics of Flight, Airport Design, Travel and Disease, Determining the Locus of a Flight Plan, How Does a Radio Work?, Tools of Navigation, Flight Delays, Weather Charts, and Weather Statistics.

Science Karaoke http://www.scientainment.com/karaoke.html

Includes a tutorial on how to make Science Karaoke with *Powerpoint*. Science Karaoke is also a very effective mnemonic device.

Flinn Scientific, Inc http://www.flinnsci.com/Sections/Safety/safety.asp

Material on chemical and laboratory safety.

Community Science Action Guides http://www.fi.edu/guide/index.html

Sixteen lesson plans and student activities that support student investigation of local science issues. Themes are Water, Life Science, and Energy.

Science a GoGo http://www.scienceagogo.com

Latest science news, scientific hot topics, and bizarre research findings. Also, a science discussion forum.

kidcyber http://www.kidcyber.com.au

Units of work, lesson plans, and WebQuests for primary education. Topics include Planet Earth, Space, Technology and Inventions, Animals (e.g., Threatened & Extinct Species, Animal Digestion, and Classifying Animals), and Food and My Body.

physics.org http://www.physics.org

A site for questions on physics. Uses natural language query software to answer questions with websites from a database of refereed resources.

TeachersFirst.com http://www.teachersfirst.com

Lesson plans and web resources for K-12 classroom teachers.

Artemis http://artemis.goknow.com/artemis/index.adp

A digital library for students to search, organise, and evaluate science information related to project-based investigations.

The Globe Program http://www.globe.gov

This hands-on, school-based science and education program for primary and secondary students links students and scientists worldwide as collaborators in environmental research.

Bridge Building http://www.42explore.com/bridge.htm

A collection of websites about bridges, bridge construction, and bridge-building contests.

Humour

A statistician is a person who can stand with one hand on a stove hotplate and the other in ice, and tell you that on average she feels pretty good.

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The Science Education Review (*SER*) is an international, peer-reviewed periodical aiming to provide primary and high school teachers with the latest, and best, ideas in science education from around the world. *SER* also publishes original articles, including research articles, and much more.

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