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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Falling Bullets

A bullet falling from the sky can readily kill. At the end of the 1991 Gulf War, for example, 20 Kuwaitis were killed after being struck by falling bullets that had been fired in celebration.

The bullet from a military rifle might leave the rifle with a speed of around 800 m/s and, if fired directly upwards, climb to a height of some 3 km. As it moves through the air, (kinetic) energy will be transferred to other forms of energy (heat and sound), resulting in the bullet returning to the ground with a much-reduced speed of around 150 m/s. However, a bullet speed of less than one half this (around 60 m/s) is sufficient to shatter bone (like a skull!), and around half this speed again (30 m/s) will penetrate skin.

For this reason, Los Angeles, for example, can be a somewhat hazardous place to be during Independence Day and New Year's Eve celebrations. Moving indoors around midnight can be wise! In some places around the world, celebratory shooting into the air is illegal.

Science Story

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

The Discovery of Artificial Sweeteners: Good Luck and Bad Science?

By: Stephen Rowcliffe, Grange School, Santiago, Chile stephenrowcliffe@hotmail.com

Saccharin is the world's oldest artificial sweetener, and was discovered in 1879 by Ira Remsen and Constantin Fahlberg at Johns Hopkins University. The sodium salt of saccharin (orthobenzoyl sulfimide ($C_7H_4NNaO_3S$) is about 300 times sweeter tasting than sucrose and has been of great benefit to diabetics and dieters since it first went on sale in 1907. This is because it has no calorific value, being excreted from the body, after consumption, unchanged in the urine, and yet allowing users to enjoy the sweet taste they crave.

The discovery of the sweetness of the chemical came quite by chance, when Fahlberg failed to wash his hands before dinner, after spending the day working on coal tar chemical derivatives under the supervision and guidance of Remsen, his research professor. He had spilled some chemicals on his hands during the day and, later that evening when he reached for a slice of bread, he found to his astonishment that it tasted extremely sweet. He spent a long time finding out the exact substance that had caused the sweet taste, licking various chemicals on his clothes and around the lab until he found the one responsible. He was quite lucky that he didn't make himself seriously ill in the process!

The two scientists jointly published the discovery of saccharin in 1880. Remsen lost interest in the chemical, as he was not a believer in commercial gain through the exploitation of science, but Fahlberg was much more ambitious--and ruthless. He found a way to mass-produce the chemical and then patented it in 1884, without giving any mention to his former partner or cutting him into any of the money. Falhberg became extremely wealthy from the sale of saccharin, and Remsen was understandably extremely annoyed. He was quoted as saying of his former colleague: "Fahlberg is a scoundrel. It nauseates me to hear my name mentioned in the same breath with him." However, he eventually overcame some of his ill-feelings for his former colleague, and was part of the group of scientists who declared the chemical safe for human consumption in 1907.

Most of our other artificial sweeteners were also discovered by chance; cyclamate, by Michael Sveda, who inadvertently rested the butt of his cigarette in a pool of chemicals on his lab bench at the University of Illinois in 1937, finding it pleasantly sweet when he returned it to his lips moments later, and aspartame in 1965 by Jim Schlatter, who was working on a cure for ulcers at the time and had accidentally smeared some of the chemical he was studying onto his fingers from a flask. When he licked his fingers to pick up a piece of paper, he discovered the taste that millions of people every year enjoy in diet soft drinks and sugar-free gum.

Possibly the most bizarre example of such an accidental discovery was due to a simple language miscommunication. Shashikant Phadnis, an overseas graduate chemistry student working for British sugar giant Tate & Lyle in 1976, misunderstood a request to *test* a chemical compound of sucrose and chlorine. Due to his incomplete grasp of English, he heard the word *taste* and gamely drank some of the chemical, the safety of which was completely unknown! Thankfully, he was unharmed, and in the process discovered yet another of our popular artificial sweeteners, the addition of chlorine having made the sucrose taste hundreds of times sweeter than normal.

The way in which these popular food additives were discovered seems incredible by today's standards of lab health and safety, as the scientists' lives may have been at risk from poisoning. In recent years, there has actually been some doubt as to the safety of many artificial sweeteners, with cyclamate banned in the 1970's and saccharine, in (extremely) high doses, shown to cause bladder cancer. However, they have helped many obese people to lose weight and many diabetics to keep their blood sugar levels under control, and so have undoubtedly made a significant contribution to society.

Learning From our Students: Photovoice and Classroom Action Research

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Abstract

In this project, Photovoice, a participatory action research tool, was used to establish a relationship between teacher and students and an understanding of students' ideas of, and about, science. The background to the research, the action research and Photovoice methods used, and what was learned from the study are discussed. Suggestions are made for how Photovoice and action research will be applied to future teaching.

Project Background

> The first day, desks are clean, book bags are new, pencils are sharp, and who or what is going to walk into the classroom? What are the views, beliefs, attitudes, and ideas of the students in my room; and how am I going to connect with them and their notions of science?

As a new teacher, I worried about these profound questions during the weeks and months before school started. During my teacher training, we had been drilled with the refrain: "Begin with the students' knowledge and experiences and connect what you want to teach to what your students already know." Based on an undergraduate research project I had worked on with co-author Helen Meyer, I felt a Photovoice action research project could begin to answer my questions about how to "connect with students." Since Photovoice provides students with cameras to create images of their ideas, I thought it would be an engaging activity to begin the school year. As a new teacher, I was both afraid and excited about starting my teaching career with a research project. In any case, I wanted to really implement my theoretical grounding in critical pedagogy, give voice to my students, and teach with my students' ideas in mind.

Purpose of the Study

The overall goal of the project was to explore the use of Photovoice as an action research and pedagogical tool for learning about my teaching and physical science students. Photovoice action research was developed by Wang and Burris (1994, 1997) to study the health of women in developing countries; and, in particular, to identify labor issues affecting the overall health of Chinese women. Wang and Burris (1994) modeled this participatory action research method on Freire's (1968) work with Literacy Circles and South American men. However, while Freire used Literacy Circles to democratically develop concepts of education, empowerment, and consciousness-raising through dialogue (Freire, 1968, 2001), Wang and Burris used photographic images rather than text to reduce barriers to participation for the illiterate women.

The Photovoice process requires participants to take pictures. These images then become a focus for communication between the participant researchers and the researcher. The participants share their ideas behind an image, their beliefs about what the image represents, and their attitudes about the selected image (Kroeger & Meyer, 2005). In a later section, I outline the specific steps I used in my modified version of Photovoice.

In my science classroom, the dialog that occurred after the pictures were taken became an important piece of the action research process. For my students, their pictures became a tool for getting them to think and talk about their science ideas without feeling like I was evaluating their science knowledge. As a student-centered tool, Photovoice allowed me to get to know my students through their own lives and voices, rather than by looking at their past science classes and school records.

Research Questions and Methods

I wanted to answer two primary questions:

1. What do my ninth- and tenth-grade students (14- and 15-year-olds) think about science outside of school?
2. How can I, as their teacher, make use of what I learn about my students to guide my teaching?

To answer these questions, I used a modified version of Photovoice action research. I followed the reciprocal action research cycle suggested by Stringer (1996) (Figure 1), but focusing primarily on application in a classroom rather than a community setting. I used this model because it suggested that I should elicit my students' ideas and permit these to guide classroom instruction and assessment activities.

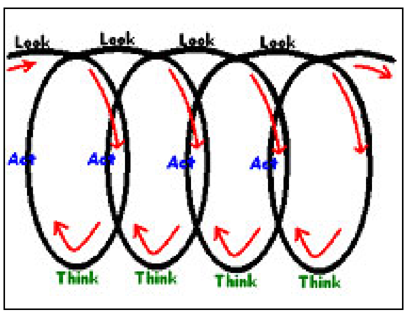


Figure 1. The reciprocal action research cycle.

Ultimately, and aside from its non-invasive nature, the decision to use action research was based on its foundation being good pedagogy. Using action research as my model of inquiry, I was able to analyze and evaluate my teaching and then apply what I learned to my future teaching. In this way, it developed into a productive cycle of asking: "What are my students views/ideas/beliefs?" "How do they apply to my classroom?" "What can I do to further understand their views/ideas/beliefs?"

The Research Project

In the first week of the school year, I assigned each class of students to groups of 4 or 5. Each group had one disposable camera to share, allowing each student to take five pictures. The topic of the pictures they were to take was Show Me Science. They were asked to take a picture in each of three locations; in and around the school, in their homes, and outside their homes. Then, their last two pictures could be of anything that made them think of science. After taking a picture, students completed a Science in a Picture summary sheet (Appendix A) for it. Each student in a group had 1 day to take his or her five pictures, and then the camera was passed to another student in the group and the summary sheets turned in. This process was repeated until each student in the group had taken five pictures. I collected all the cameras at the end of the week and took the film to be developed.

After the pictures were developed, and during a class session, the students selected and mounted three of their pictures on a paper (Figure 2) and wrote three sentences explaining each picture and the science they saw in it. The sentences were written on the back of each collage, serving as notes for students during presentation to others. These pictures then became the center of a "conversation" about what science is outside of school. They also became each student's personal representation of content, and ideas of interest, that I used in the classroom throughout the year. In a constant reintroduction, analysis, and application of student-centered inquiry, the Photovoice pieces were used to elicit student input and extend the classroom environment into students' lives.

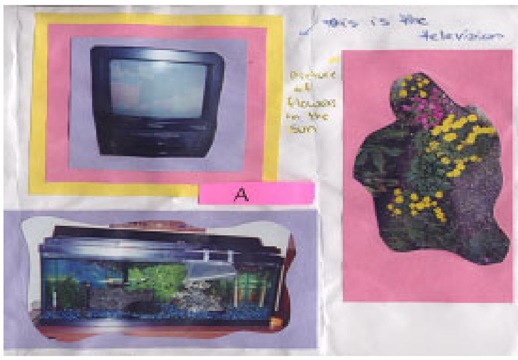


Figure 2. A sample picture collage (clockwise, from top left: television, flowers, terrarium with house plants).

I used the students' pictures in my classroom teaching to get to know my students and a little about their homes, and as a stimulus for discussion and reflection as a relevant science topic came up. I also used them for concept-mapping the ideas represented in them (Figure 3). In addition to using the pictures with the students, I used what I was learning about my students to develop my teaching. Between assignments and projects, I reflected in order to establish links to content and themes, and to develop future applications.

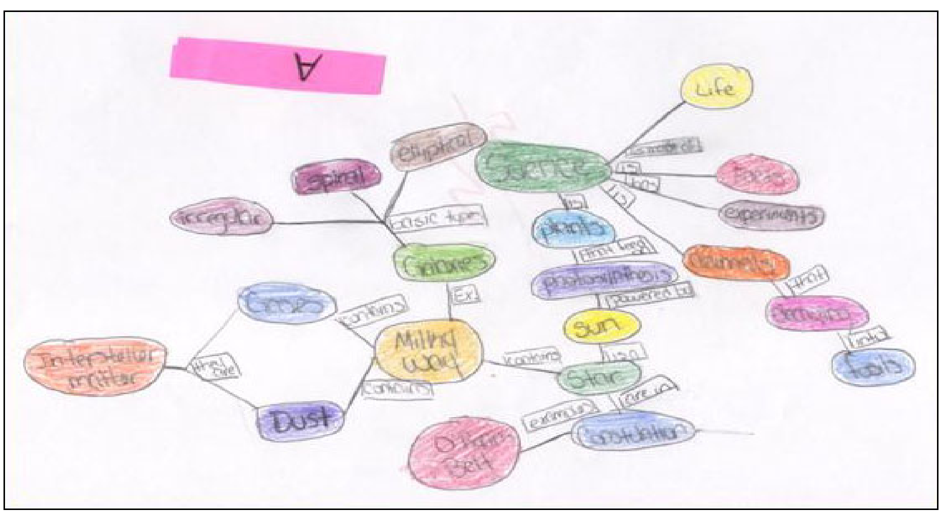


Figure 3. A sample concept map.

Figure 4 maps the various data-collecting points I used in this action research. At each point where students generated data based on either their pictures or a related activity, I reflected on what I had learned from the teaching episode.

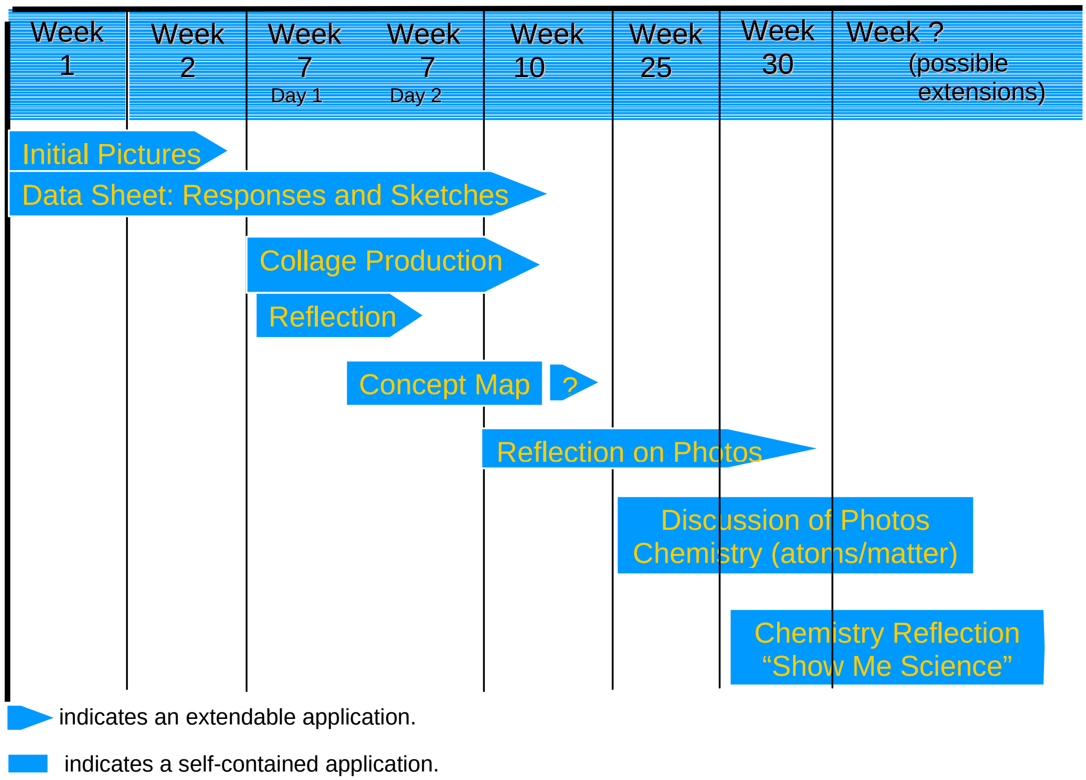


Figure 4. Summary of photovoice activities and applications.

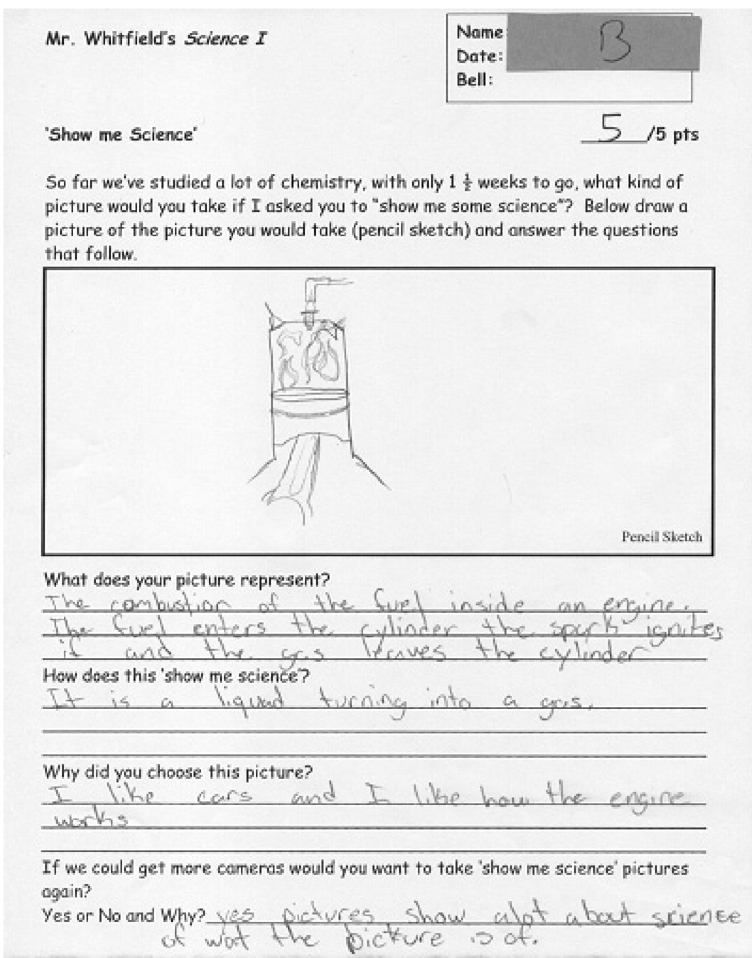
Findings

I used the students' photographs, and other items gathered during the school year that arose from the photographs (e.g., concept maps, drawings on quizzes, and paragraphs the students wrote as part of their chemistry reflections), to find themes for my students' ideas about what science is and where they see science in their lives. First, the photographs represented limited categories. Most noticeable was the huge number of pictures that represented biology; grass, trees, house plants, pets, and so on. The second largest category of photographs was of appliances and electronics. Second, when asked to explain their pictures, many revealed recognition of a concept but without any application to a correct and larger science knowledge base. For example, one student remarked about her picture of flowers in a yard: "This is science because flower [sic] product photosynthesis. Photosynthesis is produced in the sun."

My attempt to extend these concepts using concept mapping was met with moderate resistance. The students were not good at constructing concept maps, and I had not instructed them very well. They also resisted trying to draw connections between the pictures they had taken. The students' concept maps did not demonstrate recognition of a hierarchy of science concepts. For those students who could place concepts in a superordinant-subordinant structure, there were limited opportunities to use them for classroom application or extension because the maps were very abstract and difficult to analyze. Therefore, as shown in Figure 4, my teaching did not feature extension or application activities that resulted from the concept mapping.

I found that a much more effective use of Photovoice was to have students reflect on their pictures, and then follow this with whole-class discussion, as it was a way to reintroduce content "produced" by students. I use the term *produced* because students often treated the items represented in the pictures as “theirs,” as if they had ownership of the grass, flower, sky, or pet they had photographed. Student interest in their photos was used to further discussion on topics in class. They would use an item in their picture collage as the starting point for an explanation, or as an example. They made comments like: “When my dog in my picture runs outside, he is accelerating.” Finally, the students themselves commented on how images were powerful representations of content. One student even stated that “the pictures are more noticeable” and that he felt it “easier to look at the pictures of science than write about it. I think that you can actually see it more easily than read it and try to visualize,” where I assumed the “it” to mean science content.

When I reflected on the students’ discussions and comments, I felt I needed to extend my action research to include further forms of representing science other than the photographs, leading me to develop more means of visual representation in my teaching. I also incorporated more visual representation options, for ways to express ideas, on my quizzes and tests. I began allowing students to draw diagrams, and to explain themselves in written passages by accompanying them with sketches (Figure 5). Some students seemed to be relieved that they could now both draw a picture, and respond in prose, on assignments.


Mr. Whitfield's *Science I*

Name: B
Date:
Bell:

'Show me Science' 5 /5 pts

So far we've studied a lot of chemistry, with only 1 ½ weeks to go, what kind of picture would you take if I asked you to "show me some science"? Below draw a picture of the picture you would take (pencil sketch) and answer the questions that follow.

Pencil Sketch

What does your picture represent?
The combustion of the fuel inside an engine. The fuel enters the cylinder the spark ignites it and the gas leaves the cylinder

How does this 'show me science'?
It is a liquid turning into a gas.

Why did you choose this picture?
I like cars and I like how the engine works

If we could get more cameras would you want to take 'show me science' pictures again?
Yes or No and Why? yes pictures show alot about science of wat the picture is of.

Figure 5: A sample drawing and extension for a homework assignment.

This interest in visual representation highlighted some unique differences among students. Some students seemed very comfortable and adept at using images to explain themselves, while not having very strong writing skills. I had seen these students as being weak on content, and would have continued to misunderstand them had it not been for opportunities to use visual representations. My reflections on my Photovoice action research helped me develop my teaching in ways that took my students' interests, knowledge, and ways of expressing themselves into account, providing a clear and direct example of how Photovoice can be used to empower students to participate in instructional decisions and let their voices be heard.

Conclusion

Photovoice served to extend the classroom into my students' lives, and grounded me in a more responsive student-centered model of instruction. It enabled students to contribute to the development of instruction, while allowing me to establish a baseline understanding with my students. The Photovoice action research process used developed into a responsive learning model for me, a new teacher. The flexibility of action research created a dynamic research model, as it provided a systematic way for me to critically analyze and implement my pedagogy. What was lost in objectivity was compensated for by it being a truly non-invasive and responsive research method. What was important, though, was that throughout the process of collecting data and analyzing student work, I constantly reflected on what was happening and used the information in my practice.

This photovoice action research project has generated more questions for me to investigate in my future classrooms. Areas that I have learned about, and areas in which I am interested in using action research to further my understanding, include the following:

1. The visual representation of concepts seems to be a very powerful technique, and this could lead to an investigation of how they can be tailored in the classroom to serve instructional goals.
2. I found that using concept mapping to elicit students' concept hierarchy was very difficult, and am wondering if there are better ways?
3. While the content of the photographs the students produced had limited applicability to the classroom, parallels could be made with relative ease. I would like to investigate possibilities for different ways to frame the project, so that students would be guided to gather photographs with greater classroom application.
4. The students seemed to enjoy having their work, and that of their peers, reintroduced as the focus of instruction--what I call a means of constant application and a recycling of student-centered instruction. After seeing the benefit of this, I wonder if there are ways to measure this benefit to student-centered instruction?

As a final thought, and a reminder of Photovoices's origins, other opportunities to return to the students' photo collages, as a point of discussion or other learning activity, are limited only by how often one can find ways to apply the students' ideas to the teaching process, and by associated time constraints. Next year, I will have another group of new and unfamiliar science students with whom I will need to become familiar. Photovoice will again provide an unobtrusive means to guide my instruction and apply students' ideas to lessons throughout the year. Another group of students will be given a voice in their own instruction, and I will gain insights into their beliefs and values regarding the content I am prescribed to teach.

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Appendix A

Science in a Picture Summary Sheet

Mr. Whitfield's *Science I*

Name:
Date:
Bell:

Science in a Picture

Your task is to take five (5) pictures of the science around you. You will be given a disposable camera to record your images during one afternoon. This is a classroom endeavor; the camera is the property of the class. Failure to take your pictures *and* record your responses will result in a loss of points for the assignment. Also, other students in the class will not be able to record their own images if you do not return the camera promptly (the next day). Also, this is a Science class, so please refrain from taking pictures of friends and the like.

- Inappropriate images will not be accepted, and anything violating the school code of conduct will be dealt with seriously.

Camera icon: ________

Exposure (picture) number from the camera: ________

Location: ____

What is this a picture of? (Two complete sentences)

Picture Sketch:

What were you thinking of when you took this picture? (Two complete sentences)

Describe to someone else why this is science? (Two complete sentences)

Demonstration

While the activities in this section of *SER* have been designated demonstrations, some 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 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.

The Returning Ball

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Needed. One high-bouncing ball (e.g., a rubber Hi Bounce ball), water, and a table.

Invitation. Challenge students to try to throw the ball out in front of them in such a way that, when it bounces from the floor (and the floor only), it returns to the thrower. (Different balls, including a tennis ball, say, could also be tried in this part of the activity.)

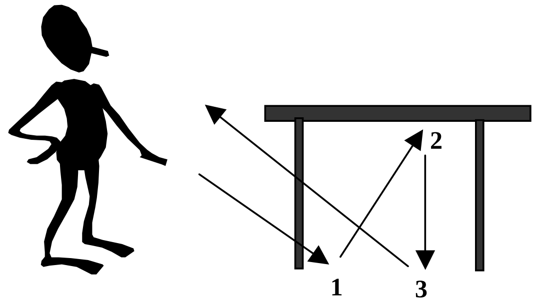
Exploration. Give a number of students a try. Some may achieve the feat by throwing the ball with backspin and, if so, use their success to illustrate the importance of careful observation in science; that is, ask the class to "watch closely, what is needed for the ball to return to the thrower?" If a student does not succeed, demonstrate the use of backspin on the ball yourself.

Concept introduction. Invite students to explain why the ball returns to the thrower. This is an example of the force of friction at work. Friction is the force that opposes motion when an object rubs against another surface, and a force can change the motion of an object. When the spinning ball hits the floor, the floor grips its outside surface and the ball gets pushed away from the floor in the direction the top of the ball was spinning. The friction actually pushes the ball in the new direction. (Careful observation will also show that the rebounding ball is now spinning in the opposite direction.)

Ask students if the spinning ball would behave in the same way after bouncing off a slippery surface (i.e., with little friction present). Try it, by first dipping the high-bouncing ball in water. What happens? You should find that, in the absence of friction, the ball does not grip the floor and return to the thrower.

Friction can be both a benefit and a hindrance. We need it to help us stand up, and to start or stop moving. Without it, we'd be slipping around like a stick of hot butter! In the case of car tyres and the soles of sports shoes, the more friction the better. At other times, though, friction is a nuisance because surfaces that rub against each other can get very hot. In a car engine, for example, we reduce friction, and therefore the associated heating effect, by using an oil lubricant. If your car engine runs out of oil, the metal parts will get so hot that they melt!

Concept application. Challenge students again, this time to throw the high-bouncing ball so that it bounces from the floor, strikes the underside of the table, and comes out from under the table on the other side. Allow selected students to try, only to find that it is impossible (provided the ball strikes the underside of the table with sufficient force, and doesn't just glance it). In fact, quite the opposite occurs; the ball returns to the thrower, as shown in the following diagram! Why?



Friction is again at work. Each time the ball strikes a surface, the surface grips it and changes the direction in which the ball is spinning. After it strikes the floor for the second time (Point 3 in the diagram), its spinning sends it back to the side of the table from which it was thrown. Finally, demonstrate that the feat is possible after friction is reduced. Dip the ball in water and then observe it move (slide) through to the other side of the table.

Student Activity

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

Seeing Blood Cells

Needed. A clear, blue sky and your eyes.

Stare at the blue sky, and then allow your eyes to go out of focus. Observe the small spots moving around. Are they moving at random (i.e., without a pattern), or do they follow definite paths? You should find that they follow definite paths.

Explanation. What you are seeing are white blood cells moving through blood vessels in your retina, at the back of your eye. Blood vessels carry nutrients (digested food) and other things around your body, including to your eyes. Blood consists of red blood cells (which carry oxygen), white blood cells (which fight infection by attacking germs), and platelets (which help to clot blood, thus being important when you cut yourself) floating around in a liquid called plasma. Only the white blood cells are large enough to be seen in this experiment.

For interest. Patients with immune system problems can have too few white cells, and doctors do frequent blood tests to check on their white cell count. However, medical researchers are using the method of this experiment to train patients to do their own white cell count. Patients learn to compare the number of spots they see with charts, and can then estimate their white cell count without the need for blood samples to be taken.

Trouble in the Kitchen: A Problem-Based Activity in Human Biology

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Abstract

In Ontario, the secondary school science curriculum advocates the use of laboratory activities to reinforce specific scientific concepts and promotes the development of skills in scientific investigation and communication. Students in biology courses are often expected to identify unknown substances using standard tests, but rarely are these tests integrated into a problem-based learning situation. This activity provides an opportunity for students to demonstrate critical thinking and deductive reasoning skills, while also demonstrating procedural aptitude. To be successful, students must conduct a series of controlled experiments and, by analyzing the results, solve the dilemma of which food to serve to which hospital patient.

Introduction

It has been suggested that there is a positive correlation between conceptual and procedural knowledge (Hiebert & Lefevre, 1986; Johnson & Siegler, 1998). These are often evaluated independently, and rarely in a framework that permits the assessment of applied knowledge. Consequently, there is a need for approaches that encourage students to combine both types of knowledge to solve problems. In the study of digestion, biology students are often expected to investigate the effect of parameters such as temperature and pH on enzyme activity, or to set up controlled experiments. Further, in earlier science courses, they are taught the basic food groups such as carbohydrates, fats, and proteins. In addition, procedures for determining the presence of the monomers that make up these groups may be introduced. Such procedures include the standard test for a simple sugar, for starch (a polymer of glucose), for amino acids (the basic units for proteins), and for lipids. However, rarely are they asked to combine this knowledge to solve a problem.

This activity overview describes a situational problem that requires students to conduct a series of controlled experiments, providing an opportunity for them to show their critical thinking and deductive reasoning abilities while demonstrating procedural knowledge. Teachers are invited to implement it in a way appropriate to their particular context.

Scenario

Christmas is nearly ruined when Marge has to spend the day at Springfield General Hospital to remove the faucet her son has stuck to his forehead. Dr. Hibert, brandishing a bone saw, frightens Bart who runs away. Finally, ending up in the kitchen, Bart finds trays of prepared meals in containers labelled with patients' names. With a mischievous grin, he removes the labels.

You are a dietician at Springfield General Hospital responsible for preparing the special supplements for a group of patients who require specific nutrients to speed up their recovery. The supplements are administered as a power shake. Having prepared and labelled the supplements for each patient, you are called to help search for a boy with a faucet stuck to his head. When you return you find the labels are missing. Each shake was individually prepared for patients with specific disorders, and if they get the wrong one, it could have dire consequences. You do not have time to prepare fresh portions, but you do have time to conduct some simple tests to determine which major nutrients are present. You must then provide each person with his or her correct power shake and explain your reasoning.

Pre-Activity

Remind students of the test reagents used to detect the presence of the three basic food groups: carbohydrates, fats, and proteins. In addition, the test for glucose--a simple carbohydrate--and starch--a polymer of glucose-- is addressed, but the expected positive test results for each of these macromolecules is not given. This is to ensure that positive and negative controls are used. In order to complete the necessary tests, reference should be made to appropriate safety measures, such as the use of safety glasses and care in the use of the Bunsen burner or hotplate when setting up a water bath.

Patient List and Medical History

Mr Cranky has a sweet tooth, but is also diabetic. His insulin treatments were interrupted because of a recent urinary tract infection and he now shows signs of hyperglycaemia that can lead to death. Since he is unable to produce insulin, his meal must be free of simple sugars. The absence of insulin triggers the use of fats and fatty acids as an energy source and this leads to an increase in ketone body formation in the blood. Fats should therefore be avoided in the supplement.

Ms Yellowstone has infective jaundice, which she caught while on safari. She is now anorexic due to excessive vomiting, and experiences stomach pain. Her shin and eyes have a yellow colour. She is in the early stages of the disease and becomes ill if food containing fats are included.

Custodian Willie suffered severe third degree burns to 80% of his body during a fire in the school kitchen. He has had several skin grafts and, in order to speed up the healing process, he needs a diet rich in amino acids.

A young singer, Brittany S., suffers from chronic renal failure, where her kidneys are progressively and irreversibly damaged. As the condition advances, there is a build-up of urea and uric acid as waste products of metabolism. Many of her symptoms are due to urea accumulation, which results from protein breakdown. Protein in her diet may result in hiccups, muscle spasms, and increasing drowsiness, which precedes terminal coma and death.

Cleo Rhinestart was an obese man who enjoyed feasting on high carbohydrate foods, until he began to show sensitivity to particular foods such as gluten, found in wheat and rye. Cleo Rhinestart also suffers from swollen and painful lower joints and is to be tested for the presence of excess uric acid, which can cause gout. For the last 48 hours, he has been on a fat free diet and now requires a high fat diet in order for the x-ray test to be completed.

Baby Herman, normally a very quiet child, has become irritable and has a ravenous appetite but gains no weight. After some tests, the results suggest that he is unable to produce the pancreatic enzymes amylase, lipase, and trypsin. Digestion is impaired and absorption cannot occur, and this explains the increase in appetite. Although the appropriate enzymes can be added to his food, his diet has to be modified to reduce the amount of fat, as digestion and absorption of proteins and carbohydrates are reduced in the presence of fats in the intestine. The doctor has prescribed a fat free diet.

Students might be asked to research additional information about these diseases, symptoms, and dietary requirements, using websites such as Diabetes (2005) and Celiac Sprue Association (2005).

Teacher Preparatory Materials

Sources of protein include albumin, gelatine, or skim milk powder. Where fat is required, a small amount of lard is rubbed into Borax powder, giving a powdery texture. This reduces the likelihood of direct observation of the fat by students.

Diet A contains equal parts of protein, starch, and glucose, Diet B contains equal parts of fat/borax mixture, Diet C contains equal parts of glucose and protein, Diet D contains protein, Diet E contains equal parts protein and starch, Diet F contains equal parts of glucose, starch, and fat, and this information is summarized in Table 1.

Table 1
Constituency of Each Diet

Diet	Contents			
	Glucose	Starch	Fat	Protein
A	+	+		+
B			+	
C	+			+
D				+
E		+		+
F	+	+	+	

Expected Results

Diet A is for Baby Herman, because it lacks fat but contains the other foods. His prescribed diet should be fat free, but contain carbohydrates and proteins. The addition of the enzymes permits the digestion of the food supplements, and absorption occurs more readily in the absence of fats.

Diet B is for Cleo Rhinestart, because it lacks starch due to his obesity and sensitivity to gluten, which is found in starch. He also requires a high fat diet.

Diet C is for Ms Yellowstone, because it lacks fats and starch. The sugar provides the energy requirements and the protein replaces lost of nutrients due to vomiting

Diet D is for Custodian Willie, who requires a protein diet for tissue repair and healing. Although glucose and fats are needed, amino acids are the highest priority for tissue repair.

Diet E is for Mr Cranky. His diabetic condition means that simple sugar should be excluded. To reduce ketone build-up as a consequence of fat utilization, fats should be avoided.

Diet F is for Brittany S. She suffers from renal failure, which results in urea and uric acid waste build-up. These wastes are a result of deamination of proteins; hence a diet excluding proteins is necessary.

Conclusion

School science traditionally involves the use of prescribed lab activities that, while attempting to combine theory with practice, often fall short. The development and use of situational problems, like the one described here, challenges students to combine conceptual knowledge with procedural knowledge and collaborative skills to solve a problem associated with digestion in humans. The problem-based nature of this activity also encourages students to work cooperatively and collaboratively while using basic laboratory skills. In addition, it facilitates the application of logical and sequential thinking and enhances the development of deductive reasoning skills.

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Critical Incident

An Invitation

Readers are invited to send, to the Editor at editor@ScienceEducationReview.com , a summary of a critical incident in which you have been involved. A critical incident is an event, or situation, that marks a significant turning point, or change, for a teacher. The majority of critical incidents are not dramatic or obvious, but are rendered critical through the analysis of the teacher (see Volume 3, p. 13 for further detail). 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.

The History of Understanding

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Once when I was in the optical laboratory, I asked one of my second-year students to describe the reason why a beam of light is refracted when traveling from air into glass. She answered that refraction occurs because light corpuscles are attracted by glass corpuscles. I was much surprised, and inquired where she had learned this explanation. She had brought a well-known course in optics. I asked her to find the required passage and read it aloud for the benefit of other students in the laboratory. She found it and began reading: “Isaac Newton considered that refraction of light is due to the attraction acting between light corpuscles and glass corpuscles,” and added that she learned this without any doubt because Newton is always right. This accident taught me a remarkable lesson. It is always useful to discuss and compare the ancient and contemporary interpretations of physical phenomena in order to convey the idea that it took a lot of time and effort to come to modern thinking, and that any great scientist can have his or her own misfortunes in a field. Though the light indeed consists of corpuscles, their attraction has no relation to refraction.

Editor: It is common to find students' alternative conceptions matching superseded historical ideas, so this is another reason for the desirability of addressing the latter.

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 .

Erupting

Deep down below the earth,
A faint rumbling can be heard,
Boiling hot magma is on the move,
The sleeping giant has stirred.

Bubbling and frothing towards the top,
Tossing up boulders into the sky,
Molten rock oozing over the edge,
The giant's so hot, it could easily fry.

Slowly the lava creeps down the mountainside,
Fearful people scurrying out of its way,
Screaming and running from the burning river,
The giant volcano has erupted today.

Andrew Tierney, 8 years
Australia

That's Science

What's Science asked Johnny looking up at the sky,
Well said Mrs Mook have you ever wondered why . . .

An apple tastes fine but a lemon tastes sour,
A bee sting hurts and you're itching every hour.
That's Science!

Your mum tells you to eat things like beans and peas,
But you want ice-cream and you beg her please.
That's Science!

You can walk fine on grass but you slip in snow,
You can take off fast when they yell out go!

That's Science!

When you jump up high you come back down low,
When you fall, you don't always land on your toes.
That's Science!

There's a reason behind everything we do and say,
And we learn more reasons everyday!
That's Science!

Hilary Campbell, 14 years
Australia

Transforming Your Practice: Hero or Heretic

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Abstract

How do you transform your own practice, and the practice of your peers? How do you act as a change agent in a positive, open dialogue with peers? The author seeks to explore this complex, often difficult issue, hoping to encourage others to look at their practice, and the practice of their peers, and ask: "Can we do better?" Can we better engage our students as active learners? Can we improve the teaching and learning process for our students?

Introduction

In this paper, I wish to explore a number of issues exposed by the following extract from a question distributed, by the Editor of this journal on behalf of a teacher, to journal readers:

> My teaching to date has been fairly traditional, although in accord with the overall culture of our school. Lecturing to passive students, for example, is commonplace in the school, and quiet students sitting in straight rows has a long tradition and appears to be valued. However, in accord with current recommendations for science education reform, I am keen to try to introduce some changes in my classes. (P. H. Eastwell, personal communication, August 26, 2004)

I empathise, on a number of levels, with this teacher of Science. I too have worked in schools in which the rationalist belief in the transmission of knowledge was the dominant pedagogical paradigm. I too have sought to change the experience for my students. I too have sought to change the pedagogy of my colleagues.

This quote could well have described much of my experience with science as a student during the 1970s. I made lots of notes from the blackboard, answered lots of questions from text books, and about once a fortnight I completed a practical activity that may, or may not, have made sense of the preceding concepts.

Whitehead (1989) describes the concept of a living educational theory, the product of a systematic reflective process on the nature of how to improve one's personal practice. It has five stages:

1. You identify a problem because some of your educational values are negated.
2. Imagine a solution to the problem.
3. Act in the direction of the solution.
4. Evaluate the outcomes of the solution.
5. Modify your actions and ideas in the light of your evaluations.

Whitehead suggests the starting point for a cycle of one's living educational theory is the question: "How do I improve this process of education here?" This question may be the result of a reflective teacher responding to a challenge from a student, such as: "Why do I have to learn this sh**?" (Blades, 1997), which has certainly been my experience. In other cases, the impetus to question one's pedagogy might stem from reading about other ways to teach science, or hearing about such from teachers in other places.

How can you enhance the classroom environment for your students? Stoll, Fink, and Earl (2003) list the following 10 features of successful teaching and learning that enhance student engagement:

1. Use cooperative learning rather than competitive learning.
2. Stimulate cognitive conflict.
3. Encourage moderate risk taking.
4. Praise good work.
5. Make academic tasks interesting.
6. Provide feedback that is connected to learning and effort.
7. Identify many intelligences, showing that they are not fixed but incremental.
8. Encourage self-images as learners.
9. Increase student self-efficacy.
10. Encourage volition.

These features are not commonly found in the traditional classroom. In my experience, students seated in serried ranks, all working quietly to receive the scientific truth from the teacher, tend not to work cooperatively, are rarely caused to experience cognitive conflict, rarely take risks, are treated often as identical in regard to learner characteristics, and rarely reflect on their own learning. However, a traditionally constructed learning environment need not be void of these features.

Rowe (2003) believes that teachers are the single most important determinant of student success. He believes that quality teachers and teaching, supported by strategic professional development, is what matters most. He claims that what works is the early identification of students at risk, followed by appropriate intervention that deals with their concerns, on-going, strategic, individual-teacher, and whole-school professional development, and a relentless commitment by the whole school community to ensure that success for all students becomes a reality. He believes that this requires the presence of four factors:

1. Well-trained staff.
2. Higher expectations of student outcomes.
3. Structured teaching focused on the learning needs of individual students.
4. Engaged learning time.

According to Rowe (2003), students want teachers who have knowledge and understanding of what they teach, are enthusiastic for their subjects, make student learning the core of what happens in the classroom, treat each student as an individual, manage the distractions that disrupt and prevent learning for students, care for, and are encouraging of, their students, and are fair and just in their interactions with students.

These features of successful teachers and schools are independent of pedagogical approach (Rowe, 2003), but in my experience it is less likely that a teacher who structures a classroom around quiet children sitting in ranks and learning the "facts of science" can be seen to be treating his/her students as individuals. It may also suggest that the teacher has either not questioned his or her practice, or has made a conscious decision to teach in a traditional manner.

Not Alone

So, having decided to change your practice, how do you get started? The first, possibly most important thing to remember is that you are not alone. Many others have struggled, or are struggling, with change and writing about their experiences. Blades (1997) writes of his experience in Canada with the management of curriculum change to better engage students and better suit their perceived needs. Vaille Dawson (Dawson & Taylor, 1997) has struggled with implementing constructivist approaches in her teaching and discovered that different groups of students respond differently to change. Bentley, Fleury, and Garrison (in press) offer an excellent look at how critical constructivism can be used in preparing pre-service teachers. Scharmann, Shroyer, and Cherin (1996) describe how, despite training in student-centred techniques and Science-Technology-Society (STS) themes, trainee teachers on rounds were still unlikely to implement STS approaches with direct instruction due to pressure from supervising teachers and their own discomfit with the STS approach. These are but a few examples of teachers and academics working with approaches that attempt to treat students as individuals and approach scientific knowledge as a constructed form of knowledge.

Another factor to consider if you are to be successful is to ensure that you do not work alone in your school. It is important to find supportive, significant, critical friends (Taylor, 1998) within your school who are able to help you through regular reflective debriefings. If possible, this group of like-minded colleagues might conduct an action research project within the school setting, investigating the effects on student engagement and learning outcomes of changing the dominant pedagogy. For both intellectual and emotional support, I would also recommend enrolling in post-graduate study. The most important benefit of working toward a degree is that you are in touch with recent research and trends in pedagogy and scientific thought, and this provides another group of critical friends from whom to seek support.

Take it Slowly

Humans tend to resist change, especially as we age. Take it slowly with students, other teachers, and your school. As Geelan (2000) writes, when addressing the move from teacher-centred pedagogy to student-centred pedagogy, one can leave an "empty center." He found that having vacated the central position of control, before his students were empowered to assume that central position, left a void. He had moved faster than the students were able to cope with. It is important to set a pace of change that the others can keep up with. The students are less encultured into the way of one's school (maybe this means the earliest year groups in your school are the best place to start) and, being young, are more open to change. The teachers are more set into a way of doing things and, being older, are less open to change. They will require you to prove the value of the change (often over and over again) before they invest the personal energy required to change their own practice. By talking about your student's successes informally over morning coffee, or formally in meetings, and by having your students present their findings to the school community, it is possible to include more and more of your colleagues in what you are doing.

Heretic

Expect to be seen by some as a heretic. Your attempts to cause change will be attacked by deeply entrenched colleagues unwilling to change. As I found in my attempts to innovate (Simpson, 2005), one of the main impediments to change are the procedures of power at work within the social matrix of the school (Foucault, 1980). Part of that social matrix is the phenomenon of teaching as team game. The school expects that the teachers will act as members of a team, treating students in approximately similar ways to maintain a certain standard of behaviour and a certain standard of achievement.

For many science educators, transmission of important content to students is vitally important. Science teachers tend, by dint of training, to be conservative and to hold a rationalist belief in the existence of an objective truth waiting to be found and the ability of science to find it. This tends to also mean that they believe that they are able to teach these self-evident truths to students, or are at least expected to try. This is not the place to have a conversation about the nature of scientific belief, but when applying constructivism pragmatically to the teaching of children, one needs to understand that students enter the room with views of the information that one wishes to teach that they have constructed for themselves. Before you can successfully reconstruct their knowledge in the direction of scientific understanding, one must undermine their confidence in their own beliefs. For the majority of students, this does not occur simply by telling them facts. I believe that they need to experience the making of scientific knowledge, not just be told about it. This belief is not harmonious with a rationalist approach to the teaching of Science.

The management of students' behaviours is often quoted as being important, with students sitting quietly in class, taking notes, and answering questions seen as productive. Students moving about the room, interacting with each other, and making noise is seen as unproductive. However, does managing their behaviour in this way mean stifling their creativity and engagement with the subject matter at hand? Consider a classroom where students sit facing each other, learning by actively interacting with each other. A classroom where students' work is displayed, students freely move about the room seeking materials and advice from their peers, there is constant chatter about the work at hand (most of the time), and there is lots of student activity as they experiment with new ideas. This is my classroom (Simpson, 2005, in press). My students successfully build cognitive structures, in line with western scientific thought, that they also tend to retain.

Hero

Look forward to being seen as a hero. For many of your students, you will be a hero. You will make their experience of science education fun. They will look forward to your classes. You will have opened up the experience of science to include them, their own constructions, and their own experiences, through purposeful activity.

The traditional pedagogy of teaching and learning has allowed students with linguistic and logical-mathematical intelligences to experience success. It has also privileged students with aural/visual learning skills. What of our kinesthetic learners? What of those with other intelligences; musical, visual-spatial, intrapersonal, interpersonal, or naturalistic? They exist in our classrooms, but we have to change our pedagogical approaches extensively to be inclusive of their needs and to allow them success. Many studies, including my own (Simpson, 2005) have shown that classes in openentry, non-selective schools are diverse places. Students need to be treated as individuals, and appreciate it when they are (Stoll, Fink, & Earl, 2003). To these students in particular, you will be a hero. If you are able to influence other teachers to reconsider the manner in which they teach, and they become cognisant of the range existing in their student's characteristics, you will have also gained professional respect from them, as their relationships with their students will greatly improve.

Recommendations

So, after all that, what recommendations can I make? Working as a change agent with both colleagues and students, you need to strive to have all parties consider their deeply-held beliefs about pedagogy, which are based on thousands of hours of encultured experience, and find those beliefs to be without foundation for our new millennium. Probably, at best, you can cause a pedagogical thoughtfulness in others, if they find that your experiences resonate with theirs (Geelan & Taylor, 2001). The following steps may be useful:

Step 1. Enrol in post-graduate study. This will expose you to many writings on the subject of alternative pedagogies and link you with like-minded educators outside your school from whom you can receive moral and emotional support (and there are times you will need both!)

Step 2. Set up an action research project with like-minded colleagues that seeks to display how your pedagogy can more fully engage the diversity of students in your care and enhance their educational outcomes. It is important to have critical friends within your workplace from whom to gain support and with whom to share ideas and reflect on experiences. Make sure that you have the permission of the school leadership to carry out your research.

Step 3. Take it slowly. You are trying to change the manner in which your colleagues view the nature of truth in science and how scientific truth can best be taught. You may be asking them to give up a rationalist belief and to replace it with a neo-relativist belief in the nature of scientific truth (Simpson, 2004) for the sake of the next generation of adults operating in our society, some of whom will use scientific knowledge, or its application, in their daily lives.

Step 4. Share your and your students' outcomes and experiences within the school community and within the wider education community. You are about to become a risk taker, and things won't always work, but you must share both the successes and the failures to help you and your colleagues reflect on your experiences and those of your students. Your experiences need to be shared with other educators; you may be responsible for someone else becoming a hero (or heretic).

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Students' Alternative Conceptions

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

Weight of a Candle

A candle is placed on a balance and lit. What happens to the balance reading as the candle burns?

(a) No change, because the candle just melts.
(b) No change, because the candle changes shape but not mass.
(c) No change, because the weight of the flame does not change.
(d) Increases, because the burning candle combines with oxygen from the air.
(e) I have a better idea. Please explain.

Comment: The mass of the candle will decrease--Choice (e). The candle wax is used up because it reacts with oxygen in the air to produce gases (carbon dioxide and water) that move into the air. Also, some unburnt carbon from the wax (i.e., the smoke) will also move into the air.

Source: Calik, M., & Ayas, A. (2005). A comparison of level of understanding of eighth-grade students and science student teachers related to selected chemistry concepts. *Journal of Research in Science Teaching*, *42*, 638-667.

Teaching Techniques

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

Students' Questions

Questioning is not only central to scientific enquiry, but is essential for active and meaningful learning. The following are some ways to engage students in asking questions about aspects of what they are learning that are puzzling them:

- Pause at intervals during a lesson, ask students to write down questions individually, share the questions and try to answer them in pairs, and then address interesting or unusual questions in small groups and subsequently as a whole class.
- Ask students to write questions, both during class and homework, in perhaps a learning journal or diary. Collect the questions and compile into a class list.
- Display a Question Board in the room. Use the students' questions to initiate enquiry.
- Provide for a period of free question time during a lesson.
- Brainstorm questions at the beginning of a topic.
- Keep a Question Box in the classroom, into which students may put their anonymous questions.
- Take turns around the class, with each student, or group of students, preparing a question for the rest of the class.
- Assign a question-making activity for homework.
- Establish a Problem Corner in the classroom, and invite students to supply Questions of the Week.

Source: Chin, C. (2004). Students' questions: Fostering a culture of inquisitiveness in science classrooms. *School Science Review*, *86*(314), 107-112.

Reflections from a Computer Simulations Program on Cell Division in Selected Kenyan Secondary Schools

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Abstract

The application of computer technology in education is a relatively new approach that is trying to justify inclusion in the Kenyan school curriculum. Being abstract, with a dynamic nature that does not manifest itself visibly, the process of cell division has posed difficulties for teachers. Consequently, a computer simulation program, using animated colour graphic images capable of presenting the dynamic nature of the process through a multi-sensory approach, was developed from the existing school biology syllabus and implemented for a period of 4 weeks. Data was collected and analysed to help unravel what was actually happening as the teachers and the students interacted with the computer simulation program and/or instructional materials during cell division lessons. Results indicate that the computer simulation program created a community of meaning makers by enabling learners to aggregate their insights through co-elaboration and self-teaching while interrogating the learning experiences presented by the simulation.

Students’ protocols lend support to the idea that augmenting laboratory work with computer simulations can greatly enhance pupils’ understanding of cell division concepts.

To read the full text of this article (8 pages), please **click here**.

Ideas in Brief

Summaries of ideas from key articles in reviewed publications

Habits of Mind, Scholarship, and Decision-Making in Science and Religion

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In a number of articles, it has been claimed that the habits of thought in science and religion are so different as to make these areas of thought--and, consequently, science and religious education--incompatible. The supposed contrast is between a willingness to adopt beliefs, or to change one’s mind, on the basis of carefully assessed empirical evidence (science) and a blind, unquestioning faith in the authority of religious books and leaders (religion).

However, in Gauld (2005), I argue that close scrutiny of the writings of both scientific and religious authors--and especially those writers with a foot in both camps--shows a much greater similarity. In both scientific and religious scholarship, high regard is placed on the assessment of evidence, a willingness to evaluate claims made by others, and a demand that claims be supported by good reasons. Indeed, what are usually called scientific attitudes seem to underlie good scholarship in any area.

Robert Merton showed that the practice of science requires commitment to norms such as those expressed in the so-called scientific attitudes (Merton, 1938, 1957, 1976), as well as to counter-norms expressed in such attitudes as “hold on to the theory you believe to be true for as long as you can” (Merton, 1963, 1968, 1976). This encourages a scientist to look for alternative explanations if empirical evidence seems to contradict a theory. For example, it is possible that the problem may be with the experiment rather than with the theory.

In both science and religion, there is a hierarchy of beliefs, from rather peripheral ones which are more open to question through to very central beliefs which are usually related to one’s world view and which are questioned only in extreme circumstances. The notion that the world can be completely explained in naturalistic terms is such a core belief held by many scientists. In religion, while belief in the existence of God is such a central tenet, there are many debates involving religious scientists about how the concept of God is related to the practice of science. Many Christians who work as scientists are willing to adopt a methodological naturalism--that is, a working assumption that the world can be largely explained without resort to a concept of the supernatural--only as far as this is possible to do and without a firm commitment that such a procedure will always be possible.

The frequent claim that science education, based on careful consideration of evidence, and religious education, based on the inculcation of a blind faith, are incompatible appears to emerge from a comparison between the best science education and the worst religious education. The worst of both are similarly dogmatic and unquestioning, while the best of both encourage students to give due consideration to appropriate evidence and to be willing to make their decisions in the light of this evidence.

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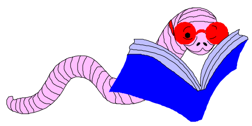

Research in Brief

Summaries of research findings from key articles in reviewed publications

An Instruction-Preference Interaction in Different Delivery Models of Computer-Assisted Instruction

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While many previous computer-assisted instruction (CAI) studies have primarily focused on the comparative efficacy of computer-assisted versus traditional instruction (Chang, 2001; Kulik & Kulik, 1991), there have been rather fewer examples of research exploring whether the effects of different instructional delivery models of CAI on tenth graders' attitudes toward subject matter were influenced by student preferences of learning environment. Chang and Tsai (2005) conducted a quantitative study examining the interaction of CAI delivery model and preference of learning environment on students' attitudes.

Three hundred and forty-seven 10th-grade (180 girls and 167 boys) Taiwanese students studying Earth science, from eight classes at a public senior high school, took part in the investigation. Each of the eight groups was randomly assigned to either one of the following instructional delivery models of CAI: the teacher-centered model or the student-centered model. Students' preferences of learning environment were measured by a Chinese version of the Constructivist Learning Environment Survey (CLES) originally developed by Taylor and Fraser (1991). Student attitudes toward science were acquired through the use of The Attitudes Toward Earth Science Inventory (ATESI) (Chang & Mao, 1999), which consists of 30 items intended to investigate students' attitudes toward Earth Science.

The results show that neither the instructional delivery model of CAI, nor student preference for learning environment, affected student attitudes toward the subject Earth Science. However, a significant interaction between the student preferences and treatment was found. That is, the teacher-centered instructional approach seemed to impact positively on the attitudes of less constructivist-oriented students, whereas the student-centered method was more beneficial to more constructivist-oriented students. Specifically, constructivist minded students rated the subject they had studied more positively if they were in a student-centered learning experience, and nonconstructivist minded students rated the subject less favorably if they had been in a student-centered learning situation. Accordingly, expository-oriented students seemed to develop better attitudes to the subject if they were in a teacher-centered learning environment, and non-expository-oriented students judged the subject less positively if they had been in a teacher-centered learning situation. The findings suggest that classroom instruction should pay more attention to the interaction between students and learning environments, and teachers should also be aware that the mere introduction of constructivist-oriented software/instruction does not necessarily guarantee that all students will benefit affectively from it; and vice versa, this holds true for traditional instruction.

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The Splashdown Effect: Measuring the Effect of Science Enrichment Programs on Science Attitudes of Gifted High School Girls and Boys

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Abstract

The benefits of enrichment programs for the enhancement of students' science achievement are well established. However, little evidence is available on the value of these programs for increasing students' confidence and motivation for science. One problem in measuring changes in students' science attitudes is that students may suffer from a temporary "big pond, little fish" phenomenon when they are with academically strong students in their enrichment program rather than with students in their usual school settings. To study the influence of science enrichment programs for improving student science attitudes, it is therefore important to assess the program effect that students experience as they return to ("splashdown" in) their home high school after completing their enrichment program. It may be only then that students can fully recognize how they have benefited from their program. We found that gifted high school students experienced strong splashdown effects following an intensive summer science program, and these effects were especially strong for students who returned to academically weaker schools (smaller "ponds"). Our findings provide strong support for the importance of evaluating splashdown effects following enrichment programs so as to measure the full impact of science enrichment on students' motivation and confidence to achieve in science. (This paper is a summary of Stake & Mares, 2005)

Introduction

Educators have expressed concern that students in the United States perform poorly in science relative to students in many developed countries (e.g., Collins, 1997; George & Kaplan, 1998). Partly as a response to these concerns, science enrichment programs for gifted students have been developed across the country. Many of these programs take place on college campuses away from the students' home high schools. Studies that have evaluated the effectiveness of these enrichment programs have consistently shown that, by and large, these programs are successful in providing students with a better understanding of science methods and content (e.g., Pyryt, Masharov & Feng, 1993). In particular, inquiry-based, participatory educational approaches have been effective with gifted as well as mainstream high school students.

Although students' science achievement appears to improve with science enrichment, the value of science enrichment programs for increasing confidence and motivation to achieve in science has not been established. Changes in confidence and motivation for science have been positive for some students and negative for others (Stake & Mares, 2005). It is important that we better understand how enrichment programs influence science attitudes because science-related interest and confidence lead to long-term persistence and achievement in science. In fact, Houtz (1995) reported that science achievement was more closely related to science attitudes than to aptitude for junior high school students, and Marsh and Yeung (1997) found that topic-specific self-confidence predicted choice of coursework better than topic-specific academic performance. It is clear, therefore, that if students are to persist and succeed in science, it is not enough that they acquire more science knowledge and display a talent for science. They must develop and maintain a high level of motivation and confidence in their ability to have a successful science career.

Measuring Change in Science Attitudes

Despite the importance of science attitudes, the measurement of change in science motivation and confidence presents special challenges for evaluators. To measure changes in these science attitudes, one must ask students to describe how they subjectively feel about themselves as science students as they enter their program and as they complete it. In making their self-ratings, students necessarily compare themselves to fellow students, and their "yard stick" for comparison tends to shift when they are in an enrichment program for gifted students. At the beginning of their program, they likely compare themselves to students in their home high schools, whereas when they make their post-program self-ratings, their comparison group is likely to be the gifted and motivated science students in their enrichment program. Thus, students may see themselves as highly gifted and motivated for science at the beginning of their program but may evaluate themselves less positively once they have spent a significant amount of time with their science peers in their enrichment program. This change in self-ratings is known as the "big pond-little fish" phenomenon.

The Splashdown Effect

If students' self-ratings of science confidence and motivation are attenuated by their big-pond experience, then once back in their home high school, this effect should lessen, and students should be better able to recognize and incorporate what they learned from their program into their views of themselves. We refer to this delayed recognition of program impact on science attitudes after re-entry to the home high school as the *splashdown effect*. This effect should predict positive change in confidence and motivation during the months following the program. In addition, if students are affected by their current science peer group, then the splashdown effect should be stronger when students return to schools with less academically capable students (smaller ponds) than to schools with more academically capable students (larger ponds).

Study Methods

We tested the splashdown effect with a group of participants who completed summer science enrichment programs at the University of Missouri-St. Louis. The participant group comprised 47 girls and 41 boys who were drawn from 38 high schools in the St. Louis area. Students were selected competitively on the basis of their academic performance, teacher recommendations, and test scores. The science enrichment programs were 6 weeks in length and comprised a broad and intensive science enrichment experience designed in accordance with the National Science Education Standards (National Research Council, 1996). Students were engaged in original research in an inquiry-based learning environment under the supervision of a university research mentor. For more information about this program, see Stake and Mares (2001, 2005).

Students' science attitudes were assessed at four points in time:

- *Pre-testing*: Self-rating scales of science confidence and motivation were administered on the first morning of the program.
- *Post-testing*: The self-rating scales were administered for a second time at the close of the program.
- *Splashdown assessment*: Approximately 3 months after returning to their home high schools, students were interviewed privately and individually about how they viewed themselves and their high school since they had returned following the program. Students also completed questionnaires to measure changes in science confidence and motivation that they recognized in themselves since returning from their program. The items on these measures are included in Appendix A.
- *Follow-up*: Approximately 7 months following the program, students were mailed the self-rating scales of confidence and motivation, completed them for the third time, and returned them to us by mail.

Splashdown Findings

The statements made by students during the interviews were audio-recorded, transcribed, and coded into categories. The splashdown effect was highly evident in the students' comments during the interviews. Virtually all students indicated during their interview that they had observed some positive differences in themselves after returning from their enrichment experience and none described negative changes. The major categories of splashdown changes described by the students, the percentage of students who described the changes, and examples of student comments are as follows:

1. Enhanced confidence to achieve in science (61.5%): "I feel more comfortable in science class, just knowing that I spent 6 weeks [in the program]."
2. Enhanced confidence in general (44.9%): "I realize I am more prepared for college than I probably thought I was."
3. Greater motivation and interest in science (48.7%): "When I first came back I did notice I am more inquisitive, especially in the sciences."
4. Increased science knowledge and understanding (69.2%): "I am able to understand my science classes better because of the program experience."

5. New sense of feeling smart and better prepared relative to other students in the home high school (38.5%): “I feel more confident because I know that most of the kids around here haven’t had the chance to do everything I have.”

In addition to these qualitative findings, students described themselves on the self-rating questions (Appendix A) as having experienced a strong splashdown effect. On a scale from 1 to 7, the average splashdown confidence rating was 5.58, and the average splashdown motivation rating was 5.62. However, students’ splashdown ratings varied a great deal from 3 (slight disagreement that a splashdown effect was felt) to 7 (strong agreement that a splashdown effect was felt). In support of the splashdown theory, students who reported a stronger confidence splashdown effect during the splashdown assessment changed more in confidence from post-testing to follow-up, and those who reported a stronger motivation splashdown effect changed more in motivation from post-testing to follow-up. Moreover, all students in the United States take the standardized American College Test (ACT) prior to entering college, and students who returned to schools in which students had lower average test scores on the ACT (smaller ponds) reported stronger splashdown confidence than students who returned to schools in which students averaged higher ACT scores (larger ponds). Thus, when the high school peer comparison group had lower standardized academic test scores, and were therefore demonstrating less academic ability and achievement, students experienced a stronger splashdown effect, as expected.

Conclusions and Implications for Measuring the Effectiveness of Science Enrichment Programs for Gifted Students

Our results strongly support the concept of the splashdown effect. Most students were better able to recognize the value of their science enrichment program once they had returned to their home high schools. Even those students who described themselves as less confident and motivated at post-testing than at pre-testing and, therefore, seemingly discouraged by the big pond of the enrichment program, reported high levels of splashdown confidence and motivation once back in their high schools. Further, splashdown measures predicted increases in confidence and motivation in the 7-month follow-up period and were linked to the size of the pond of the home high school. Students who returned to schools in which students had lower ACT scores were especially able to identify positive changes in themselves as science students once they were back in those schools.

Our findings indicate the importance of conducting follow-up assessments of the effectiveness of science enrichment programs. We did not find significant change in confidence and motivation when only the period from pre-testing to post-testing was included, but we did find significant changes when the entire period from pre-testing to follow-up was assessed. Our findings suggest that, unless follow-up testing is included as a part of program evaluation, the full effect of science enrichment programs on student science attitudes will be underestimated. To determine the impact of enrichment programs on student attitudes, program evaluators should assess program effects that become evident after students have returned to their own schools. These findings have implications for the allocation of resources for science education. When considering the value of science enhancement programs, administrators should consider not only the benefits of these programs for increasing students’ knowledge but their value for enhancing students’ science interest and confidence to achieve in science.

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Appendix A

Quantitative Splashdown Measures

Each of the statements below describe how you may (or may not) feel as a science student in your school, now that you have successfully completed the program. Use the 1 to 7 scale to show the extent to which you agree or disagree with each of the statements. Mark your answers in the space provided to the left of each statement.

```
|__________|__________|__________|__________|__________|__________|
1          2          3          4          5          6          7
Disagree   Disagree   Disagree   Neither    Agree      Agree      Agree
strongly              slightly   agree nor  slightly              strongly
                                 disagree
```

My Experiences in the Program

_____ 1. Made me feel more confident of myself in my high school classes. [C]

_____ 2. Made high school science seem easier to me. [C]

_____ 3. Made me realize how much more motivated I am in science compared to many students in my high school. [M]

_____ 4. Made what we do in high school seem simpler than it used to because of the comparison to what we did in the program. [C]

_____ 5. Made me even more interested in doing extra science projects and activities. [M]

Once Back in High School This Fall

_____ 6. I realized how much I had learned last summer in the program. [C]

_____ 7. I saw I was ahead in science compared to students who weren't in the program. [C]

_____ 8. I could see that I am especially focused on science--more than a lot of students in my high school. [M]

_____ 9. I became sure that of all subjects I take in high school, science is my favorite. [M]

_____10. I saw that I am especially capable as a science student. [C]

[C] = splashdown confidence item; [M] = splashdown motivation item.

Readers' Forum

Inquiry Learning

In relation to *The Science Education Review*'s present treatment of inquiry classroom management issues in particularly the *Your Questions Answered* section, I would like to reflect on my experiences with inquiry. First, I recommend the following:

1. Reduced class sizes. Thirty-two students should be the upper limit. Even 32 is difficult to manage in such a way to provide meaningful work for most of the students in a lab setting.
2. Provide release time for teachers. Full-time teachers in many private schools teach four sections of classes and not five. This provides more time for the development of lessons. My experience is that the overall workload in the public and private sectors is similar, but that the work in private sector teaching has more of a focus on agenda items such as the development of inquiry-based learning.
3. Have teachers work in teams, or at least pairs. Accountability, even to a single colleague, is important.
4. Schools should redevelop the position of a full-time lab technician. I think this is hugely important. Running a lab-based course involves many hours of extra work for which the classroom teacher is not trained. This work involves organizing the material/equipment, getting the requisite funding, developing and submitting the orders, inventorying all material once it arrives, reordering material as needed, ensuring that live material arrives only when needed, ensuring that live or dated material is properly maintained until needed, maintaining the proper disposal of all hazardous material, and so on. In addition to that quadrant of work, the teacher must also maintain the daily running of the lab program, which often involves setting up, maintaining, and breaking down up to a dozen lab stations several times each day.

This list could go on, but ultimately it comes down to a cost/benefit analysis that takes place on different levels. On one hand, the teacher must balance their 24-hour day, remuneration, other school commitments, and overall time in the year. I was recently faced with the dilemma of using a BSCS approach of using the chemical equation of photosynthesis to generate, and then answer, several questions about photosynthesis via student-generated labs. I felt the lab was worthwhile, so it was done. However, the extra work involved in this one class day involved locating and purchasing a large quantity of the aquatic plant Elodea and setting up an aquarium at school to maintain the Elodea until needed. Additionally, I had to purchase extra light bulbs for the light fixtures from our school lab. I mention this because I don't think I teach at an underprivileged school, and most high schools that I have seen possess limited and insufficient lab equipment for students to work in groups of 3. So all told, this 1-day lab cost time in the form of two side trips totaling about 1.5 hours and an initial outlay of about 50 USD. The money will be reimbursed, providing I fill out the needed paperwork according to protocol. None of these items are insurmountable, but they do add up.

The second level of cost/analysis benefit is one of efficacy of the lesson relative to student learning. What is the best method for students to internalize the processes of photosynthesis in a meaningful way? Is a wet lab (with all the additional costs) more effective than a well-structured presentation that includes graphic organizers, anthropomorphized skits through the Thylakoid membrane, contextual and anecdotal stories, along with probing questions? Or better yet, assuming that all other teaching methodologies are in place, is the addition of the wet lab worth the associated costs?

As an overarching framework in the development of an inquiry class, I think that teachers would be well served to move towards a model-based approach to science learning. Science is about collecting and analyzing data to discover patterns. Science classes should follow this lead and focus on data. Science inquiry can involve collecting data, manipulating data, and/or explaining data. Given the available resources within the classroom, a teacher may choose to work from a pre-existing data set rather than to generate new data. This is still inquiry-based learning. Students should be given opportunities to develop explanatory models based on data sets. A well-designed, model-based lesson could include several data sets that progressively force students to re-evaluate and modify their explanatory models to account for the data at hand.

Kevin Scully, Rodriguez High School, Fairfield, CA, USA

Editor: Kevin's reflections remind us, quite legitimately, that inquiry does not always need to involve hands-on, experimental work.

? ? ? ? ? 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!

Individual Student Accountability

What structures might I use to make each student personally accountable for content learned during a cooperative activity? (*Editor:* This question relates to Item 10 of the Inquiry Classroom Management Checklist, pp. 27-29 of this volume.)

I use two-part worksheets for each student, with one part being completed in groups and the other part by each student individually.

Amany Abd El Aziz, National Center for Educational Research and Development, Egypt

One method is to prepare a list of three or four questions for each group to review together after the activity. A group leader, chosen by the group, will ask each question during group review. Then, I have an oral review with the whole class, and ask the same questions. Students save these questions and answers in their notebook for later study. After several activities, the questions can be used to play a Family Feud game.

Mary LaCrosse, USA

When I want to check for mastery of a concept or information, I give my students a "qwik qwiz," as I call it; a short question that assesses for me. I can then sort students who need extra assistance from those who have understood the content. For example, when we are learning about the seasons, I write a scenario where the students are going to look at dinosaur fossils in Argentina during their summer vacation. What clothing would they pack, and why? I will also have students apply skills such as graphing, used during group work, in individual tests or quizzes. The students learn that they will be accountable, so they need to participate.

Jan Van Kley, Greenfield Middle School, Greenfield, IN, USA

Editor: The Your Turn technique (Volume 2, p. 133) is superb for this purpose, and could be used in conjunction with Mary's suggestion above. Also, please find the Cooperative Quiz in Volume 1, pp. 72-74.

Zap From a Car

Why do some cars "zap" you as you touch the outside door handle, yet others don't?

You may notice this particularly after the car has come from a ride. As a result of friction between the moving car body and air, some electric charges are rubbed from one material and move to the other. Assuming the tyres to be insulators, this leaves the car body charged, and these charges concentrate on the sharp points or edges of objects, like a door handle. So, when you take your hand close to the car door handle, charges jump between your hand and the door, and you get zapped! How much charge a car body acquires depends on what kind of material/paint has been used. Some surfaces lose charges easily, while others may not.

Magan Savant, Hong Kong

I would like to suggest two other possibilities. First, your clothing can become charged when it rubs on the seat as you slide towards the door. The amount of charging will depend on the material from which your clothes, and the seat, are made. If you have insulating shoes, the charge on you may be discharged (i.e., cause a spark) as you touch the door handle. To avoid this zap, first hold a metal part of the car door or chassis and keep hold till you are outside the car.

Second, the rubber car tyres might become charged as they rub on the road surface, and these insulating tyres could then induce a charge, in the body of the car, that will cause a zap. Interestingly, even a stationary car can become charged by, for example, wind-blown dust.

Peter Eastwell, Editor

Further Useful Resources

IHMC Cmap Tools (http://cmap.ihmc.us) Software to construct, navigate, share, and criticize knowledge models represented as concept maps, including collaborative concept maps.

Science Buddies (http://www.sciencebuddies.org) Free, online help for science fair students, offering a Starter Kit (science fair project outlines), a Topic Selection Wizard, an Ask an Expert forum for specific questions, and many other reference sources.

School Science Lessons (http://www.uq.edu.au/_School_Science_Lessons) School science experiments from the "low cost" science teaching movement, simplified versions of classical experiments, experiments using locally available substances and kitchen chemicals, and environmental science activities.

WhaleNet (http://whale.wheelock.edu/Welcome.html) Web-based inquiry (WBI) activities that utilize authentic data--in this case, data transmitted by satellite tags placed on marine mammals--to study, and formulate conclusions about, migration patterns.

Tilt (http://tilt.lib.utsystem.edu) Provides a tutorial for evaluating the quality of the content of a website.

History Exhibits (http://www.aip.org/history/exhibits.html) Exhibits and other online resources for history of physics and allied fields. In the *Moments of Discovery* exhibit, follow discoveries through the scientists' own tape-recorded words as famous physicists recall how they discovered the key to nuclear energy.

Secondary Online Science (S.O.S) (http://www.channel4.com/learning/microsites/S/sos/) Three games, Fashion Victim, Sound Park, and Energy Quest, providing a fun way for 11- to 14-year-olds to be involved with science.

Research & Writing for High School and College Students (http://www.ipl.org/div/aplus/) A step-by-step guide for researching and writing an assignment.

Google™ Image Search (http://images.google.com) Obtain images and animations to display with the data projector, use in PowerPoint, or print and hang from the ceiling to add interest to the classroom.

Global Virtual Classroom (http://www.virtualclassroom.org) Aims to help integrate technology into classrooms and curricula and link schools to the information superhighway. In the Contest, schools from around the world collaborate to build websites that are judged on the quality of their content and presentation, and on the collaboration that occurred. The Clubhouse provides an environment for schools to come together to communicate and work together on topics of mutual interest. One product of the project is the Science WOW Factory at http://gvc03c32.virtualclassroom.org .

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