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Ideas for enhancing primary and high school science education

Did you Know?

Air fresheners do not remove odours from the air. Rather, they either numb the nose so offending odours cannot be smelt, or mask the odour with a stronger scent. Removing odours is a more expensive option, and can be achieved by using absorption agents such as charcoal or silica gel.

Science Story

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

Nazi Atrocities

Following on from the story in the last issue, we now consider another barbaric example of the moral blindness of scientists and others in relation to ethical issues. The atrocities of Nazi Germany are not only well known, but were considered ethical by the best scientific and political minds in the country at the time. Millions of people were tortured or maimed, hundreds of thousands of Germans were sterilised, and genocide was ordered. Horrific human experiments were conducted, including the sewing together of twins to create Siamese twins and the injection of crippling or lethal toxins and pathogens.

However, these atrocities also occurred amid great ironies. The Nazis were most successful in promoting a personal health campaign. The strong anti-smoking campaign was based on the work of German scientists, who were the first to produce a research-based consensus that smoking causes lung cancer. The Nazis mandated the production of whole grain bread, promoted organic farming, and campaigned against carcinogenic food dyes. Hitler himself directly supported several cancer institutes. Animal welfare was also a concern, as exemplified by the banning of experiments that caused animals to suffer. Breaking this law exposed a person to possible imprisonment in a concentration camp.

Biology (and particularly genetics) and biologists played a fundamental role in Nazi Germany, with more than 60% of German biologists being members of the Nazi party. Fritz Lenz, a German human geneticist, even proclaimed Nazism to be "applied biology." What is more, United States biologists also found Nazism appealing. William Hueper, the "Father of American Occupational Cancer," applied for a position in the Reich. It is background such as this that must surely have influenced present scientific research policies, such as the need to obtain voluntary and informed consent before experimentation involving humans.

Source: Moore, R., Jensen, M., Hsu, L., & Hatch, J. (2003). Lessons of history: Ethics & the public's views of science & society. *The American Biology Teacher, 65*, 85-89.

Using WebQuests to Successfully Engage Students in Learning Science

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Abstract

WebQuests are a powerful teaching and learning device that have developed rapidly in recent years, especially in the Humanities. In Australia, the use of WebQuests in Science has become popular. The multimedia product of students' investigations can be shared with a variety of audiences. In this article, I will explain what I understand to be a WebQuest, how I have used it to engage students in their own learning, and the important lesson that introducing WebQuests has re-taught me.

Introduction

WebQuests were first developed in the United States by Bernie Dodge and Tom March, have been used extensively there, and are now becoming popular in Australia. Teachers of humanities have been the central proponents of this approach, but it also offers much to science teachers, especially those who wish to engage their students in a critically constructive manner. Students are required to engage in an investigation of particular phenomena and to prepare a multimedia report to share with a designated audience. In this article, I will describe what I believe a WebQuest is, some of the background epistemology, and examples of how I have recently used the WebQuest in my own teaching.

What are WebQuests?

WebQuests are student-centred activities that use the Internet as the major source of information to support student investigation, which is usually carried out in small groups. I use groups of 2 or 3 students, because psychologists tell us that a phenomenon called social loafing occurs in groups any larger than three. Each WebQuest has six essential components, and these are now described.

1. There is an **introduction**, which explains clearly and concisely what the WebQuest is about and hopefully inspires students to action. For example, in my Good Nutrition WebQuest for Year 10 (16-year-old) students, developed to focus their exploration of the human digestive system and nutrient requirements, the following statement is used:

> Welcome to our WebQuest. In this activity, you will be required to investigate practices of diet and exercise that promote good nutrition in humans in order to respond to the following statement: "Western Society's obsession with body image threatens the long-term health of individuals and the species." You will need to present your findings in a way that can be shared with the class, school, and/or school community.

2. The **task** is then set out. It relates directly to the introduction, and describes and explains precisely what is required of each student. This may take the form of a focus question that defines the task, followed by a series of activities to be completed. Students receive, or can download, all the appropriate files as they require them. For example, for my Year 10 Motion WebQuest, I use the following:

> Your task is to complete the following activities with your partner(s), and to present a multimedia report that includes answers to the questions asked. Groups may have either 2 or 3 members--no more!
>
> *Experiment 1:* Interpreting Ticker Timers
> *Experiment 2:* Measuring Speed
> *Experiment 3:* Measuring Acceleration
> *Experiment 4:* Reaction Times
> *Science in Action:* SONAR: The Sight of Sound
> *Science in Action:* What Goes up . . .
> *Activity 1:* Blood Alcohol Content
> *Activity 2:* Alcohol and Driving
> *Question Sheet 1:* Velocity
> *Question Sheet 2:* Acceleration
> *Question Sheet 3:* Motion Pictures
> *Question Sheet 4:* Newton's Laws

Your report must be produced using a variety of information and communication technologies (e.g., MS Word, MS Excel, MS Publisher, MS FrontPage, MS PowerPoint, and PhotoShop) and be e-mailed to me at simpg@woodleigh.vic.edu.au . The concepts that must be explored in your report are Newton's First Law of Motion, Newton's Second Law of Motion, Newton's Third Law of Motion, speed, average speed, acceleration, velocity, force, momentum, friction, gravity, inertia, reaction time, reaction distance, stopping distance, and the effect of alcohol on stopping distance.

3. Students are given a list of **resources**, primarily from the Internet, that can be used to successfully complete the activities listed in the task. The teacher has already found the appropriate sites to inform the various questions the student will need to answer. In this way, it is possible for the students to be sheltered from inappropriate sites on the Internet and to be more successful in searching for information. In the case of my Motion WebQuest, the students received the following information:

Background Information
How Stuff Works (http://www.howstuffworks.com/), an excellent site for inventions such as how clocks work.
Beakman & Jax & Levers (http://www.beakman.com/lever/lever.html), an excellent site for students and teachers about levers. Simple language and good diagrams.
ParkPhysics (http://www.learner.org/exhibits/parkphysics), an excellent site exploring Newton's three laws of motion in relation to amusement park rides.
Johnston's Homepage (http://www.qnet.com/~johnston/index.html), a gory site, not for the faint-hearted. This page discusses the effects of car accidents on the victims, their families, and the cars.

Current News
Physics Gateway (http://www.psigate.ac.uk/ROADS?subject-listing/physics/num-physics.html), a search engine for physics websites.

Search/Resources
Physics Hot List (http://www.kn.pacbel.com/wired/fil/pages/listphysicsva.html), a WebQuest created by Deakin University students.

References
Hypertext Webster Dictionary (http://work.ucsd.edu:5141/cgi-bin/http_webster)
Roget's Internet Thesaurus (http://www2.thesaurus.com/thesaurus)

Grabbing Web Images
(http://www.kn.pacbell.com/wired/beyond/grabweb.html)

4. The **process** students should follow to successfully complete the task is laid out step by step. This gives them a strong framework to follow, so that all students should be able to complete the activities successfully. My Good Nutrition WebQuest offers a good example:

Select your partner(s).
a. Discuss the work to be completed and prepare a plan of action.
b. What questions will each of the members investigate?
c. Check out the websites listed in the reference section for helpful information.
d. Check out the Web. When you find something you like, check the Web page for a copyright notice. Often, students are encouraged to copy things that will be used in the classroom. Sometimes people don't want their work copied at all. A good practice is to look for an e-mail link on the page and then use it to ask for permission.
e. Copy any text you want.
f. Save any images you like by downloading them.
g. Be prepared to omit anything that copyright owners tell you they don't want you to have.
h. Now you have your information, you will need to sort through it. Ask yourself the following questions:
  i) Do I have enough information on each of the questions listed above?
  ii) Do I have images that will help me explain these things in my multimedia report?
  iii) Have I collected all the bibliographical details of the sites I've used, and books that I've used, for my reference list?
i. If you have answered *yes*, go to step k.
j. If you answered *no*, go back to step a. What will you need to do to complete this project successfully?
k. Prepare your multimedia report.
E-mail or present your report by the Due Date.

5. Students are supplied with an **evaluation rubric**. This ensures they are fully aware of how they will be assessed, and on what basis. I am still developing my application of these. Figure 1 provides a rubric that I am developing, with a colleague, for a Year 10 Future Space Travel WebQuest. This WebQuest invites students to question how science and technology are used by society to achieve the particular ends of the society. It is an attempt to cause students to explore the ethical dimension of the use of scientific knowledge. Each piece of work is assessed for achievement on all criteria listed in the rubric. The criteria provided address the attributes of students'

multimedia product only, but could be extended to include their presentation to an audience.

Criterion	Beginning	Developing	Accomplished	Exemplary
Explanation of concepts	The report contains answers to the questions listed in the task description.	The report contains complete answers to the questions listed in the task description.	The report contains detailed and complete answers to the questions listed in the task description.	The report contains richly detailed and thorough answers to the questions listed in the task description.
Use of inquiry scientific	The process of scientific inquiry has been used to investigate our future world.	The process of scientific inquiry has been used to effectively investigate our future world.	The process of scientific inquiry has been used thoughtfully to investigate our future world.	The process of scientific inquiry has been used thoroughly to investigate our future world.
Use of reasoning and logic	Scientific reasoning has been used to investigate our future world.	Scientific reasoning has been used effectively to investigate our future world.	Scientific reasoning has been used thoughtfully to investigate our future world.	Scientific reasoning has been used thoroughly to investigate our future world.
Use of scientific language	The student has used scientific language to communicate what they understand about our future world in a simple manner.	The student has accurately used scientific language to communicate what they understand about our future world in a simple manner.	The student has used detailed scientific language to communicate what they understand about our future world in an accurate manner.	The student has used richly detailed scientific language to communicate what they understand about our future world in an effective manner.
Statement of values	The student has stated a straightforward viewpoint that displays a view of the role of science and technology in our society.	The student has stated a detailed viewpoint that displays a view of the role of science and technology in our society.	The student has stated a thoughtful viewpoint that displays a detailed view of the role of science and technology in our society.	The student has stated a complex viewpoint that displays a richly detailed view of the role of science and technology in our society.

Figure 1. Evaluation rubric for a Future Space Travel WebQuest.

6. In addition to sharing their mutimedia reports with the class, school (e.g., peer-selected best work presented at an assembly), or the broader community, the quest is brought to a close with a **conclusion** that challenges learners to act upon what they have achieved. For example, following the Good Nutrition WebQuest and follow-up work on the human circulatory and respiratory systems, I asked students to consider how they might promote the work of the Heart Foundation. They have negotiated,

and are presently organising, a Dance-A-Thon. The idea is to raise awareness of how to keep a healthy heart, promote the work of the Heart Foundation, and raise money for this Foundation.

There are many WebQuests on the Web that deal with political, social, and environmental issues and inspire students to take a position and act upon that position. A quick Web search will uncover some great examples, with the Queensland University of Technology hosting an excellent teacher resource at http://rite.ed.qut.edu.au/oz-teachernet/projects/webquests/index.html .

Constructivist Post-Epistemology

This use of WebQuests is based upon the constructivist approach to learning. That is, learners create knowledge and understanding through meaningful and purposeful engagement with tacit and propositional objects, and this knowledge creation is mediated through social contact (i.e., communication with other students and their teacher). The WebQuests suit my own constructivist-inspired, student-centred learning approach, because they are so flexible. I am able to create a series of linked tasks which have enough direction and structure to assist students who require that, but which also allow more able independent students to negotiate their own path to the students' conclusion. Students who come to my class with a diverse range of learning style, learning ability, multiple intelligence, prior knowledge and experience, and personal enculturation (process by which one learns by engaging with one's culture) are able to share what they have and build upon these foundations in the way most appropriate to them.

WebQuests are excellent vehicles for engaging students with information and communication technologies, as students are able to use the Web to find information and share it, and deliver their completed work electronically. I require my students to use readily available programs such as Microsoft's PowerPoint, Front Page, Publisher, and Excel to complete their tasks and then e-mail them to me. Students are encouraged to use a multimedia format to explain what they have learned from the WebQuest, and to share this with their peers (as a minimum) and within the greater school community, as appropriate.

Webquests can also be used to answer a criticism of constructivism that it fails to consider ethics and values. Ernst von Glasersfeld (2000) did not intend the radical constructivism he developed to include a consideration of ethics and values but, with the move toward critical constructivism, this has become a concern (Lewin, 2000). Teachers and educational bureaucracies have become interested in the development of ethical positions by students, particularly in regard to the use of information in our society. With WebQuests, students can be required to respond to questions that focus on the appropriateness of the application of scientific and technological developments in relation to, for example, the environment, genetics, or issues of social justice.

How I Have Used WebQuests

I must confess to being a self-taught novice. During 2002, a colleague showed me some work he had completed on a WebQuest following a professional development session he had attended. He encouraged me to look on the Web for some ideas for my own classes. The Web contains thousands of examples of WebQuests designed by teachers for all subjects and all sorts of topics. Most of them are free. The author of the WebQuest usually just requires that you acknowledge them as the original author. As little has been done in Science, and most are from the United States and not directly applicable to my Australian setting, I have adapted some I've found on the Web or just used the format and developed my own.

During the early part of 2003, I became concerned that my students and I were operating in a teacher-directed manner. As it is my first year in a new school, I had been getting to know both the students and the school's systems, so I had not been innovative in my teaching approach. Rather, I had been working with the materials in the form presented to me by the existing staff. I decided to prepare the WebQuests in reaction to my own disenchantment with the students' preference for a teacher-directed transmission model, and the students' apparent disengagement with learning Science. During the second term this year, I developed and used two WebQuests--one to investigate Newton's Laws of Motion for my two Year 10 classes (16-year-olds in their final year of compulsory secondary schooling) and the other to investigate cells and microscopes for my Year 7 class (13-year-olds in their first year of secondary schooling). I do not claim my work to be exemplary applications of the WebQuest approach, but rather offer some of it to exemplify this curriculum innovation. For the second semester (Terms 3 and 4), I have developed a Good Nutrition WebQuest and a Future Space Travel WebQuest for use with my two Year 10 Science classes.

The school has an Intranet powered by a product called "Learning Point," which allowed me to set up a folder for each of the WebQuests and associated tasks for students to access either in the class or from home. I booked eight notebook computers, for regular student use, from the school's notebook collection, and asked the Laboratory Technician to establish a trolley of experimental equipment for student use for each class. I explained what was required of the students, giving each of them a copy of the WebQuests and all the tasks, but not the supporting notes, which were available on the Intranet. It would also be possible to run a WebQuest-style project with limited access to computers. Having prepared all the materials in advance, one could give the students the materials either as required or as a booklet, and either book computer time or require the computer component to be completed for homework.

The tasks were a collection of experiments to complete, some question-and-answer style assignments, and some research activities. I assisted students with planning their team's approach to the work, and set a timeframe for completion of all the tasks and submission of a final multimedia report. The students then set to work. During each class, they would choose what they needed to work on and I would move from group to group, encouraging them to engage with the concepts and helping students requiring assistance. In some classes, I gave short lectures on major concepts to ensure that all students had a few notes on the most important ideas. This was usually done in response to lots of questions about a particular concept highlighting a need to intervene and direct the students' knowledge-making.

Ramifications for my Teaching

Student responses to the WebQuests reflected the commonly experienced phenomenon that conceptual change takes time. Not only did I ask students to question their prior constructions of motion (Year 10) and the cellular basis of life (Year 7), but I also required them to question their deeply-encultured construction of the teaching and learning process. In conversation, the Year 10 students described a difficulty with the WebQuest approach, feeling that I did not explain enough to them. In contrast, the Year 7 students expressed satisfaction with the amount of teacher direction and responded to questioning that they preferred the freedom to choose what they were doing.

As the teacher, I was satisfied with the manner in which the students responded to the challenges of the WebQuest approach. I was also quite surprised by the response of the Year 10 students, as they were their most productive and most engaged during the semester when working with the WebQuest. The experience has reminded me that I must hasten slowly to achieve conceptual change and pedagogical change. Vygotsky (1962) suggested that concept formation is only truly possible at or following puberty, and that it is a creative process that is applied when a problem arises that cannot be solved by existing concepts. This theory of concept formation was expanded by Posner, Strike, Hewson, and Gertzog (1982) when they stated that conceptual change requires four phenomena:

a) dissatisfaction with existing conceptions,
b) presentation of intelligible new conceptions,
c) new conceptions that are initially plausible, and
d) new conceptions that hold the promise of further fruitful applications.

Teaching Science involves providing a rational basis for conceptual change, change that will be resisted by the student (Posner et al., 1982). This view of conceptual change is shared by constructivism, which can be used as a tool for teachers to guide the conceptual change of their students.

My students were asked to question the teacher-directed nature of their previous science education experiences. For some, this was the first time they had been caused to do so. I will continue to develop my students as focussed learners, less in need of teacher direction and more interested in collaborating with their peers and sharing control of the learning environment. I will certainly continue to use WebQuests frequently with these groups, but I will ensure that they feel more supported by the teacher, at least in the early stages.

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Demonstrations

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

Teaching General Chemistry Concepts, to Blind and Visually Impaired Students, Through Hands-On Demonstrations Inclusive of Sighted Students

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Introduction. It is usually taken for granted that the physical sciences, which include chemistry, are visual subjects. In chemistry, for example, acid-base indicators and color changes during a host of different types of reactions are considered quite normal, and are taken as mainstay concepts of any chemistry, or chemistry-related, science course. This holds true whether the material is taught in middle school, high school, or at the college level. Such thinking presents a problem for a visually impaired person, for whom a knowledge of the chemical sciences ultimately is as important as for any other student.

Various research has been published that considers how to overcome such problems and challenges in teaching the physical sciences (Brazier, Parry, & Fischbach, 2001; Flair & Setzer, 1990; Hiemenz & Pfeiffer, 1972; Ratliff, 1997; Tallman, 1978; Tombaugh, 1981; Womble & Walker, 2001), but most of the available literature suffers from one of two drawbacks. The experiments and ideas presented are either specific to blind students, and not particularly inclusive of sighted students (Flair & Selzer, 1990; Ratliff, 1997; Tallman, 1978; Tombaugh, 1981), or the materials and equipment needed are sufficiently expensive that many school systems will not be able to justify their cost for one or two blind, or visually impaired, students (Tallman, 1978; Tombaugh, 1981). We sought to overcome these problems by designing a series of activities that are best described as hands-on demonstrations, all of which are relatively inexpensive, are applicable to sighted students as well as to blind students, and are adaptable for teachers who do not have a deep, technical background.

Hands-On Demonstrations. The following are hands-on demonstrations that have proven valuable in starting discussions about chemical concepts in classes where students are as young as fourth graders, and as old as eight graders.

1. ***Guar gum and water.*** A thick, colloidal suspension can be made that is over 90% water, simply by mixing water and the powdered gum in a 30:1 ratio. Guar gum is an edible food thickener, and blind students can feel the suspension form, and all students can stick their hands into the resulting “goo.”

   For safety: Guar gum may be purchased from many chemical supply houses, and is sufficiently non-toxic to be edible. However, many grades of guar gum indicate that they are not for human consumption.

2. ***Bouncing putty made from Elmers® glue and borax soap powder.*** Adding a saturated solution of borax soap powder, in a 1:10 volume ratio, to Elmers ® glue (or other glue containing milk protein or polyvinyl alcohol [PVA]) that has been thinned 1:1 with water produces a thickened, bouncing putty that can be felt by all students.

   For safety: Both Elmers® glue and borax soap powder are safe to handle with bare hands, though neither should be eaten.

3. ***Methanol and water, or barium hydroxide octahydrate and ammonium chloride.*** The first of these two pairs, methanol and water, heat noticeably when

mixed. The heat can be felt through a glass container holding the mixture. The second pair, both of which are white powders, become cold to the touch when mixed together. Again, the cooling can be felt through a glass container.

For safety: Methanol may be purchased from many chemical supply houses. It should not be ingested, and should be kept away from flames. As well, it is wise to minimize skin contact. Barium hydroxide octahydrate and ammonium chloride may also be purchased from chemical supply houses. They should not be eaten, skin contact should be minimized, and skin should be washed thoroughly after contact. Additionally, the reaction produces an ammonia odor, and should be conducted in a well ventilated area or outside.

4. ***Liquid nitrogen and balloons.*** Immersing balloons into a low form dewar flask or styrofoam container of liquid nitrogen causes the balloons to shrink in size, which students can feel.

   For safety: Liquid nitrogen is obtained from cryogen gas suppliers or, in smaller amounts, from hospitals. It can cause frostbite on contact with skin, and the containers should be handled with insulated gloves.

5. ***Dry ice in balloon or surgical glove.*** Placing chunks of dry ice (solid carbon dioxide) into a balloon, or surgical glove, and then sealing the balloon or glove, allows the dry ice to sublime and the balloon or glove to expand. Students can feel the expansion as the dry ice sublimes.

   For safety: Dry ice may be purchased from some grocery stores. Surgical gloves may be purchased at medical supply houses. Upon contact with skin, dry ice can cause frostbite, especially when it is broken into small pieces and fresh surfaces are exposed. Care should be taken to wear insulated gloves when handling it.

Discussion. Making a goo from guar gum and water serves as a starting point for a discussion of solubility, including how one material dissolves in another and what sized particles must be present for a material like the goo, a colloid, to form. Sighted students find it amazing to see the solution thicken, and blind students find it equally exciting to feel a solution go from the consistency of water to the consistency of paste. We usually mention to students that gelatin desserts have particles similar in size to the goo they have made, and that table salt and sugar have smaller particle sizes, which is why they dissolve in water.

The bouncing putty made from Elmers® glue and borax soap powder gives a result that looks and feels much like the goo, but that is the result of a different process. The milk proteins in Elmers® glue are long-chain molecules, and the borax in the soap powder acts to cross-link one chain to another. In this experiment, students are introduced to the idea of long-chain molecules, and the term *plastic* is used in the discussion. We point out that there are many different types of plastics, that the molecules in Elmers® glue are not exactly the same as those in plastics, but that the glue and plastics share the common property of containing long-chain molecules. When borax is added, we discuss the idea of cross-linking in terms of making a net from a series of strings. A common analogy students understand is that a person can walk through a doorway with strings of beads hanging down in it. However, one cannot walk through a doorway with a net strung across it. This real-world example is an excellent starting point for a discussion of plastics, and how molecular shape and size affect macroscopic properties.

The methanol and water, and barium hydroxide octahydrate and ammonium chloride demonstrations are both excellent examples of how energy may be released by substances, or taken in by them. When students feel a solution become warm through the container in their hands, or when they feel a mixture become cold in its container, they are naturally curious as to why. We discuss how simply mixing two substances can give off heat energy, or take it in. We discuss the idea of heat as a form of energy, and the idea of matter representing stored energy that can be released as heat.

In 4 years of presenting chemical concepts to student groups that include both sighted and blind students, the liquid nitrogen demonstration is invariably the best received. While this has not been quantified, it has been obvious from the students' excitement and behavior. Perhaps because they have not seen, or worked with, liquid nitrogen before, this hands-on demo is always fascinating. The experience of having a balloon shrink down to an almost non-existent volume, just by slowly immersing it in a container of liquid nitrogen, is always one the students enjoy. It also serves as the beginning point for a discussion of gases, and how they act when they are heated and cooled. We discuss what differences there are when water, for instance, is a liquid or a gas. We try to draw from the students the idea that gases occupy much more space than the corresponding amount of liquid, and discuss what this means in terms of the density of gases versus that of liquids and solids.

Coming a close second to the liquid nitrogen demonstration is the dry ice in surgical glove or balloon. While it is far easier to insert chunks of dry ice into a glove than into a balloon, the latter can be used if gloves are not available. In addition, the gloves are made to withstand much more stress. In practical terms, this means a student can add several hundred grams of dry ice, tie off or rubber band the glove, and allow the glove to expand possibly to the size of their own torso. Whether sighted or blind, students enjoy the feel of the glove as it continues to grow. While the experiment is fun, the authors take care to always point out the enormous difference in volume that the same material occupies when it is a solid compared with when it is a gas.

All the hands-on demonstrations that deal with a phase change, from a solid directly to a gas, or from a gas to a cooled gas and liquid, serve as a jumping-off point for a discussion of both these states of matter, as well as of what atoms and molecules are. We take considerable time to discuss how solid and liquid matter have atoms and molecules closer together, often in a more ordered manner, than in gases. In these discussions, we have used styrofoam balls, either glued directly together or attached with small, wooden pegs, to show the molecular shapes of such substances as water, carbon dioxide, and ammonia gas. Students can hold each shape to feel how one molecule differs from another. While this teaching aid was aimed specifically at those students who are blind or visually impaired, sighted students also enjoy this tactile tool. It helps all students to get a feel for how matter is constructed at the molecular level.

Conclusion. Although these hands-on demonstrations do not address all the concepts of a general chemistry course, they do cover a wide range of topics. A teacher might use them to discuss such concepts as solubility, concentration, polymers and plastics, gas laws, density, and phases of matter. A teacher does not need a deep background in science methods to initiate such discussions, or to make the demonstrations effective. These simple, hands-on demonstrations are useful throughout a broad range of student ages.

All the materials for these demonstrations are inexpensive enough to be purchased from the normal, operating budget available to most schools. Each demonstration serves as a starting point for a discussion about the behaviors of chemicals, or the properties of matter. As such, they should be widely adaptable to teachers in almost any school environment.

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"Ignorance is not the problem in the world. It's the things people 'know' that aren't so." *Will Rogers*

Student Experiments

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

Learning and Having Fun With Electric Letter Soups

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Abstract

In this activity, students integrate their knowledge of electric circuits and language arts to cooperatively create a device that helps them detect the component letters of a mystery word hidden in a secretly wired poster board. Only the correct letters will make a light bulb glow.

Introduction

For most children, electricity is a fascinating topic. They love to play with wires, batteries, motors, and light bulbs. A very common, and educational, activity that I did with my students at the 2002 Arkansas Tech University Summer Camp for Gifted and Talented Students was to challenge them to make a light bulb work using two wires and a size D cell. After much exploring and questioning, students were able to perform the task. Figure 1 shows a basic electric circuit using two wires, a dry-cell battery, and one light bulb. Their next challenge was to make the light bulb work using only one wire and the size D cell. After a while, the students again made the light bulb work. Doing this simple activity helped them learn how circuits work and to observe electrical phenomena first-hand in a safe environment. We all know how dangerous electricity can sometimes be.

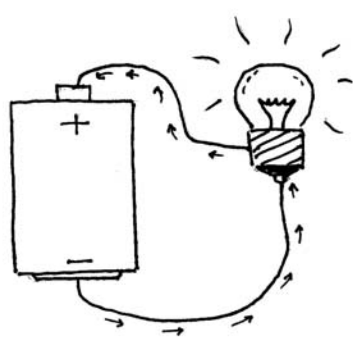

Figure 1. Diagram of a basic electric circuit. The chemicals inside the dry-cell battery provide the voltage (energy per unit charge) necessary for the electrons to move around the circuit, creating an electric current.

Electricity is not just fun. According to the National Science Education Standards (National Research Council, 1996), electricity is a required topic to cover in K-4 science classrooms. At the end of fourth grade, students should be able to recognize that "electricity in circuits can produce light, heat, sound, and magnetic effects" and that "electrical circuits require a complete loop through which an electrical current can pass" (p. 127). Students in upper elementary (fifth and sixth grade) should also know that "electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced" (p. 155). Figure 2 shows a diagram of the interior of a light bulb, demonstrating that the electrons in fact complete a loop inside the light bulb and through the circuit. This diagram is also useful in dispelling the misconception that electrons jump from one side of the filament to another, creating sparks that produce light.

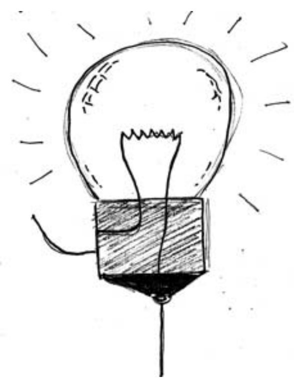

Figure 2. Diagram of the interior of a light bulb. Knowing how a light bulb is wired is important in presenting the argument that electrons are on a closed circuit. A light bulb will not glow when the filament breaks, preventing the electrons from completing their journey through the circuit.

Building the Devices

One way to reinforce students' knowledge of electric circuits, while also integrating language arts, is to use a resource I call Electric Letter Soup. The purpose of the Electric Letter Soup activity is for students to unscramble letters to discover a mystery word. These letters are hidden in a specially-designed poster board wired in such a way that only the needed letters can produce a closed circuit, making a light bulb turn on. I suggest that teachers divide students into cooperative groups of 2 or 3 students each. The materials needed to build the poster board circuit and the letter-detecting device include two dark poster board rectangles (8½ x 11 inches), one single-hole puncher, aluminum foil, scissors, one D-size cell, one small light bulb, two wires (each about 12 inches long), and transparent adhesive tape.

Using the single-hole puncher, the groups create four rows of equally-spaced holes in one of the poster board pieces. Marking the poster boards where the holes are supposed to be will make the job easier. The teacher can also prepare templates for students to use as a reference. The first and third rows must have seven holes; the second and fourth rows must have six. Ask the groups to assign each hole a letter of the alphabet. At the end of this step, each group will have the letters arranged as shown in Figure 3.

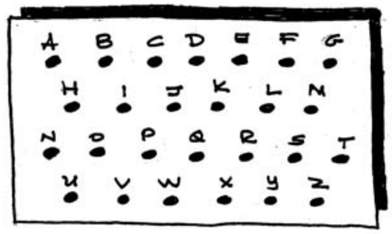

Figure 3. Poster board piece with holes. Each hole is assigned a letter of the alphabet.

The second step in the process is for each group to decide what mystery word to hide in the poster board piece. The only rule that will decide what words can be used for this activity is that the chosen word must be made of non-repeating letters. Once the mystery word is chosen, each group will cover the holes with the letters that do not belong to the chosen word using small, individual pieces of aluminum foil and transparent adhesive tape. To prevent unwanted electrical contact, the tape must cover the aluminum foil completely.

The next step is to connect the letters that form the mystery word with strips of aluminum foil. Take the word *dog* as an example. Cut two strips of aluminum foil and tape them in such a way that the aluminum foil observed through the holes assigned to the letters *d*, *o*, and *g* are interconnected. The pieces of aluminum foil used to cover other letters must not come into contact with the aluminum foil strips used for the mystery word. Figure 4 shows the connections between the letters in the word *dog*. When the connections are done, the groups will use the second piece of cardboard to cover the aluminum foil connections.

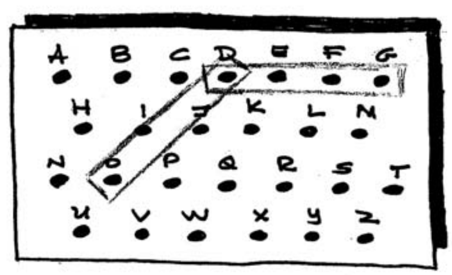

Figure 4. The aluminum foil connections between the letters *d*, *o*, and *g* are presented. Although there seems to be connections with other letters, like *e*, *f*, and *i*, these will be covered with plastic tape to prevent them from activating the electrical detecting device. *Remember:* The connections need to be made at the back of the poster board!

The final step of this process is to prepare the letter-detecting device. Each group takes two copper wires and strips some of the plastic cover from the ends. Next, connect one of the wires to one of the dry-cell battery poles and wrap the other extreme around the metal section of the light bulb. Connect the second wire to the other pole of the dry-cell battery. The teacher should remind students to secure all connections with adhesive tape. The detecting device should look like the one shown in Figure 5. The students are ready for the letter search!

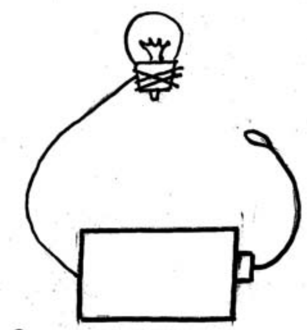

Figure 5: Letter-detecting device. Transparent tape can be used to safely adhere the wires to the dry-cell battery and light bulb.

Finding the Mystery Word

After much cooperative effort, the Electric Letter Soup activity is ready for fun. Students need to exchange wired poster boards among themselves, place the metal tip at the bottom of the light bulb in one of the holes, and touch each of the other holes until the light goes on. When that happens, it means that the letters assigned to those holes are part of the mystery word. To make the search simpler and faster, each group must provide a small hint. I suggest telling the search group one of the vowels that make up the hidden word. By placing the metal tip, at the bottom of the light bulb, in a vowel, the groups can perform the search more effectively. Figure 6 shows how the light bulb will behave when a correct and an incorrect letter are contacted.

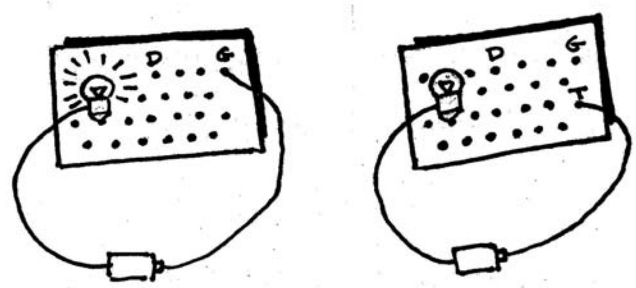

Figure 6. When two of the letters of the word *dog* are contacted (the light bulb is located in the vowel *o*), a closed circuit is created, making the light bulb glow. If an incorrect letter is contacted (the letter *t* in this example), the circuit remains open and the light bulb will not be turned on.

Conclusion

As science educators, we are aware of the advantages of integrating two or more disciplines to create meaningful connections, of using hands-on activities to teach a concept or reinforce learning, and of using cooperative learning to emphasize adequate social behaviors and help students learn from each other. I think this activity combines progressive ways of teaching science. An extension of this activity might be to have the entire class prepare an Electric Sentence Soup. In this scenario, each group wires a poster board to hide a different word in a sentence. I am certain that colleagues will think of further creative ways to extend the Electric Letter Soup activity.

Reference

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

The Problems With State Educational Standards

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Abstract

Although prescribed standards for science education are the basis for educational reform in virtually all states in the United States, these standards are often problematic. Indeed, an emphasis on prescribed standards often (1) frustrates and inhibits good teachers, (2) marginalizes many at-risk students, (3) produces curricula that ignore fundamental ideas in science (e.g., many states' standards do not mention the word *evolution*), and (4) do not enhance teaching and learning. It is teachers, not prescribed standards, who are the most important ingredient of science education.

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

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 .

Scientific Evolution

Science is here, there, everywhere
From water to things a lot more rare.

Scientists test ideas by experimentation
Performing it mainly on civilisation.
Whatever the reason, whatever the cause
We have evolved, we cannot pause.

We have long protected plants and flowers
We have used the sun to generate electric powers.

Fertiliser kills many insects living their way
We have destroyed their long-gone happy days.
We have poisoned our produce, according to tests
But farmers are glad they've removed their enemy pests.

GM food brings a frightful warning
To no delight in a red-sky morning.

Electricity in many places
Are unrenewable to reusable cases.
Renewable energy can be used today
However it is impossible to some
No matter how much they pay.

Planes have taken us all the way round
But is it necessary to go faster than sound?

The Internet has connected the globe
But legal matters are to be resolved.

Robots have helped us in numerous ways
But will they take over humans some day?

Science is inevitable, it will never stop.
New discoveries will be made
Better or worse, knowledge forbade.

Anthony Hui, Year 7
Australia

Fossils

I come down across stones lightly,
a part of them. Sandstone, shale,
something else that's old-bone white—
perhaps the granite knows.

(The translation of time from stone
to stone
takes time. Things
move slowly.)

Tribobites mix quietly with small fishes.
Coal knows more by far than I.
Anthracite blinks in the sun,
smiling sleepily, thinking deeply of seed-ferns.

There was a time when things
fought to the death to decide
whether a clutch of eggs
would bear scales or feathers.

But now, *Archaeopteryx* is just
a clumsy arrow bent in sandstone,
with a three- or four-chambered heart
that still sighs with your ear held close.

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Rough Ascension and Other Poems of Science, by Arthur J. Stewart
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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.

Which of the following cause the phases of the Moon? (There may be more than one.)

a. The shadow of the Earth falling on the moon.
b. Clouds covering part of the Moon.
c. Planets casting a shadow on the Moon.
d. The shadow of the Sun falling on the Moon.
e. None of the above. I have a better idea. (Please explain.)

Comment: It is the relative positions of the Earth, Moon, and Sun that cause the phases of the Moon.

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

Teaching Techniques

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

Decision-Making Matrix

Science cannot provide complete answers to all questions (Eastwell, 2002). Consider, for example, the different ways by which domestic electrical energy might be provided to a region or country. The possibilities may include the use of coal-burning power stations, solar cells, wind generators, gas-powered turbines, hydroelectricity, and nuclear energy. Ask which is the best, and it quickly becomes clear that a number of factors (criteria) need to be considered. One choice may provide cheaper electricity, for example, yet produce more environmental pollution. Some alternatives may have a more pleasant visual impact. Which would be the best choice overall? Well, it really depends upon the relative weight one gives to each criterion, and this is also likely to vary from person to person. It is for such reasons that we need politicians, because politics requires the trading-off of factors that have no natural trade-off.

Asking students to read about, and to discuss, socio-scientific and controversial issues will increase their awareness of the factors involved, but this is not sufficient. To make the learning experience more meaningful for, and longer-lasting in the minds of, students, they need to be invited to do something with the information they have gathered. This might involve the preparation of a report, performing a role-play, or writing a letter to the editor of the local newspaper, and will typically require each student to advocate a particular overall position. The Decision-Making Matrix is an excellent tool for arriving at such.

Using the supply of domestic electricity as an example, the possible choices are listed down the left-hand column of the matrix (please see diagram below). Determine as many criteria as possible (the analysis level of Bloom's taxonomy) and list these as column headings. A Round Robin (see Volume 1, p. 65) might be used to determine the criteria.

Decision-Making Matrix

Choices	**Criteria**					**Total**
	Cost/kWh	Pollution **5**	Visual impact **2**			
Coal-burning			Few needed 4 **8**			
Solar						
Wind			Wind farms ugly 2 **4**			
Gas						
Hydro						
Nuclear						

Students then need to research information about these criteria for each choice, and summarise their findings in the cells of the matrix (knowledge, comprehension, and application cognitive levels). For each criterion, each choice is given a rating of 1-5 (or 1-10, perhaps), with *5* being the highest, most preferred rating (evaluation). For example, on the *Visual Impact* criterion, one might rate a coal-burning power station a *4* because not many of them will be needed and therefore seen, whereas a wind farm might be rated a *2* because many windmills across the countryside might be considered quite visually distasteful. One then simply adds the scores for each choice to arrive at a series of totals, with the choice having the highest total score the preferred option.

A limitation of the process just described is that all criteria enjoy the same weighting, and this may not be appropriate. To refine the process, we also weight each criterion from 1 to 5 (or 1-10, perhaps), with *5* again being the highest, most preferred rating. If pollution is a major concern, then it might be rated a *5*, whereas visual impact might only score a *2*, and so on (see the red scores in the matrix above). In each cell, a weighted score is calculated by multiplying the original score in that cell by the weight given to the relevant criterion. For the visual impact of a coal-burning power station, for example, the weighted score would be 4 x 2 = 8. Adding the weighted scores for each choice then gives a series of weighted totals, with the choice having the highest total again being the preferred option. As evidence of their planning and research, students might be asked to include the Decision-Making Matrix as an appendix in a submitted task.

Reference

Eastwell, P. H. (2002). The nature of science. *The Science Education Review, 1*, 43-48.

Sound in the Science Lab

Contributed by: Margaret Underwood, International Education Consultant
MargaretU@compuserve.com

Students have different needs for sound in their learning environment, and the appropriate use of sound can help learning, concentration, and student noise levels. Some students prefer silence while they are learning. In the extreme, these are the students who will complain, during an examination or test, that the student seated next to them is breathing and it is distracting them from their work. “Could you please stop the noise,” they will ask. At the other end of the spectrum are the students who desperately need sound in order to focus and concentrate. If you don’t provide it, they will--by tapping, humming, muttering to themselves, singing, and the like. Often, this is below the level of their conscious awareness, so when you ask them to stop doing it, they look at you with surprise and ask what they should stop doing.

The research shows that when students' sound needs are met, they concentrate better, retain more, and even do better in tests. (If you would like the research references, please e-mail me at the above address.) So the question is: "How do we cater for these different needs in a classroom?"

For those students who need silence, a simple set of ear plugs is a useful addition to their classroom kit. Allowing students to use these when they are studying or working on something (provided you are still able to get their attention in some way) really assists them to maintain control of their own learning, to focus, and to concentrate. Even children under 5 years of age have been able to use ear plugs appropriately in classroom situations.

For the students who need the presence of sound, there are two options: either a sound system for the classroom (with a remote control for the teacher), or a personal Walkman--tape or CD. Over many years of working with classroom teachers, I have received constant positive feedback about the use of a sound system in the classroom. Many teachers have been surprised by how much quieter their classrooms are after adding sound. They are also pleasantly surprised by the number of students, who previously had difficulty getting any work done, who simply get on with whatever they have been asked to do without any prompting from the teacher. You don't need many CDs either. Most teachers have found a selection of four or five CDs works very well. Students become accustomed to the music and will actively request certain pieces.

The type of music you choose to play is also important. We know that, after 5-10 minutes, largo movements from the Baroque period entrain the brain into the alpha frequency range of listening. The music should not be obtrusive or loud. Rather, the best effects are achieved when it is played softly in the background. This alpha frequency range (8-12/15 cycles per second) is the frequency range that gives the brain access to long-term memory and learning. Vivaldi, Bach, Mozart, and Pachabel are all ideal for the classroom. Many adolescents may initially object to music that is unfamiliar to them. However, after gaining an understanding of why you are playing it and a period of time in which to gain familiarity with the music, you will find they will become very fond of it, as their systems will naturally recognize and appreciate something that helps them focus and learn. After this type of music had been used in the classrooms for a few months, one of the first high schools in New Zealand to introduce it had astonished parents reporting that their children were requesting that they purchase Vivaldi and company to help them learn. You can always also agree to play their music when appropriate (i.e. not when learning is taking place) in the classroom.

The portable remote control that many simple and cheap sound systems have today is very useful for the teacher. It fits neatly into your pocket and, wherever you are in the classroom, you can raise or lower the sound according to need. With respect to individual Walkmans, there needs to be some rules or guidelines for their use. First, if the school is purchasing the Walkmans, buy those with a playback function only (no radio). Have a selection of cassette tapes or CDs available in the classroom. Finally, to protect the listener's ears, no one else should be able to hear the music, and the teacher must be able to get a student's attention immediately.

Of course, students should only be allowed to listen to music, or use ear plugs, if their grades and behaviour improve. As with all the strategies I am sharing with you, we are looking to improve learning. If that doesn't happen, then obviously this is a strategy that is not appropriate for that individual or group.

"When even the brightest mind in our world has been trained up from childhood in a superstition of any kind, it will never be possible for that mind, in its maturity, to examine sincerely, dispassionately, and conscientiously any evidence or any circumstance which shall seem to cast a doubt upon the validity of that superstition. I doubt if I could do it myself." *Mark Twain*

Ideas in Brief

Designing a Rubric

A well-crafted rubric can be an indispensable tool for assessing a performance task. Rubrics have three basic elements: criteria (or parts of a task), standards (or levels) of achievement, and indicators, as exemplified in Figure 1 for a task requiring students to research a topic, draw a diagram or construct a model, and share their findings and understandings using an oral presentation.

Criterion	Standard			Self-evaluation
	Excellent	Fair	Developing	
Research paper	6 Discusses and justifies . . . 2 No spelling or grammatical errors 9 Discusses the . . . • • •	3 Discusses . . . 1 One or two spelling or grammatical errors 6 Discusses the . . . with one omission or error	(No points) (No points) 3 Discusses the . . . with more than one omission or error	
Diagram or model	2 Uses correct colours • • •	(No points)	(No points)	
Oral Presentation	• • •			
WOW	3 Included something extra that demands attention!			

Figure 1: Sample structural overview for a performance task rubric. Each number gives the points scored for demonstration of that indicator.

In contrast to a rubric, a checklist contains only criteria and marks to be awarded for each, but is a useful starting point for developing a rubric. Bednarski (2003) offers the following advice for designing and using a rubric.

- The number of standards/levels may vary with the task, but two or three standards generally work best.
- Always order the standards with the highest level first (on the left).
- Avoid ambiguous wording (e.g., few, most, limited, creatively) in the indicators, the "rules of the game."
- Do not use two or more indicators that measure the same thing, as this could penalise students more than once for the same shortcoming.
- Keep rubrics manageable by avoiding excessive length and complication.
- Assign points to each indicator to reflect its weight/importance.
- An overall grade (*A* to *C*, say) may be assigned on the basis of the total obtained from adding the points scored on each indicator mastered. For example, an *A* might correspond with a score of 47-50 out of a possible 50. Determine the grade

score range so that students can still receive an *A*, even if they fall short on either one of the more highly-weighted indicators or one or two of the less weighty indicators.

- Do not assign points for unacceptable performance. Accomplish this by not including indicators that describe such in the rubric. Rather, where there is no acceptable performance, assign either “No points” or leave the grid position blank. In particular, the lowest (last) level for a particular criterion is not for unacceptable achievement and also does not necessarily represent a *C* grade.
- A “work habits” criterion may be used to assess effort, meeting deadlines, contribution to group work, etc..
- To encourage creativity, include a “WOW” criterion. This awards points to a student who does something noteworthy that is not required by the rest of the rubric, or something above a highest standard. This does not penalise students who meet all the expectations of a project, as the WOW points are bonus points that are added to the total score (but which are not included in the total possible score).
- Provide a self-evaluation column. Asking students to reflect upon, and evaluate, their work prior to submitting it will encourage increased student-teacher communication and motivate students towards submitting quality products.
- Spell out expectations by issuing rubrics to students at the beginning of tasks.
- Where a project involves consecutive dependent tasks (e.g., research, followed by a presentation), use the rubric to evaluate each task before proceeding to the next. This provides students with the opportunity to address deficiencies that might otherwise result in them being penalised again for the same shortcoming.
- Really good rubrics develop over time, as the result of revision that includes student feedback.

Reference

Bednarski, M. (2003). Assessing performance tasks. *The Science Teacher*, *70*(4), 34-37.

Desirable Science Teacher Characteristics

The *Benchmarks for Scientific Literacy* (American Association for the Advancement of Science, 1993) and the *National Science Education Standards* (National Research Council, 1996) are both based on research about best practice in science learning, which also provides very little support for the traditional lecture supplemented by worksheets, reading, and a verification lab. Leonard, Penich, and Douglas (2002) identify desirable traits for a standards-based teacher, which include the following:

- Promote in-depth learning by selecting the concepts to be taught in a course rather than trying to “cover everything.”
- Use primarily inquiry-oriented activities rather than lectures and/or reading.

- Teach science to all by providing activities that appeal to all learners, including linking learning with current events.
- Use collaborative groups to model the work of scientists.
- Use questions, rather than instructions, to begin lessons.
- Seek students' explanations before offering yours, and after they have had direct experiences with the concepts involved.
- Emphasize deep understanding of concepts rather than memorization of information, and this includes assessment practices.
- Seek higher-order thinking via active learning, which includes experimental and field work.
- Encourage use of multiple predictions/explanations when investigating questions.
- Teach the methods of doing science (e.g., asking questions, proposing hypotheses, recognizing variables, designing and carrying out experiments, and communicating with others).
- Encourage students to use data sources to make decisions, and to draw evidence-based conclusions.
- Apply learned concepts to familiar and new contexts.
- Teach aspects of the nature of science (e.g., that science is empirical, tentative, and testable).
- Use technology regularly to facilitate student learning of concepts.
- Use a variety of assessments, including portfolios and rubrics.

The student-centered, minds-on, standards-based classroom will display much student activity and may be more noisy than a traditional setting.

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American Association for the Advancement of Science (1993). *Benchmarks for scientific literacy*. New York: Oxford University.

Leonard, W., Penick, J., & Douglas, R. (2002). What does it mean to be standards-based? *The Science Teacher*, *69*(4), 36-39.

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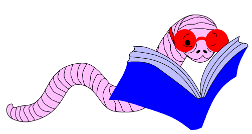

Research in Brief

What do Preservice Teachers Learn From Their own Education Experiences?

Present reforms in science education advocate a constructivist approach, with students actively involved in learning that reflects how science is done, and Plelps and Lee (2003) investigated how preservice teachers' prior experiences with education might either help or hinder the achievement of such a goal. During 1990-2000, they collected data, from 62 chemistry methods students and 181 science methods students, concerning their beliefs about teaching. Multiple sources of data, including journal entries and descriptions of ideal lessons, were used.

The beliefs of these teachers about teaching were, in general, as follows:

1. "Content is king," and the most important need is to know the content that is to be downloaded to students. They saw science as being able to recall information and calculate correctly, even though we know that such routine problem-solving does not lead to the desired level of conceptual understanding. In short, their view of science was restricted to a body of knowledge to be passed to the next generation.

2. Such information can be transferred to students by communicating it well, by being in control of the students, and by entertaining them (especially by including demonstrations) to prevent them becoming bored.

3. Labs are a necessary part of teaching science. However, when probed, they generally could not say why.

4. Methods courses are of little value. The experiences of these students with education, and the views they had formed about what constitutes good science teaching, were so uniform that they saw little need for a course aimed at helping them develop strategies for teaching.

Many years in the classroom impacts preservice teachers' views about the nature of teaching and learning. Typical schooling requires much passive listening and regurgitation of information, and modelling this behaviour leads to teachers teaching as they were taught. This makes it difficult for them to embrace new approaches.

Science education graduates are expected to be ready to implement inquiry-based programs, even though college science is generally not taught this way. If teachers do in fact teach as they were taught, then college science instructors can play a key role in facilitating the reform process by using interactive, hands-on, discovery approaches in both college methods and science content courses. One or two science methods courses alone cannot compete with years of modelling from instructors.

References

Phelps, A. J., & Lee, C. (2003). The power of practice: What students learn from how we teach. *Journal of Chemical Education*, *80*, 829-832.

Readers' Forum

Science and Religion

Regarding the separation of science and religion (Volume 2, p. 52), I suggest reading Shermer (1999). Michael Shermer is the publisher of *Skeptic* magazine, the director of the Skeptics Society, and the host of the Skeptics Lecture Series at the California Institute of Technology. He also writes a monthly column for *Scientific American* magazine.

He points out that faith is static, while science is dynamic. As time passes, conflict arises unless faith can adjust to the changing view of the world. To those of faith who feel threatened by science, the message is simple: "O, ye of little faith, if you believe, don't worry so much." The existence of God is unprovable in either direction and must be left to faith. Until science is able (if ever) to reduce humans to automatons, faith remains possible.

So, scientists who attack religion are not doing science. Religious people who attack science are doing neither their religion nor science any favors. In the long run, science will always win, although, for Galileo, it took nearly 400 years.

Reference

Shermer, M. (1999). *How we believe: The search for God in an age of science.* New York: W.H. Freeman and Company.

Harry Keller, USA

? ? ? ? ? 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!

Is science education culture free?

With a very high probability, the answer is no. All of us have some cultural biases and stereotypes, whether we like to admit it or not (although most of us like to pretend we don't), and these biases come through in all our interactions. I was asked to review several science books, and often a generic sentence about scientists was followed by the pronoun "he," yet we all know that both genders contribute to the pool of scientific information. For many years, textbook publishers have been aware of the bias towards white males and are trying to fix the tendency to tell the history of science by including contributions of only one gender and cultural group while including only a few “token” females and persons of color. In the past, the authors of most science text books were males with European ancestry; they weren't doing anything wrong per se, they were just telling history from their own perspective. Now that we know the inequity exists, we have a responsibility to fix it and most science educators are well aware of the problem and have educational outcomes geared at teaching global science. So the answer is no, but we are trying!!

Pamela Galus, USA

There are many authors who would suggest that the pursuit of science is a socially determined, and therefore culturally contingent, exercise. Bruno Latour and Steve Woolgar have undertaken some very interesting studies of cultures in scientific institutions that were repeated by Max Charlesworth in the Australian setting of the Walter and Eliza Hall Institute. Karl Popper and Thomas Kuhn wrote extensively of the cultural dimension of science. In Australia, David Turnbull and David Wade Chambers have written of the science of indigenous cultures of the Pacific and Asia, as has David Peat for the North American setting. So the short answer is, no. The use of science by cultures, and the culture of science itself, suggest that science education is a culturally and socially contingent exercise--see Rosalind Driver (enculturation) and Glen Aikenhead (acculturation).

Gary Simpson, Australia

In my opinion, as a woman of color, science education has been harmed by omitting cultural significance. I believe science has deep roots in culture which, over time, have been weeded out of the classroom. When I want to make science more interesting to my students, I seek out cultural references. This type of information is not addressed adequately in the textbooks. Many of my students see science as a dominant white male discipline. It takes significant work to show them scientific contributions made by women, people of color, and people of different cultures. I am thankful that my state standard does encourage multicultural awareness is the sciences. Little by little science is becoming richer because of this awareness.

Adrienne Fong, USA

No. Like all other knowledge, it is deeply expressive of culture.

Jim Butler, Australia

I strongly believe that science education is greatly influenced by the culture. However, the culture itself is driven by the needs of a society, which are directed by government educational policies. I live in Jordan, in the Middle East, and I believe my personal experience with science education has been culturally driven. Students in schools are streamed into an arts stream and a science stream. "Good students," as judged by their maths and science performance, are allowed to join the science stream. It is a more prestigious stream and, of course, unless you are in a science stream in a school you cannot continue your education to become an engineer or doctor.

Historically, the country had few doctors and engineers, and these professions were highly regarded. I was trained to be an engineer, but went into teaching simply because, in my days, it was the achievers who became either doctors or engineers. In my culture, parents still care a lot about the performance of their children in maths and science--much more than, for example, in languages, art, or history. However, could this be a universal value? Scientists are regarded world-wide as the ones who invent, discover, and come up with answers that affect the quality of our lives. It would be interesting to learn about experiences from other parts of the world.

Suha Abu-Dayyeh, Jordan

No education can truly be culture free. If you believe otherwise, come to the US and observe the evolution vs. creationism debates taking place here. Teaching science requires making choices. What do you include? What examples do you provide? For example, impulse may be explained in the context of either baseball or cricket, depending upon culture. Although these examples may seem trivial, the impact on students can be profound. Regardless of the result, the education activity will always be culturally associated.

Harry Keller, USA

Science education is not culture free in the United States, so I am sure that the same is true internationally. In the southern United States, many students are closed-minded to evolution because of teaching at home and at church. The farther north, or closer proximity to a large city, the more open-minded the students become. The variations in values and religion around the world would insure that the culture of the student, and the culture of the teacher, influence science education.

Nicole Harvey, USA

Invited commentary by Glen Aikenhead, University of Saskatchewan, Canada. The responses above all agree that science education is not culture free, but they do so from quite different perspectives. Some focus more narrowly on the act of teaching and on teaching materials, from the point of view of biases. I agree with Pamela that we have a responsibility to address inequities, but I recognize my position as a cultural bias as well, knowing that some other colleagues may have a cultural bias towards continuing the status quo inequity.

Gary, and then Jim, broaden the issue to include science itself (content found in school science) or to include *any* knowledge system for that matter. Thus, we have cultural biases inherent in: (1) the disciplines of science (including the white, male, and middle-class biases that Adrienne reminds us of, and more subtly, including cultural biases in concepts such as impulse that Harry speaks about), and (2) the classroom instruction of that content.

Suha and Nicole extend the latter issue by noting the influence on science education practice from the cultural bias of society--for example, a society that values the type of schooling in which science classrooms function to screen and categorize students into winners and losers. Therefore, in a number of different ways, science education is imbued with, and is formulated upon, cultural biases. One finds these biases articulated in historical accounts of the Anglo origin of the science curriculum in the UK in 1867 and later in the US in the 1890s. The science curriculum was developed soon after the modern labels "science" and "scientists" were invented by people establishing the British Association for the Advancement of Science in the 1830s. The science curriculum was established for very political reasons--culturally biased (for recent summaries of this history, see Aikenhead, 2003; Gaskell, 2003; Osborne, 2003).

My own (academic) approach would be to posit a well-established definition of *culture* and then examine the degree to which science education fits such a definition. For instance, one of the mainstream anthropological concepts of culture is: "norms, values, beliefs, expectations, and conventional actions of a group" (Phelan, Davidson, & Cao, 1991). On each count (norms, values, beliefs, etc.) science education can be characterized as having defining characteristics of a culture (Aikenhead, 1996, 1997, 1998). Therefore, science education is not culture free, but is very much a cultural activity.

Given the cultural nature of science education, we can now raise the issue as Adrienne does: "Whose culture is privileged?" And we can consider the serious problem faced by students whose cultural personal identity is at odds with the culture of science or the culture of a science education classroom.

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Why does our hair turn grey?

Our hair doesn't actually turn grey. Rather, it changes from its natural colour, through grey, to white due to a loss of pigmentation. Hair gets its colour from melanocytes, which are pigment cells that produce melanin, made by the action of our genes in the cells of the root of each individual hair follicle. Over time, tyrosinase, the chemical that causes the melanocytes to produce melanin, is produced in less and less quantity as the genes responsible switch off, causing hairs to become unpigmented. This occurs slowly, and we appear to become progressively greyer until all our hair follicles become unpigmented and our hair appears white. This process usually begins at the temples for men and the crown for women. By age 35, 25% of people have some grey hair and, by age 50, one half of the population appear grey-headed.

For most people, the process is natural and irreversible, and has nothing to do with our lifestyle or hair care habits. However, antimalarial drugs, a diet seriously deficient in zinc or iron, or conditions such as celiac disease or ulcerative colitis can cause temporary greying. In addition, shock or trauma can cause a person's hair to "turn grey overnight." This is also a temporary condition, caused by pigmented hair falling out.

Gary Simpson, Woodleigh School, Victoria, Australia

Further Useful Resources

Chemical Misconceptions: Prevention, Diagnosis, and Cure

http://www.chemsoc.org/networks/learnnet/miscon2.htm

Materials that identify student misconceptions in chemistry and provide strategies for addressing them.

The Essential Guide to Rocks

http://www.bbc.co.uk/education/rocks/index.shtml

Includes an animation and interactive timeline of 4600 million years of geological history, 10 virtual walks around Great Britain, ways to explore geology in your own home or locality, and many practical activities.

The Museum of Unworkable Devices

http://www.lhup.edu/~dsimanek/museum/unwork.htm

A celebration of fascinating devices that do not work. Challenge yourself to explain why this is the case, and then read the explanations provided.

Severe Acute Respiratory Syndrome (SARS)

http://www.cdc.gov/ncidod/sars/

A site, provided by the Centers for Disease Control and Prevention (CDC), that contains content ranging from information for the general public to specifics about coronaviruses, the cause of the disease. Includes prevention, travel advice, diagnosis, and quarantine.

Our World of Water

http://www.iwapublishing.com

The contents of this new children's book, by Joan Stephenson, include *The Water Cycle*, *Water in Ancient Times*, *Britain After the Romans*, *Water in the 20th and 21st Centuries*, *Water Around the World*, *Why is it so Important to Drink Water*, *Questions and Answers*, a *Glossary*, a *Wordsearch*, and instructions for how to build a water clock.

Rough Ascension and Other Poems of Science

http://www.celticcatpublishing.com

The poems in this collection by Arthur J. Stewart, ecologist, senior scientist, essayist, and poet, are divided into four sections: *Technological Progress*, *Digging Out*, *Rough Ascension*, and *Dissecting Time*. The book also contains two essays: *On the Need for Poetry by Scientists* and *Contrary Ecologist*.

Style Guide

http://www.economist.com/library/styleGuide/

A style guide for good writing from *The Economist* magazine. Includes abbreviations, accents, capitals, figures, hyphens, italics, singular or plural, punctuation, spelling, and titles, as well as some common solecisms and dos and don'ts.

The Longevity Game

http://www.nmfn.com/tn/learnctr--lifeevents--longevity

This game, produced by an American insurance company, allows you to assess the impact of relevant factors, which include blood pressure, stress, wearing a seatbelt, and drinking, on your life expectancy. While existing medical conditions are not accounted for, you can change your answers and see the impact of lifestyle changes on your life expectancy.

Self-Test Exercises in Introductory Geology

http://www.indiana.edu/~scstest/jd/intro.html

A series of interactive, web-based, multimedia exercises. Most are computer graded.

ACD/ChemSketch 5.0 Freeware

http://www.acdlabs.com/download/chemsk.html

A freeware program that may be used to construct chemical equations, molecular structures, and laboratory diagrams. Incorporates many advanced features, including the ability to show molecules as coloured objects rotating in space.

Humour

The lecturer needed to address the effect of detergent on the immiscibility of oil with water. He didn't want to simply tell them, though--a demonstration was called for. So he prepared a real duck and small pond of water for the day. The students arrived and were suitably impressed by the sight of the duck paddling around in the pond. The lecturer poured detergent onto the duck's feathers, and the duck continued to swim. More detergent, and more swimming. Even more detergent, and the duck was still swimming. No amount of detergent was going to stop this duck.

The students left, delighted by the duck's performance, if little else. And then it dawned! The water level in the pond was so low that the duck had never been swimming in the first place. It had just spent the entire lecture walking around the pond. True story.

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