Volume 4, Number 1 – 2005

THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

As the well-known theorem goes, "There are many incorrect ways of getting the right answer," and the following exercise is a great way to respond to the student who demands credit for a correct answer, even though his working shows no merit. Ask him how much credit he thinks should be given for the following solution to the task: Simplify $\frac{16}{64}$. *Solution:* Cancelling the *6* in the top line (the numerator) with the *6* in the bottom line (the denominator) gives ¼ (the right answer!).

Science Story

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

Nuclear Testing and Baby Teeth

During the late 1950's and early 1960's, nuclear testing in the USA was conducted above ground. While there was a lack of awareness about the dangers of radioactive fallout, there was concern about radiation levels and possible implications for health. A research project, set up at Washington University, St. Louis, aimed to investigate the matter by analyzing children's teeth sent in by local residents.

The researchers studied levels of strontium-90 (^{90}Sr), a dangerous byproduct of nuclear fission. Being chemically very similar to calcium (same group in the periodic table), ^{90}Sr in contaminated grass eaten by cows, say, could be ingested by growing children drinking the milk and find its way into their bones and teeth.

The results showed a dramatic increase in ^{90}Sr in the body during the years of above-ground testing, and this was supported by similar studies in other parts of the country. The conclusions of this study, together with other evidence, caused the USA to sign a 1963 international treaty banning above-ground nuclear testing. Similar tooth analysis research is being carried out today, aiming to determine if living near a nuclear power station leads to increased levels of ^{90}Sr in the body.

Source: Becker, B. (2003). Questions from the classroom. *ChemMatters*, *21*(4), 2.

Making Real Virtual Labs

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Abstract

Francis Bacon began defining scientific methodology in the early 17th century, and secondary school science classes began to implement science labs in the mid-19th century. By the early 20th century, leading educators were suggesting that science labs be used to develop scientific thinking habits in young students, and at the beginning of the 21st century, educators are still seeking to achieve this goal. Technology offers one path to success. Yet, the numerous "virtual labs" available offer little, or no, practice in scientific thinking. This paper presents a new approach to using technology, one that uses real experiments and provides students with the opportunity to think like scientists.

Introduction

Engaging kindergarten to Year 12 students in scientific processes is central to science education reform (Handelsman et al., 2004; Trautman, Avery, Krasny, & Cunningham, 2002). Yet, teachers at all levels have failed to provide students with lab experiences that truly incorporate scientific methodologies (Handelsman et al., 2004; Harlen, n.d.; Sagan, 1996; Trautman et al., 2002; Westaway, 1919).

Technology can play a key role in improving science teaching (Bruder, 1993; Friedrichsen, Dana, Zembal-Saul, Munford, & Tsur, 2001; Woodrow, Mayer-Smith, & Pedretti, 2000), and this paper introduces one technology-based approach to provide lab experiences with scientific processes built in. Science laboratories will be presented in historical context to identify current classroom needs. The use of computers as a means to present virtual demonstrations and laboratories will be reviewed as a potential solution, with reference to one particular approach, the *Smart Science* (ParaComp, 2004) education system, developed by the authors and their associates.

Early Science Laboratories in Education

Frederick William Westaway was a noted writer who authored 16 books on science and scientific method. Edgar Jenkins (2002) described him as "a notable scholar, with an unusual breadth of knowledge" (p. 93). In 1912, he authored *Scientific Method: Its Philosophy and Practice*, and new editions were issued in 1919, 1924, 1931, and 1937. In 1929, Westaway published *Science Teaching: What it Was, What it Is, What Might Be*. According to Jenkins, this book "was well-received by the reviewers and it became a staple of initial training courses for graduate science teachers" (p. 93).

According to Westaway (1919), science classes in the 19th century left much to be desired. "Thirty or forty years ago, such practical Science as was attempted in the few school laboratories then existing was of no appreciable value; the teaching was confined mainly to the lecture-room" (p. 369). He suggested that scientific method should be used in the teaching of science.

> Science has one enormous advantage over all other subjects. All facts can be obtained at first hand, and without resort to authority. The learner is thus put in the position of being able to reason with an entirely unprejudiced mind. It is this possibility of *self-elimination in forming*

> *a judgment* that must be regarded as the greatest possible specific result of science teaching. (p. 6)
>
> Pursue this discipline carefully and conscientiously, and we may make sure that, however scanty may be the measure of information which we have poured into the boy's mind, we have created an intellectual habit of priceless value in practical life. (p. 49)
>
> Let the Science teacher, then, be on his guard against dogmatizing. His chief business is to teach, not to lecture; to guide, not to tell. To lead his scholars to the pursuit and investigation of Truth should be his highest aim. (p. 50)

Westaway (1919) also reported the failure of teachers to provide lab experiences that incorporate scientific method:

> The man who is working for a science degree usually takes on trust nearly all he is told in the lecture theatre . . . How can such a teacher be expected to engage in successful heuristic teaching when he himself has never in his life undertaken the simplest piece of research work? His outlook is altogether wrong. He sets to work in school exactly as he was taught to set to work at college. How, indeed, can he be expected to do otherwise? He is entirely unaware of the specific functions that science teaching is intended to perform. He teaches Science just as he would teach History. He considers it his sole duty merely to pass on information. The spirit of his work is, 'Believe, and ask no questions.' (pp. 4-5)

Modern Science Laboratories in Education

In the late 1900s, the National Science Teachers' Association (NSTA) in the United States agreed that laboratory experience is "so integral to the nature of science that it must be included in every science program for every student" (NSTA, cited in NSTA, 2005, ¶ 1). They give their rationale as follows: "The inquisitive spirit of science is assimilated by students who participate in meaningful laboratory activities. The laboratory is a vital environment in which science is experienced" (¶ 1). "Problem-solving abilities are refined in the context of laboratory inquiry. Laboratory activities develop a wide variety of investigative, organizational, creative, and communicative skills. The laboratory provides an optimal setting for motivating students while they experience what science is" (¶ 2). Indeed, the recommendations of the NSTA are that, in middle schools (ages 11-13), "a minimum of 80 percent of the science instruction time should be spent on laboratory-related experience" (¶ 16).

Others have echoed the concept that learning scientific methodologies has great value. Carl Sagan (1996) argues for the value in everyday life:

> In the course of their training, scientists are equipped with a baloney detection kit. The kit is brought out as a matter of course whenever new ideas are offered for consideration. If the new idea survives examination by the tools in our kit, we grant it warm, although tentative, acceptance. If you're so inclined, if you don't want to buy baloney even when it's reassuring to do so, there are precautions that can be taken; there's a tried-and-true, consumer-tested method. (pp. 209-210)

Knuth, Jones, and Baxendale (1991) state: "A major aim of science education must be to help students to become good at 'scientific thought'" (¶ 5), and makes essentially the same argument as Sagan. This is not a new argument. Westaway (1919) also spoke to this point 80 years earlier:

> Children who are taught to think for themselves, to sift evidence, to get at all essential facts, are likely, later on, to prove formidable opponents to illogical systems . . . . The mass of mankind will never have any ardent zeal for seeing things as they are; very inadequate ideas will always satisfy them. (p. 48)

Simon Newcomb, a highly revered and decorated 19th century astronomer, writer, and teacher, who spent much of his life advocating the use of scientific method throughout society, "was convinced that the method, as opposed to the content, of science could and should be taught in the nation's schools, thus creating a true program of liberal education" (Moyer, 1992, p. 26). John Dewey, "who dominated educational thought in the United States during much of the first half of the 20th century, later gave wide currency to this notion, continually calling for the teaching of scientific method in its largest sense" (Moyer, 1992, p. 26).

As in the early 1900s, many teachers today provide laboratory experiences that fail to result in the benefits touted by the NSTA. For example, Carl Sagan (1996) described exactly this failure of his own high school teachers:

> There were rote memorization about the Periodic Table of the Elements, levers, and inclined planes, green plant photosynthesis, and the difference between anthracite and bituminous coal. But there was no soaring sense of wonder, no hint of an evolutionary perspective, and nothing about mistaken ideas that everybody had once believed. In high school laboratory courses there was an answer we were supposed to get. We were marked off if we didn't get it. There was no encouragement to pursue our own interests or hunches or conceptual mistakes. (p. xiii)

Carl Sagan's experience illustrates the illusion of science laboratories that expose students to a laboratory setting and some techniques, without incorporating scientific processes. Bower (2004) restates this concept more recently:

> Even programs that combine "science excitement lectures" with later "hands-on" experiments usually reinforce unproductive attitudes. For example, in most cases, the "hands-on" activities are do-it-yourself "cook-book" demonstrations . . . These are usually primarily intended to assure that everyone gets the same, right answer. (¶ 6)

The National Science Education Standards of the United States state: "Conducting hands-on science activities does not guarantee inquiry" (National Research Council, 1996, p. 23). Handelsman et al. (2004) and Trautman et al. (2002), for example, suggest reasons for the failure of teachers to implement laboratory experiences that use inquiry and scientific methodologies. Among these are inadequate exposure to science research, fear that experiments will fail unless carefully scripted, belief in efficacy of their current techniques, unfamiliarity with technology, and a need by teachers to know all of the answers. As a result, too many teachers send their students into the laboratory simply to replicate or verify that which they have already explained and illustrated in the classroom; they send them to an unexciting and probably non-educational experience.

Virtual Science Laboratories

A virtual laboratory (virtual lab) is simply a laboratory experience without the actual laboratory, and teachers have provided paper-and-pencil virtual labs for a long time (e.g., Muskopf, n.d.). In a paper and pencil lab, the data has already been collected. The student analyzes the data and draws conclusions, thus engaging in a restricted number of scientific processes only. This type of virtual lab is more accurately described as a virtual lab report.

For several years now, software vendors have provided computer-based virtual labs. These almost always show simulations of experiments based on computer algorithms, which are often simple equations. Typically, the student selects which simulation to watch, much like picking a scene to watch on a DVD. The scene may be animated, and would most likely include a graph and data table. Like the paper-and-pencil lab, the data are predefined, this time by the algorithm on which the simulation is based. The student watches the scene and might draw conclusions about the simulation, but does not engage in scientific process. This variety of virtual lab is more accurately described a virtual demonstration (demo) or simulated lab.

In the remainder of this paper, we discuss how technology can be used to create virtual labs that closely resemble real labs, and that require students to engage in scientific processes more broadly. We call this variety of virtual lab a real virtual lab.

Real Virtual Labs

We, along with our collaborators, sought a way to use computer technology to create real virtual labs, without the limitations of software-generated virtual demos. Further, we determined that real virtual labs must require students to engage in a broad range of scientific methodologies, thereby avoiding the failure of traditional labs to provide this experience.

Real virtual labs must include real experiments. The central activity in any lab is running experiments and collecting data. For this to succeed, a real virtual lab must include real experiments from which students can collect data that are not predefined in any way. "[Bacon, who may rightly be termed the father of scientific methodology] insisted on the importance of experiment, as well as on observation. He insisted on the necessity of collecting facts. He urged that authority must be disregarded" (Westaway, 1919, p. 94).

Compare this with what the student is investigating when performing a simulated lab. Science is understanding the world around us. To understand it, you must explore it. Yet, with a simulation you are exploring an algorithm, an abstraction that attempts to model the real world. Any discovery you may make is a discovery about the algorithm, not about the world.

Rather than using algorithms to create artificial data, one needs to use real experiments. Once this decision was made, many new issues arose. In a virtual setting, students will not have direct access to equipment. Our solution was to make the computer appear to have access to a remote robotic laboratory that accepts instructions and returns a video of the experiment. Students can view this video repeatedly and stop it at individual frames to collect data. Appropriate software converts the data collection mouse clicks into real units and displays them both in a data table and on a graph, and the next section contains an example.

Whatever the mechanism, students must believe that they are working with real world phenomena, so they know they're exploring the real world. Because the experiment is real, students will accept taking data point by point. Note the contrast with a simulation, where point-by-point data collection from an equation (or algorithm) makes no sense, because the numbers are already there.

Real virtual labs must incorporate scientific methodologies. The primary goal in any lab is to engage in scientific processes. To achieve this goal, a real virtual lab needs to control the steps the students must perform in order to complete the lab. For example, given a particular question being investigated, students might be required to test one or more predictions--predictions they have made themselves and/or which have been provided by the technology. In order to complete the lab, the students might be required to perform these steps:

1. Write (or read) one or more predictions.
2. Select an experiment to test a prediction, and run it.
3. View the experiment and collect data interactively.
4. Analyze the data (including comparing graphs).
5. Evaluate the prediction (i.e., accept it, refute it, or revise it).
6. Repeat the above steps as necessary.

For students to engage in the experimental design phase, the technology must provide a large number of experiments, from which students may choose, to evaluate their prediction(s).

An Example of a **Smart Science** *Lab*

An example from our suite of about 90 labs will help explain how *Smart Science* software employs technology to create an authentic laboratory learning experience. All labs begin with an introductory exercise that includes a brief background, goals and objectives, and a pre-lab assessment. In the Vertical Projectile Motion lab, students are invited to investigate how the vertical acceleration of a relatively dense projectile (i.e., the effects of air resistance can be ignored) changes with time.

The experiments were recorded on a beach, using three projectiles of different mass: a bocce ball (colorful wooden sphere used in the Italian lawn game of bocce, 9.5 cm in diameter, mass 542 g), a bocce ball modified by hollowing it out (376 g), and a third bocce ball that had been drilled and had lead added (868 g). The projectiles were propelled by an elastic device stretched between volleyball poles, with a prepared jig allowing the stretch distance and launch angle to be set accurately.

First, students write a prediction, or view those supplied (Figure 1). We note the call to better distinguish between a prediction and a hypothesis (e.g., Eastwell, 2002), and that what is presently called a hypothesis in the software (as exemplified in Figure 1) would be considered by some others to be better termed a prediction (the term we have chosen to adopt in-text).

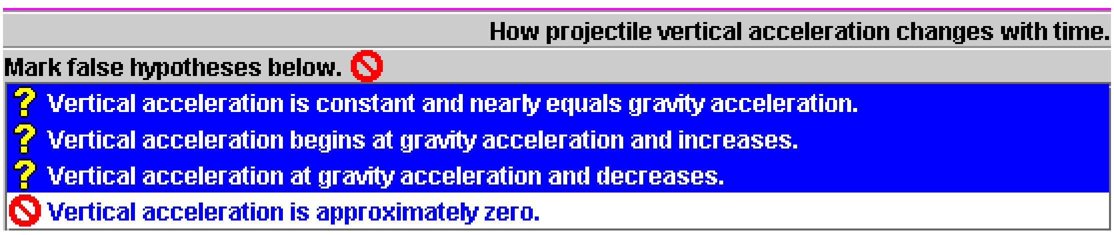

Figure 1. An example of pre-written predictions.

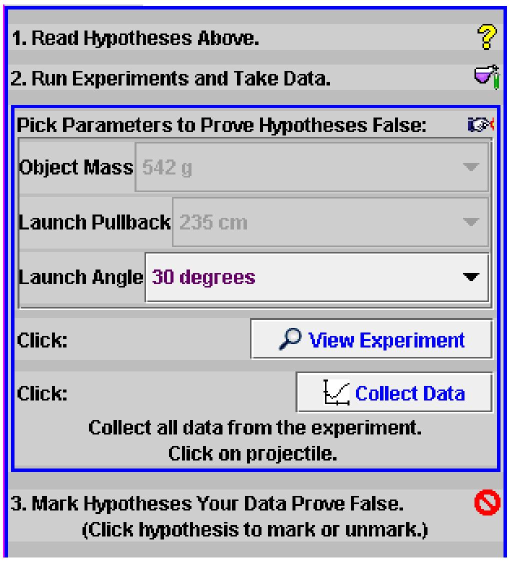

Figure 2. Experiment operation panel.

Next, by choosing parameters (Figure 2), they select the experiment to run. In this lab, students can vary the mass of the projectile and its launch angle--the pullback distance remains constant at 235 cm. The experiment operation panel of Figure 2 also instructs students how to proceed with the investigation. (In the program, Figures 1, 2, and 4 appear on the same screen.)

They view the experiment (Figure 3) one or more times. Then, data are collected point by point. As each video frame is displayed, a student very carefully clicks on the projectile. A red X appears at the click point (Figure 3), a data pair appears in the data table (Figure 4), and a black X appears on the graph of vertical velocity against time (Figure 4). Students can click anywhere in a given frame, or even skip frames, so no 2 students will have exactly the same data. Sloppy or incomplete data collection will result in poorer results, which are very evident in the lab report that is submitted. If a student decides that the data are poor, or the instructor tells the student to redo one or more experiments, the experiments are readily repeated. Only the latest data for each experiment is stored in the database.

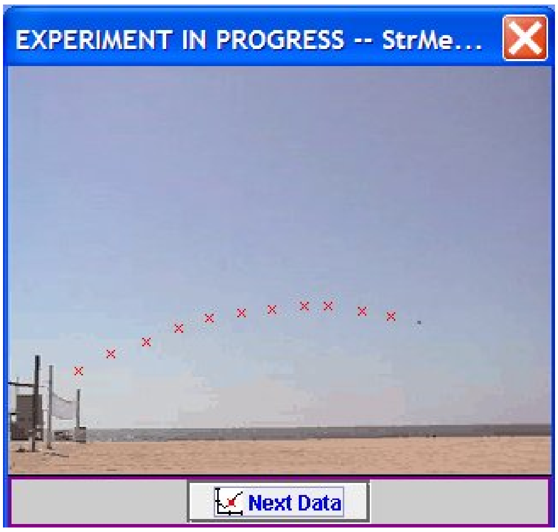

Figure 3. Data capture for Vertical Projectile Motion lab.

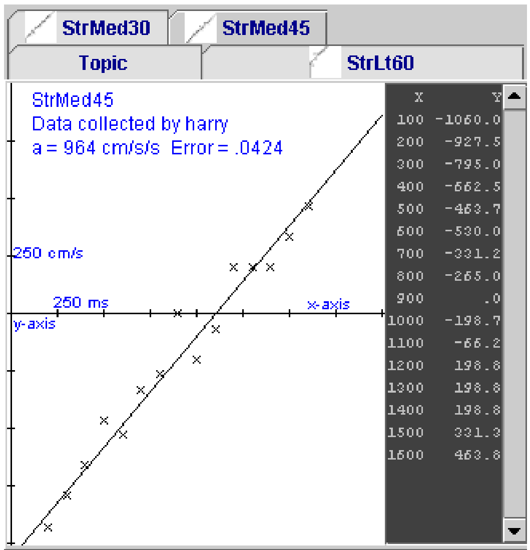

Figure 4. Data table and graph for Vertical Projectile Motion lab.

In this lab, least squares is used to fit a straight line to the data, and the vertical acceleration (given by the slope of the line) is calculated (Figure 4). Provision could be made for more advanced students to select the graphing parameters, but this feature has not yet been incorporated into the *Smart Science* system. In Figure 4, you can also see tabs for other experiments in this lab done by this group of students, each with an icon that displays the student data. Students can readily view any “page” in this electronic lab notebook by clicking on one of these tabs.

Students continue to choose, and perform, experiments until they are satisfied that they have reached an appropriate conclusion about their prediction(s), they can gain no further understanding from doing more experiments, or they run out of experiments. With *Smart Science* labs in general, it is beneficial to even provide some experiments where the parameters are such that the experiment is of no use at all in answering the question being addressed, as this can further promote students' understanding of experimental design. Note that, in Figure 1, these students had reached a point in their investigation where they had already eliminated the fourth prediction. In this lab, students should come to understand that the vertical acceleration is constant and nearly equal to acceleration due to gravity, regardless of the mass of the projectile or launch angle.

Following experimentation, students engage in a post-lab assessment, review the goals and objectives of the activity, and use the built-in provisions to write an electronic lab report. For each experiment, all three types of data display (i.e., points in context, data table, and graph) are replicated in the lab report. The written portion of the lab report comprises four parts (each with guidance on what to write): Introduction, Procedure, Results, and Conclusions.

Some Specifics of **Smart Science** *Lab Technology*

In the above example, differences in vertical positions (converted to speed) were plotted against frame number (converted to time). However, many other options are available for converting mouse clicks into data. In other projectile motion labs, the x-position is plotted against time, the y-position is plotted against the x-position, and the kinetic energy is plotted against potential energy. In another lab, vertical position (converted to force on a spring scale) is plotted against frame number (converted to mass).

Labs like Density, Gas Volume-Temperature, Erosion, Enzymes, and Liquid Volume-Temperature will, of course, not track an object, but they still measure position. The Acid-Base Titration, Phases of the Moon, Yeast Metabolism, Voltage and Brightness, and other labs measure things other than position. Nevertheless, the videos have always been arranged so that the mouse cursor is the data collection device.

The basic engine used to deliver *Smart Science* labs consists of a Java applet automatically loaded on the student computer and Java servlets on the server. Java makes the entire package platform independent. The basic configuration for a given lab is provided by an XML file, which is compiled and stored on the server. The remainder of the information is stored in HTML files.

Benefits and Limitations of Real Virtual Labs

Real virtual labs have some obvious benefits over traditional labs, including lower cost, greater safety, less time to complete, and smaller space requirements. Other benefits provided by the computer technology include student guidance, immediate support, tracking, and accountability.

Student guidance. Guiding a group of students through the inquiry process, while at the same time allowing sufficient freedom for discovery, is a truly difficult task.

> Young scholars cannot be expected to find out everything for themselves, but the facts must always be so presented to them that the process by which results are obtained is made sufficiently clear as well as the methods by which any conclusions based on facts are deduced. (Armstrong, cited in Westaway, 1919, p. 370)

With today's large class sizes, the task becomes insurmountable. The technological solution is to build the guidance into the software, to provide boundaries to exploration that gently channel the student toward the goals of the instructional unit while allowing real science to take place. By choosing the experiments and support materials, the lab designer limits the range of exploration to something manageable, while still allowing for inquiry, exploration, and discovery.

Hypothesis-based exploration. Writing (or reading) predictions, with the goal of evaluating them by experiment, helps to channel students' investigations and constitutes the core of a scientific approach. Students lacking sufficient sophistication to write their own predictions are presented with an already-written set, and they work to eliminate all but one through experiment.

Once a single prediction remains, students should use further experiments to confirm that the conclusion remains valid. The exploration is not completely open-ended, and students also do not simply do all of the experiments and then see what they can figure out from them. Of course, they have to defend their conclusion(s) in their lab reports.

Modularity and customizability. The choice of a computer-based activity automatically provides the possibility for substantive modifications to meet individual situations. Through interactions with many different schools and teachers over several years, we have arrived at a list of potential customizations. The system was created to be modular and very flexible. Some examples of custom changes are listed here. They're truly limited only by imagination and programming skill.

- Replace or eliminate assessment questions.
- Change the predictions given, or allow students to write their own.
- Replace support materials like vocabulary or background information.
- Allow students to retake assessments until a minimum grade is attained.
- Provide lower or higher reading and mathematical levels.
- Support locales by allowing for different languages in written material.

Other benefits of a technology-based system. A learning system based on computer technology should provide much more than the presentation of material alone. Students interacting with computers to experiment and understand generate a generous flow of incidental data, which should be captured. In addition, the computer can provide a plethora of learning aids.

With all student data stored in a database, the computer system can generate a variety of useful reports, for teachers and administrators, in real time. The database approach also has benefits for students, who can review previous work and update it. Dynamic web pages present the student data in ways that increase understanding.

Because the students interact with a computer, they can be provided with help immediately. The system should also provide assistance in the form of vocabulary definitions, fully worked answers to all questions, and explanations of aspects of the lab such as apparatus, possible errors, and units. The system can also provide hints on how to solve assessment questions, and even sample worked questions. A computer-based lab system should aim to have students achieve mastery of the science concepts with minimal resort to the instructor. Teachers can also be provided with additional support, in the form of online information for each lab similar to that found in the Teacher's Edition of a textbook.

Limitations of real virtual labs. No learning system is perfect, and maximal learning is best achieved using a variety of approaches. We therefore encourage teachers to also include learning experiences other than virtual labs in their programs. Any completely computer-based learning approach must sacrifice the tactile and kinesthetic aspects of a traditional laboratory, and with it some learning opportunities. Students will not feel, taste, or smell the experimental materials. For example, feeling the resistance of large masses to efforts to move them promotes an understanding of mass and inertia. Tasting baking soda and vinegar can help to develop an understanding of acids and bases.

No matter how many experiments have been prerecorded for a lab, a situation may arise where students desire a parameter set that has not been included. Of course, feedback to the lab developer may result in the addition of more experiments--but not in time for present students.

Conclusion

The challenges of today's science classroom require new solutions. Technology provides one way to help science teachers overcome obstacles and improve the learning outcome. The biggest challenge lies in the laboratory, because quality lab experiences aren't being provided as often as they should be, and because the laboratory is where students have the opportunity for first-hand experience of the methods and thought processes of science. In the lab, they may emulate the activities of scientists.

Most technological substitutes for labs are really just computer-based demonstrations that miss the essential elements of science methodology. The alternative presented here uses real experiments, together with interactive data collection with built-in scientific processes, to ensure that the important features of the lab are not lost. In addition, the computer software provides a means to channel the students' activities, to measure their performance, and to support their learning.

While the use of real virtual labs can result in a loss of some aspects of a traditional lab, their proper use can often more than compensate for this loss. The *Smart Science* system briefly described here has been in development and testing for 7 years, and has been delivered to over 30,000 students during the last 2 years. Students, and most teachers, have found it easy to use, engaging, and a valuable aid to learning science.

Editor: The authors invite researchers interested in evaluating the *Smart Science* program to contact them.

References

Bower, J. M. (2004). *Scientists and science education reform: Myths, methods, and madness*. Retrieved January 3, 2005, from http://www.nas.edu/rise/backg2a.htm .

Bruder, I. (1993). Redefining technology and the new science literacy. *Electronic Learning*, *2*(6), 20-24.

Eastwell, P. H. (2002). The nature of science. *The Science Education Review*, *1*(2), 43-48.

Friedrichsen, P. M., Dana, T. M., Zembal-Saul, C., Munford, D., and Tsur, C. (2001). Learning to teach with technology model: Implementation in secondary science teacher education. *Journal of Computers in Mathematics and Science Teaching*, *20*, 377-394.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S., & Wood, W. (2004). Scientific teaching. *Science*, *304*, 521-522.

Harlen, W. (n.d.). *Understanding and teaching science*. Retrieved January 26, 2005, from http://www.scre.ac.uk/rie/nl57/NL57ArticleHarlen.html .

Jenkins, E. W. (2002). Who were they? F. W. Westaway (1864-1946). *School Science Review*, *83*(302), 91-94.

Knuth, R. A., Jones, B. F., & Baxendale, S. (1991). *What does research say about science?* Retrieved January 3, 2005, from http://www.ncrel.org/sdrs/areas/stw_esys/3science.htm .

Moyer, A. E. (1992). *A scientist's voice in American culture*. Berkeley: University of California Press.
Muskopf, S. (n.d.). *The Biology Corner*. Retrieved January 7, 2005, from http://www.biologycorner.com/worksheets/fossilrecord.html .
National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
NSTA. (2005). *NSTA position statement*. Retrieved January 3, 2005, from http://www.nsta.org/159&psid=16 .
ParaComp. (2004). *Smart Science*. Retrieved December 8, 2004, from http://smartscience.net .
Sagan, C. (1996). *The demon-haunted world: Science as a candle in the dark.* New York: Random House.
Trautman, N., Avery, L., Krasny, M., & Cunningham, C. (2002). *University science students as facilitators of high school inquiry-based learning*. Retrieved January 26, 2002, from http://ei.cornell.edu/pubs/CEIRP_NARST_02.pdf.
Westaway, F. W. (1919). *Scientific method: Its philosophy and practice*. London: Blackie & Son.
Woodrow, J. E. J., Mayer-Smith, J. A., & Pedretti, E. G. (2000). Assessing technology-assisted instruction: A case study in secondary science. *Journal of Educational Computing Research*, *23*(1), 15-39.

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 *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.

Land Covering the Earth's Surface

Needed. Inflatable globe of the Earth.

Invitation. Ask students to guess, or predict, what fraction (or percentage) of the surface of the Earth is covered by land? (This is best done without students being able to see a globe, or map, of the Earth.) Invite them to devise a way to find out.

Exploration. Suggestions might quite appropriately include finding the answer in a book, or on the World Wide Web, and asking someone who might know. Then, hold up the inflatable globe, and ask students to propose a way of using it to find out. Again, various responses are likely--for example, counting and comparing squares on the globe, or cutting the water and land pieces out and weighing them.

Then suggest that the globe might be tossed in the air, perhaps with a little rotation, caught, the position of the catcher's right index finger, say, noted as being on either water or land, and that this procedure be repeated numerous times. A different student might catch the globe each time.

Concept introduction. Some students, if not many (depending on their age) will be surprised to find that the catchers' fingers land on water more often than on land. Ask students to calculate the fraction (or percentage) of *land* results after 10 trials, say, 20 trials, and so on. The more trials you have time for, the better, and the results should support the fact that land covers about 30% of the Earth's surface (or, for younger students, one fourth would probably suffice).

Adapted from: Crowther, D. T., & Cannon, J. (2004). Strategy makeover. *Science and Children*, *42*(1), 42-44.

Student Activity

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

The World's Simplest Motor?

Needed. A cylindrical, neodymium (NdFeB) magnet, nail, D-size cell, and length of copper (or other nonferromagnetic) wire.

I (the Editor) have seen claims to "the world's simplest motor" before, but this one--called a homopolar motor-- may now take that title. Hold the nail vertical, head down. Allow a circular face of the magnet to "stick" to the bottom surface of the nail head. The nail becomes magnetized. Then hold a D-size cell, with axis vertical, above the nail and allow the tip of the nail to stick to the ferromagnetic bottom of the battery. Finally, hold one end of the wire to the top terminal of the battery, touch the other end to the side of the magnet, and watch the magnet spin.

More advanced students could be invited to first predict the direction in which their motor will spin. They would need to identify the poles on their cylindrical magnet, and then use the right-hand palm rule, or equivalent.

Source: Chiaverina, C. (2004). The simplest motor? *The Physics Teacher*, *42*, 553.

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.

On Your Own

By: Gary Simpson, Woodleigh School, Victoria, Australia, on behalf of Elli,
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It was last period on Thursday, 4 weeks into my teaching round. Tuesday's science lesson with the Year 8's went well, so I had planned some fun activities and demonstrations about enzymes and how they work for them to do this lesson. I was fully aware of the “Period 6” syndrome, which is why I wanted the lesson to be hands-on, with some notes to begin with.

My supervisor had informed me that he would not be present that lesson, and asked if I would like to take the class with a substitute teacher, or if I would prefer to leave some work for them to do and observe the class. I decided that since they had been so good on Tuesday, I would take the class as planned, as I wanted to see how I would cope on my own. I expected them to play-up a little and test the water, but I was in for a very rude shock.

Trinity (pseudonyms are used throughout), the substitute teacher assigned to take the “extra,” had never had a student teacher before. She was new to the school, and had come over from Ireland for the year. We walked into the room, and I let the students in. They were quite noisy, but I thought they would calm down when I called the roll. This was my first mistake: I didn’t call the roll.

As I was getting myself organized at the front of the room (I had brought play-dough, bread, and a gelatin demonstration with me), Trinity began to take the roll before I had the chance to do so. My first thought was: “Hey, that’s my job,” but I didn’t know what to say to Trinity in front of the class--so I let it go.

The class didn’t know Trinity, and they therefore didn’t know her boundaries or what she expected of them. They were noisier than they had ever been with me. They ignored Trinity, and I actually wanted to step in and help her by telling them off, but I felt I couldn’t. She was the “experienced” teacher, I wasn’t, and I did not know what she’d think if I stepped in. I didn’t want to tread on anyone’s toes.

Trinity tried to get some control of the class, but couldn’t, and eventually finished the roll 10 minutes later. Already, I could see big problems. My time was being gradually eroded away from me. I was appalled with their behaviour, and after roll call, I let them know what I thought. I did not harp on it too much as I didn’t want to continue the lesson on the wrong foot. I moved on to the first activity.

Being the last period for the day, I had planned to get them taking some notes from their books. We read a paragraph on enzymes, and I asked them to pick out the main points, which were then written onto the board. They were a little better during this time, but they were not angels, by any stretch of the imagination. The notes lead into the activity of eating bread, discovering how the enzymes in saliva turn starch (found in the bread) into sugar. I had learnt from my Year 11’s not to hand out large pieces of bread--it had ended up in some very odd places in the room. The activity did not generate the discussion I thought it would, and most students said they couldn’t taste it turning into sugar.

I had to stop what I was doing after this activity, as the students were just getting out of hand. They were testing my boundaries. If my supervisor (who happened to be their coordinator as well) was in the room, they would have been in a lot of trouble! I was being too lenient, so I told them that their behaviour was disgusting, and if it continued I was letting their teacher know. Some students (the girls) got a little worried at this and settled down a little, but it did not last for long.

I decided to move on with the gelatin demonstration. It was designed to show the enzymes in the pineapple breaking down the protein in the gelatin. I had left it for a few days and an imprint of the pineapple piece was left on the gelatin. Knowing what kids are like with fingers and jelly, I walked around the classroom holding the gelatin at arms length away from them to give them a better look. Even still, one of the boys up the back of the room couldn't resist poking his pen into the gelatin.

One or 2 students were interested in the gelatin model, and some great thinking questions came out of this. However, the behaviour of the rest of the class spoiled it. It was impossible to hold a discussion with the class if only 4 students were participating and the rest were so noisy I could not hear myself speak.

Again, I had to stop the class and wait for silence. I continued to wait, and as they sat in silence, it gradually became a little uncomfortable. I did this deliberately. More time was slipping away from me. I threatened them I would not run the play-dough activity and again spoke quietly about their behaviour. I made a point not to yell at them as I felt that this would not accomplish much.

I started to explain the play-dough activity. They were to make a model of an enzyme that used the lock and key mechanism, although I did not refer to it as such. I had a model I had made with the play-dough prior to the lesson and used this to show them what an enzyme did. During my explanation, they were again noisy, and I knew that if I handed out the play-dough, it would end up on the opposite side of the room.

So, I carried out my threat--we would not do the play-dough activity, and I packed it up. I had spent quite a long time making the play-dough the night before, and was disappointed I could not run this activity. They were a little surprised I carried through with the threat. They were way too unsettled and I was unimpressed with their behaviour, knowing what they were capable of. As a consequence I set them quite a few questions from their textbook. Brett, a noisy student up the back, pointed out to me that there were only 5 minutes left of the class. I was a little shocked, and wondered where the time had gone. It was pointless to get them to start the questions, but I had to keep going as I could not go back on my word. Sure enough, 5 minutes later, the bell went, and I sent them all home, glad in a way to be rid of them, but disappointed at their behaviour all the same.

In retrospect, this lesson was doomed from the very beginning. To start with, instead of letting the students wander into the classroom, I should have lined them up outside the room, quieting them down before they entered the room. However, the science rooms are always noisy places, as they have hard floors and no carpet to absorb the noise. I should then have stopped Trinity marking the roll. Does it matter that I am a student teacher? It shouldn't. This was "my" class. If I had taken the roll straight away, the students may not have necessarily been confronted with the absence of my supervisor. They may not have noticed Trinity as much if things ran to the routine they were used to with me. It certainly was not the time of day to change routine.

During the lesson, I stopped continuously, loosing any thread I may have had of interest for the students. What I should have done was tell them off as individuals, moving students, until they began to settle down. If I continued on at a faster pace, they would have had no choice but to pay attention. Whilst I kept stopping, they did not need to "tune-in."

Realizing they were not in a mood for discussion, I should have abandoned the thought of discussing what was happening with the demonstrations and activities, and possibly got them writing some notes of their own about what they thought was happening. In this way, I could initiate some silence whilst they were writing and could pick individuals out for their answers, forcing them to work.

My boundaries were not clear to the students. They were unsure of what I would do about their behaviour, and were pushing to see how far they could go with me. I really should have clamped down on them from the start, setting a rather strict boundary once I realised what they were trying to achieve. They wanted to see me crack. Fortunately for me, I did not, and held up very well the entire lesson. This was in my favor.

Threats certainly need to be carried through. However, I think my threat and punishment came far too late for this class. I should have jumped on them early, as they are a notoriously bad class, and I know several teachers have a lot of trouble with them--far more than what I had. I did not leave them enough time to start the questions I had set.

Last period in the day is always a difficult one, especially in a noisy science classroom. In order to keep the students interested in the topic, I should have kept them moving, settling them down at first with some quite work--questions out of the book, silent reading, summarizing the section on enzymes, or just taking notes directly off the board, instead of discussing the important points from what we were reading. Then, after getting them settled, I needed to keep things moving and step on any bad behavior before it escalated to the rest of the class.

I certainly learned a lot about management issues by the end of the day, and feel confident I could run that lesson again with the class. We did end up doing the play-dough activity a few days later. In the meantime, I had spoken to them about their behavior and had placed the emphasis back on them. “Why was I unhappy about your behavior the other day? What do you think I should do next time your behavior is unacceptable?” The students came up with several solutions--one being to yell at them, and another to send them to a particular teacher they were scared of. We agreed that I would not yell at them, but if they did not behave I would send them to this particular teacher. They knew what they had done wrong that lesson, and were not scared to point out other things that I had thought were not all that bad! The class enjoyed the play-dough exercise, and was well behaved. No play-dough ended up around the room (due to our discussion of the consequences), and the exercise clarified some good questions they had about enzymes.

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 .

Plastic Bags

A few years before
Scientists weren’t sure

When plastic bags get swallowed by rainbow fish
Someone to help is what the animals wish

These days we use the Calico Bag
If you cut it up it looks like an old rag

To use a Calico bag is hygienic and cheap
Not to mention destroying the plastic heap

100 000 whales, seals, turtles, and birds die every year
Beautiful animals they are very dear

A total of 500 000 plastic bags are collected
This problem must be solved by politicians elected

Bags, lids, bottle tops are all found at sea
But the water should be plastic free

In four shopping trips a family accumulates 60 bags
No one wants to be called a dag

Please take this into consideration
While we have this problem
Please support this beautiful nation
Plastic bags--don’t use them

Suraya Nikwan
Australia

The Perfect Job

My mum’s a famous scientist,
My dad’s an engineer,
My big sister’s a chemist,
They all work with fancy gear.

They wanted me to follow in their footsteps,
To make my family proud,
But I wanted to be a pilot,
And soar through the clouds.

My dad then sat me down one night,
Trembling with a nervous fear,
He told me in a croaky voice:
“Son, it’s time for you to choose a career.”

“Why you could be a lawyer or perhaps a financier,
A school teacher, a preacher or a steward on a plane,
Why don’t you choose a job more challenging?
Which tests the things you can’t explain?”

“There’s chemistry, neurology,
Just two of many things,
If you’re looking for the perfect job,
That’s just what SCIENCE brings.”

"Even aviation,
The thing you most adore,
Includes so much science,
So much you can't ignore."

"Air resistance, uplift,
The things that make a plane fly,
Pressure at high altitude,
Without science, you would die."

"There is so much to wonder,
There is so much to learn,
How does the human body grow,
How does a fire burn?"

I'm now an aviation scientist,
The best that there can be,
And I believe that science,
Is the best thing that has happened to me.

Ryan Pickels, 12 years
Australia

Students' Alternative Conceptions

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

1. With vigorous exercise, does a person's depth of breathing (tidal volume) increase, remain unchanged, or decrease? Please explain.

Comment: Depth of breathing increases, but don't be surprised if many students opt for one of the other choices. A common misconception is that, with an increase in breathing rate, there isn't enough time to increase depth.

Source: Modell, H., Michael, J., & Wenderoth, M. P. (2005). Helping the learner to learn: The role of uncovering misconceptions. *The American Biology Teacher, 67*(1), 20-26.

2. Which gas contains the greater number of particles/molecules--1 litre of dry air or 1 litre of moist air (both at the same conditions)? Which is heavier? Please give your reasoning.

Comment: The correct answers are that both gases contain the same number of molecules, and that the dry air is heavier. Student misconceptions might include that water molecules are bigger, or heavier, than air particles, that the smallest particle of water is the drop, and that drops of water stick to the air molecules and make them heavier.

Source: Tóth, Z. (2004). Exploring students' ideas on particles. *Education in Chemistry, 41*, 10.

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

    (a) Ores are rocks containing metals.
    (b) Minerals and rocks are the same things.
    (c) The rock cycle is steady and continuous.
    (d) Weathering and erosion are the same.
    (e) Oil and natural gas come from dead sea creatures (i.e., fish and other large animals).
    (f) Metamorphism is the result of rocks being buried and heated.
    (g) A rock containing fossils must be a sedimentary rock.
    (h) Sedimentary rocks are formed by compression from the materials lying above.

Comment: All of the above are false. Most significant, though, is the fact that all were found in science textbooks! To be an ore, a rock or mineral deposit must be sufficiently rich as to be financially viable to exploit. Some rock changes are steady, but the metamorphism, igneous activity, and uplift related to plate collisions is sporadic, separated by long periods of geological time. Oil and gas come almost entirely from decayed plants (in the case of oil, microscopic plankton) and bacteria. Regional metamorphism requires the very high compression and heating associated with plate collision--burial alone is not sufficient. Low-grade metamorphic rocks can contain fossils, as the pressure and heat has not been sufficient to destroy them. The formation of most sedimentary rocks requires both compaction and cementation.

Source: King, C., Fleming, A., Kennett, P., & Thompson, D. (2003). Can you believe everything you read? What some science textbooks say about Earth Science. *Teaching Earth Sciences*, *28*(2), 8-13.

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

    (a) Given time, science can solve most societal problems.
    (b) Historically, technology preceded science.
    (c) Science comprises a system of beliefs.
    (d) Imagination is a key ingredient in the work of scientists.
    (e) Males are better at scientific thinking, so most scientists are men.
    (f) Scientists are totally objective in their work.
    (g) A hypothesis is an educated guess.
    (h) A theory becomes a law only after much scientific evidence has been found to support it.
    (i) Experiments are conducted to prove cause-and-effect relationships.
    (j) The accepted guide for conducting scientific research is the scientific method.
    (k) All scientific ideas are discovered, and tested, by controlled experiments.
    (l) Scientific explanations are tentative. They cannot be proved, but may be modified or disproved.

Comment: Statements b, d, and l are the only true ones. Science alone is insufficient to solve problems of, for example, a political or moral nature. Survival tools were made long before an understanding of them was developed. Science is based on empirical evidence from the natural world. Kekule's visualization of the molecular shape of benzene exemplifies how creative imagination has always played an important role in science. We have no evidence for men being inherently better at science than women. Being human, a scientist can easily resist evidence that contracts a point-of-view she favours. A prediction is an educated guess about an outcome, whereas a hypothesis is a possible explanation for a phenomenon. A law (a statement summarizing an observed regularity or patterns) is a different kind of knowledge to a theory (an explanation that has stood the test of time and in which we have much confidence). Evidence can support or refute a scientific understanding, but all scientific explanations must remain tentative--they can never be proven. There is no single scientific method. In addition to experimentation, scientists also use historical and observational methodologies.

Adapted from: Chiappetta, E. L., & Koballa, T. R., Jr. (2004). Quizzing students on the myths of science. *The Science Teacher*, *71*(9), 58-61.

Teaching Techniques

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

Write to Grandma

Hicks (2004) has found that asking students to write a "Letter to Grandma," explaining a topic such as voltage, series and parallel circuits, or simple harmonic motion, can be a remarkable way to monitor their understanding of physics concepts. Students are to assume that their grandmother is interested in what they are doing in school, but that she has very little science or math background. Everyday language is therefore required. This task might be set as homework in association with the study of the more difficult topics, and usually after students have had considerable practice solving quantitative problems on the topic.

Writing a letter to Grandma promotes deep understanding, and students cannot "hide" behind equations. The language used by students (e.g., encouraging Grandma to drink her milk using two straws side-by-side, as an aid to better understanding how parallel resistors can result in a greater rate of flow) can also be adopted by the teacher to communicate ideas.

Reference

Hicks, J. (2004). Letter to Grandma. *The Physics Teacher*, *42*, 508-509.

Science Autobiography

Having your students describe their previous science experiences at your school and, where applicable, a previous school(s) is a great way to get to know both them and what they have learned about science through their school years, and provides for a terrific read (Lock, 2004). Where a student cannot remember specifics for a particular year, invite them to at least give the teacher's name and say something complimentary about the teacher. Students may be critical, provided their criticism is constructive.

Reference

Lock, F. (2004). Getting to know our students. *The Physics Teacher*, *42*, 453.

Display of Student Artifacts

To make her classroom more interesting, Coffey (2004) invited her students to each bring in a science-related artifact for display. It needed to be accompanied by a written description, plus a paragraph (five sentences, or more) on its origin and interesting related facts.

Students earned extra credit for their effort, and the items quickly accumulated--seeds and nuts in bags tacked to the cork board, and shelves with fossils, animal skulls, buckeyes, acorns, petrified wood, a beehive, and the like. As the months passed, she encouraged items different to those already on display, and she grouped similar items. At times, students competed to see who could bring the most unusual artifact.

Incorporating an artifact into a lesson provided the option of having the student who supplied it give the class a brief history. After 3 years, the collection became a room on display, popular with particularly younger students in the school who visited.

Reference

Coffey, N. (2004). Collecting artifacts. *Science Scope*, *28*(2), 34-35.

Model Analysis of Lab Reports

To improve students' writing of lab reports, have them act like the teacher and mark a sample report. The sample report could be one devised by the teacher specifically for this purpose, a student report from a previous year (perhaps modified), or a combination of both. Armed with red pen, guidelines for writing a report, and the assessment rubric, students work individually, or in pairs, to identify strengths and weaknesses in the sample report, making notes on both the sample report and the rubric.

Then, for each section of the report in turn (each section could be displayed as an overhead):

- Determine the average student score, and range of scores.
- Elicit comments from students, and promote discussion, about strengths and weaknesses.
- See how many students' scores match the previously-assigned teacher's score for the section.

A similar analysis might also be performed for the overall scores awarded by students and teacher. Sitar (2004) has found that students love the process, engaging readily in energetic discussion.

Reference

Sitar, C. (2004). Successful lab reports through model analysis. *Science Scope*, *28*(2), 35-38.

Scanner Art and Links to Physics

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Abstract

A photocopier or scanner can be used to produce not only the standard motion graphs of physics, but a variety of other graphs that resemble gravitational and electrical fields. This article presents a starting point for exploring scanner graphics, which brings together investigation in art and design, physics, mathematics, and information technology.

Introduction

My initial aim in experimenting with photocopiers and scanners was to generate graphs for the study of motion (kinematics). It seemed that the scanning beam would provide a ready-made time base, the horizontal axis for displacement-time graphs (Figure 1). Taking the direction of scan as the positive direction of the X-axis, and moving a horizontal line drawn on an A3 sheet up and down at right-angles to the direction of scan, I could produce all the standard displacement-time graphs. These included curves for constant velocity and constant acceleration (both positive and negative), as well as simple harmonic motion. A scanner gives results with higher definition than a photocopier.

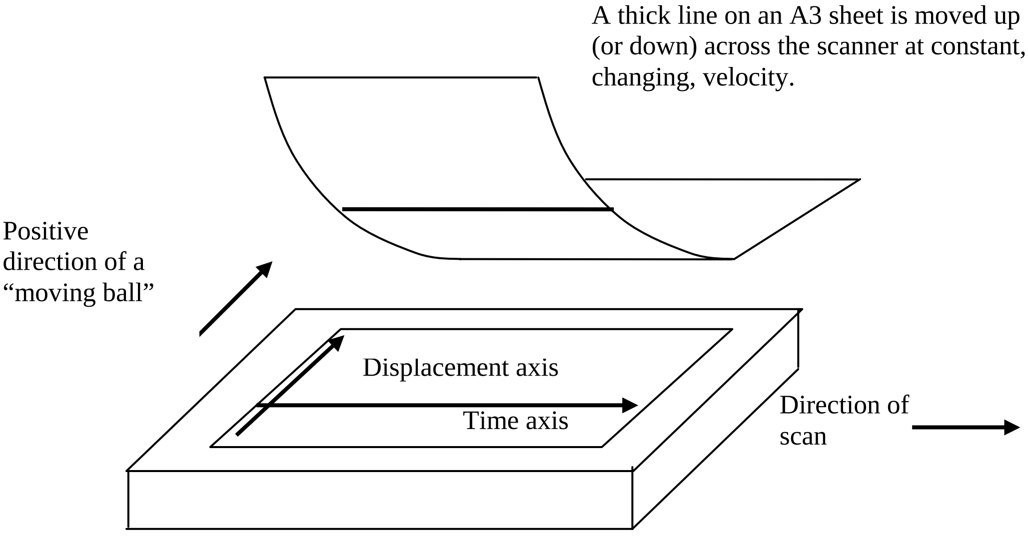


Figure 1. Scanner with lid removed. A "moving ball" is represented by an extended line. The "ball" is the point where the scanner crosses the drawn line at any instant.

Scanner Art

That may have been the end of my efforts, but out of curiosity I tried rotating the line about its center and, depending on the rate of rotation, obtained a series of interesting curves. Then, I tried rotating a pattern of intersecting lines, as follows. I drew a black-on-white wheel design (Figure 2, scan 1) that filled the width of an A4 sheet of light card. I taped an up-turned drawing pin to the centre of the scanner glass and centered the wheel face down on the pin, enabling me to rotate the wheel using one finger touching the periphery. The area outside the circle was masked in white, although this was not necessary. To make the other designs shown in Figure 2, I rotated the wheel anticlockwise at constant angular velocity, using progressively faster speeds for scans 2 through 6. The scanning direction was from top to bottom.

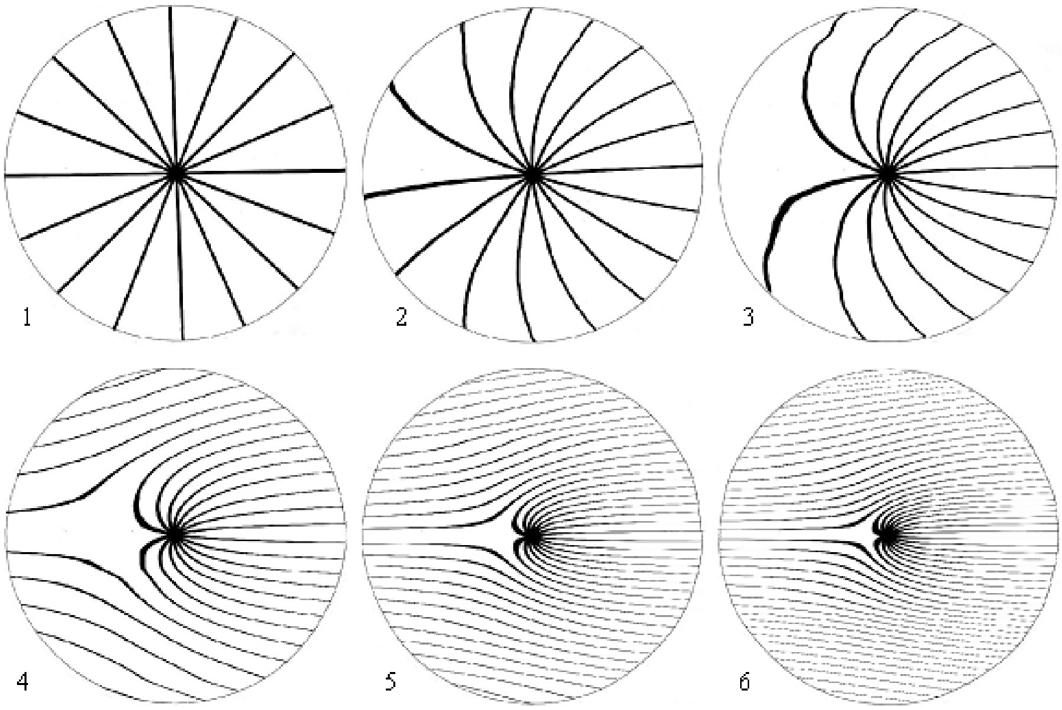


Figure 2. The results of scanning a spoked-wheel design, shown stationary in scan 1, and rotated with progressively greater angular velocities through scans 2 to 6. In scan 6, the wheel was rotated anticlockwise by finger almost three times during the period of completing the scan, and the scan passed from top to bottom.

It took an hour to make a more sophisticated wheel mechanism (Figure 3) that sat astride my scanner. A long screw served as a handle, and with a little practice it was possible to rotate the wheel with smooth constant velocity (or regular oscillations) by hand.

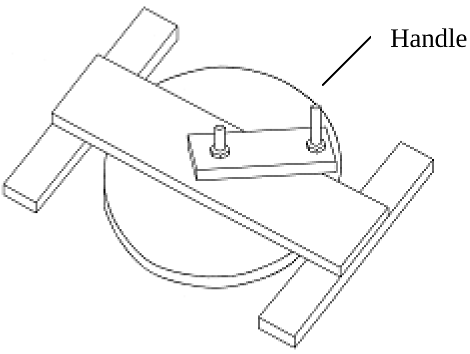


Figure 3. This rotating wheel and frame can be made of any rigid board or plastic, glue, counter-sunk screws, nuts, and washers. The frame sits astride the scanner glass. The 18-cm diameter wheel (with white underside) is rotated by hand. Drawings of lines, shapes, portraits, and so forth are loosely attached to the underside with a few dabs of a glue stick.

Attributing Meanings From Physics

The curious symmetrical patterns of Figure 2 reminded me of designs I had seen in physics texts. Could the patterns represent physical phenomena quite removed from their wheel-and-scanner origins? Based on the principle "Things that *do* the same *are* the same" (for example, if a magnet attracts both iron and an unknown solid, then the unknown must also be iron), if the scanner art mimics a physics graph, I asked myself: Why are they the same? Does one mathematically model the other? How deeply does the similarity extend? Are there broader lessons to be learned from the similarities?

After some thought, it appeared to me that scans 4 to 6 of Figure 2 model characteristics of two physical situations. The first is the gravitational field associated with a two-body system such as the Earth and Moon, represented in part by the conventional two-dimensional gravitational field diagram of Figure 4. The field shape depends on one mass being much less than the other.

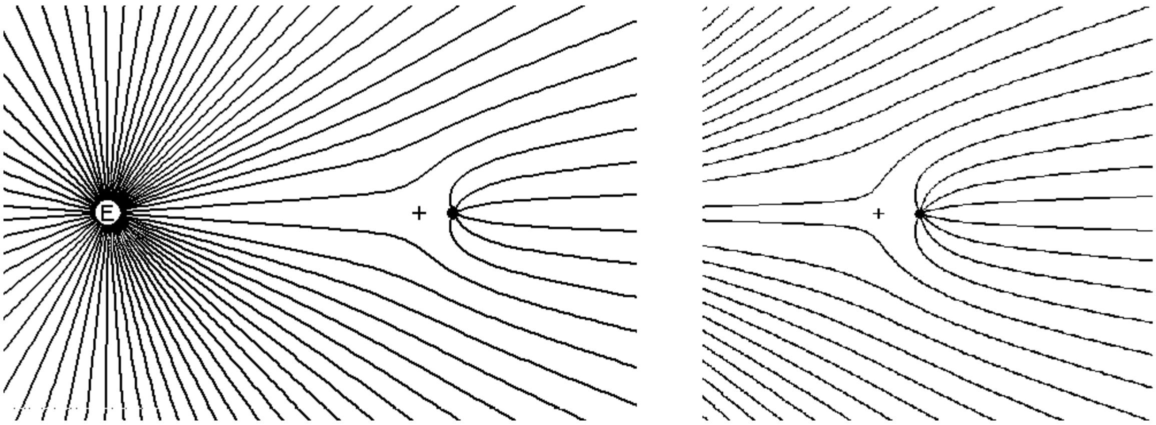


Figure 4. Two-dimensional gravitational field diagram of the Earth-Moon system. Notice the similarity between the enlarged section on the right, and Figure 2 scan 4. The neutral point in the field is marked with a cross.

The second application is the electric field surrounding two unequal electric charges. A typical field diagram (without vector arrows) appears in Figure 5.

While writing this article, a friend saw in Figure 2, scans 2 and 3, a Doppler-shift connection, though he was not sure as to why. Perhaps it was because in Figure 2, scan 2, as viewed from the top, the lines in the left semicircle are spread further apart than in the right semicircle. The fewer lines on the left may represent sound waves received by a person facing a receding sound source (the receding side of the rotating wheel). The effective wavelength is increased. Conversely, a person on the right-hand side would receive approaching waves of shorter wavelength.

Are there other physical meanings associated with these designs? Meditating on such relationships is a stimulating activity for both physics students and teachers. Are there relationships between physics and scanner art, technology, and beauty? The history of science records many examples of serendipitous insights linking phenomena from diverse areas.

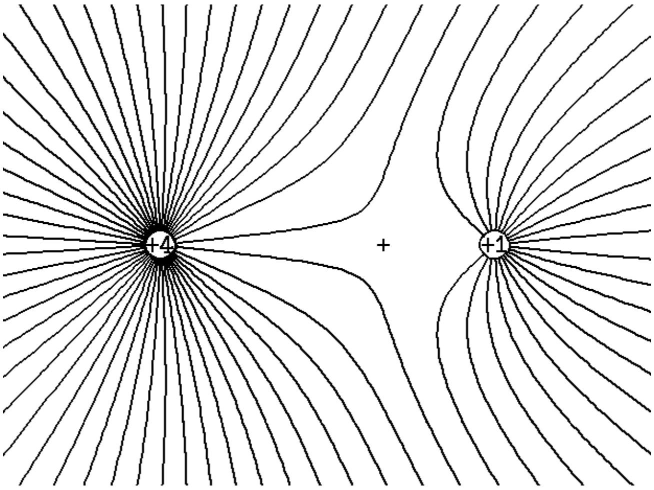


Figure 5. Two-dimensional electric field (without vector arrows) associated with two unequal electric charges. The neutral point in the field is marked with a cross.

Physics understanding is enhanced by predicting, observing, and explaining the outcomes of experiments. For example, what would happen to the pattern if the amplitude of oscillation was changed, but with the period kept constant? If the period was changed, with amplitude kept constant? If both were varied? These three questions alone generate a wealth of predictions that can be tested by the data collected. What would happen if the original pattern of Figure 2 was changed so that a wheel with 10 spokes, rather than 8, was used?

A Mathematical Analysis

Unfortunately, time limitations restrict the depth of physical and mathematical analysis students can handle in most secondary school courses. Nevertheless, in some curricula advanced students may well pursue a project based on a quantitative analysis of these, or similar, patterns. The following analysis is presented for those who have a special interest in this area, and concludes with some command lines that may be cut-and-pasted into *Graphmatica* (kSoft, 2005) software to create the shapes on the computer screen.

During scans, I was intent on turning the wheel at a constant rate, making exact timing of the period of rotation rather difficult. To quantify the rate, I used the diagrams of Figure 2 to calculate the ratio of the number of (360^0) rotations of the wheel to the period of the scan. The results, for scans 1 through 6, were 0, 0.13, 0.36, 1.2, 2.0, and 2.9 rotations per scan period, respectively.

My theoretical analysis yields the following parametric form of the curves:

$$x = 10 - t,\ y = (10 - t)\tan\left(\frac{\pi A t}{10} + \theta\right), \qquad (1)$$

where A is the turns of wheel per scan period (using values 0, 0.13, 0.36, 1.2, 2.0, and 2.9 to yield the scans in Figure 2). For each of these values of A, the eight spokes of the wheel are drawn one at a time, using for θ the values 0, π/8, 2π/8, 3π/8, 4π/8, 5π/8, 6π/8, and 7π/8). Incorporated in the equation are arbitrary values of 10 length units for the radius of the circle, and period of scan 20 time units.

Out of interest, I also changed the motion of the wheel from constant angular velocity to oscillation of the wheel with simple harmonic motion, yielding the results shown in Figure 6, scans 2 to 4.

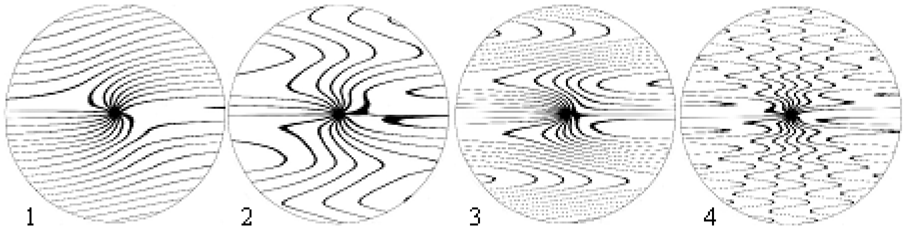


Figure 6. For scan 1, the direction of rotation was reversed half-way through the scan. For scans 2 through 4 the wheel was oscillated at varying rates through small amplitudes.

My analysis yields the following parametric form of the curves:

$$x = 10 - t,\ y = (10 - t)\tan\left(\Phi \sin\left(\frac{2\pi}{T}t\right) + \theta\right), \qquad (2)$$

where Φ is the angular amplitude, T the period of oscillation, and other variables the same as used in equation (1).

Computer plots of both equations using *Graphmatica* software agree very well with the scans in Figure 2, using, for example, command line

```
x=10-t; y=(10-t)tan(0.36*pi*t/10+a)  {0,20} {a: 0, pi, pi/8}
```

for scan 3; and in Figure 6, for example, command line

```
x=10-t; y=(10-t)tan((0.5*sin(2*pi/7*t)+a))  {0,20} {a: 0,pi,pi/8}
```

for scan 2. Could scan 1 in Figure 6 perhaps represent some strange gravitational field in space, perhaps associated with a fast-spinning star dragging its gravitational field as it rotates?

Art and Technology

Lightly pasting different graphic designs to the underside of the disk in Figure 3 provides for endless possibilities for exploring scanner art. For example, the spoked wheel of Figure 2, scan 1 may be replaced with a square or a series of nested squares, a circle or series of nested circles, or a group of concentric circles. I have experimented with groups of grey-scale and coloured shapes, CD covers, and other artwork, rotating them at different rates and beginning the scan from different starting positions (Figure 7).

Consider scan 2 in Figure 2, in which the spoked-wheel pattern was rotated very slowly. The left side appears stretched, and the right side contracted. When the spoked wheel is replaced with the silhouette of a face looking to the left, rotation expands the face and contracts the back of the head, creatively distorting the original. I made an interesting caricature of a portrait of Albert Einstein showing a Pythonesque expanded brain and shock of hair, reducing to a narrowed chin (Figure 7).

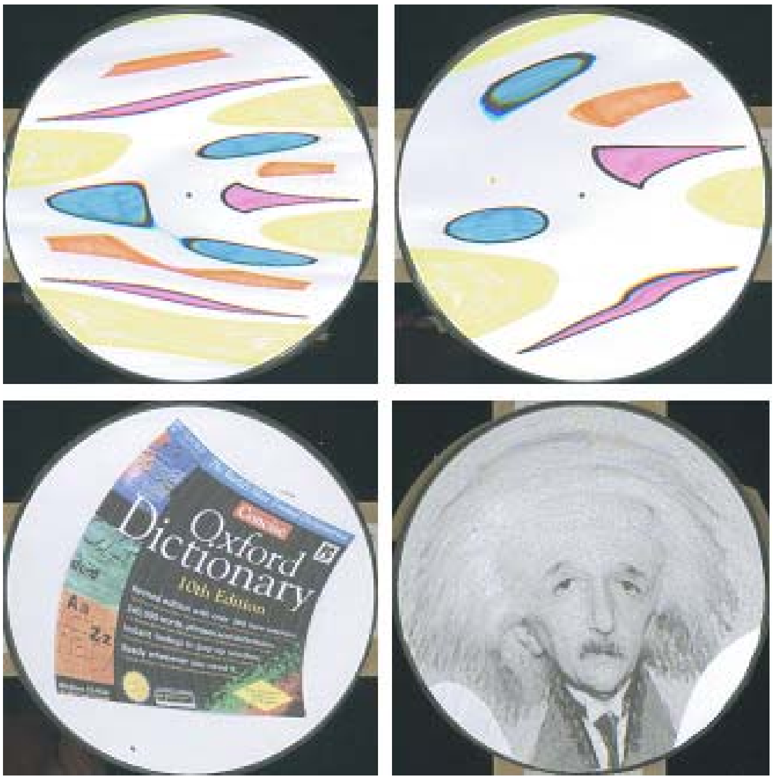


Figure 7. Scans of a few coloured squares and triangles, turned at different rates and starting at different orientations (*top*); of a CD cover (*bottom, left*); and of a photograph of Albert Einstein (*bottom, right*).

Conclusion

Two modes of scanning have been discussed; moving a shape at right angles to the scan, and rotating the shape about a central point. Many other forms of motion are possible, including free-form motion. It seems to me that younger children, less inhibited and often very confident with technology, could be very creative.

This article has presented scanner technology as a tool for generating designs that bridge physics, mathematics, and art. Its purpose is to stimulate teachers and students across all year levels to invent and explore their own applications, whether for fun or serious analysis.

Reference

kSoft. (2005). *Graphmatica*. Retrieved February 10, 2005, from http://www.graphmatica.com .

Ideas in Brief

Summaries of ideas from key articles in reviewed publications

Computer Projectors

Many, if not most, classrooms now have at least one computer. However, these computers are being underutilized for instructional purposes, mainly because it is difficult for 25 or so students to use a limited number of computers at the same time. A solution is to use a computer projector, a technology that has become increasingly affordable and which can be much more than just a glorified overhead projector (Bell & Garofalo, 2005).

A computer projector can:

1. bring technology access to all students in a room with only one or two computers.
2. increase student engagement, and improve conceptualization, by displaying still images (from the WWW, a CD-ROM, or a digital camera), multidimensional images (e.g., Chime molecule representations), animations, and video.
3. be used like a traditional demonstration, allowing a concept to be worked through without students needing to learn how to use a complex software application.
4. promote inquiry and analysis by projecting interactive simulations and spreadsheets. Have students suggest changes to the variables, predict the effects, and view the results immediately.
5. provide a focal point for a class, by bringing the whole class together to, for example, demonstrate how to use software or its features. This is beneficial in even a computer lab situation, or where all students have computer access in a classroom, and where different students will typically be focusing on something different at any instant.
6. be a money saver, by allowing a single copy software license to be purchased rather than a site license.

Reference

Bell, R. L., & Garofalo, J. (2005). Projecting science and mathematics. *School Science and Mathematics, 105*(1), 48-51.

Inquiry Classroom Management Checklist

Most of the techniques used to manage a direct-instruction classroom are inadequate for an inquiry setting, which is typically characterized by more movement, more noise, and more opportunities for students to misbehave. Indeed, concern over management issues, such as a fear of losing control of the classroom, is a major obstacle to the more widespread implementation of inquiry-based practices.

To help teachers address this issue, Sampson (2004) devised the Science Management Observation Protocol (SMOP). This 25-item assessment instrument, based on research about effective classroom management, allows a classroom observer to rate each item on a 0-4 scale. The following Inquiry Classroom Management Checklist is a modified version of the SMOP, written instead to facilitate teacher self-assessment.

Inquiry Classroom Management Checklist

Features of the Classroom

1. Do I have an effective way to get quiet in the classroom, within 10 seconds and without raising my voice or threatening punishment?
2. Do I consistently enforce a well-developed set of classroom rules, with interventions based on logical consequences?
3. Is there a set routine for students to get my attention?
4. Do students listen to me when I am talking, and do I avoid “talking over” them?
5. Is my lesson(s) student-centered and highly engaging, taking advantage of students’ curiosity?

Student Collaboration

6. Do I use a variety of cooperative learning techniques to ensure that all students are engaged?
7. Are student groups small (3 students per group is generally ideal), with each student having a significant role in the group?
8. Are students' roles assigned effectively and fairly?
9. Do students respect the ideas and opinions of others?
10. Do I use structures to make each student personally accountable for content learned during a cooperative activity?

Time and Student Engagement

11. Do I inform my students of what they need to accomplish during a lesson, and give them a timeframe for doing so?
12. Are transitions between activities short (less than 60 seconds)?
13. Do I limit the number of instructions given before a transition or activity, and make them specific and clear?
14. Do I move continually around the room, listening to students, challenging them with questions, and keeping them focused?
15. Am I "with-it" (i.e., able to communicate an awareness of student behaviour), and able to do more than one thing at a time?
16. Is the majority of class time devoted to academic tasks?

Materials

17. Do I have an efficient method for stocktaking materials at the beginning, and end, of activities?
18. Is there a standard procedure for getting, and returning, materials?
19. Are my students accountable for keeping materials in good condition?
20. During lab work, do I move often between groups, but restrict student movement around the room?
21. Does inappropriate behaviour during lab work have a consequence, and is it documented?
22. Do I assign clean-up duties to specific students?

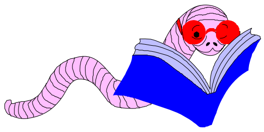
Safety

23. Have students been provided with a set of rules for laboratory work, and are they regularly reminded of them?
24. Do students know the location of safety equipment, and what to do in the event of an accident?
25. Do students wear safety glasses whenever heating, glassware, or chemicals are used?

While the above checklist identifies aspects that need to be addressed when planning to manage an inquiry classroom, it does not specify techniques for doing so. There may be multiple ways to effectively accomplish any particular checklist item, and such techniques could be gleaned by, for example, observing experienced teachers in action and by informal teacher-teacher collaboration. This journal will also make a contribution here. In the *Your Questions Answered* section of this issue, you will find a variety of suggestions for implementing the first item in the checklist (i.e., how to get all students in a class quiet and listening within 10 seconds). Other items in the checklist will be addressed progressively in subsequent issues.

Reference

Sampson, V. (2004). The science management observation protocol. *The Science Teacher*, *71*(10), 30-33.



Research in Brief

Summaries of research findings from key articles in reviewed publications

Use of Anthropomorphism and Animism in Science Instruction: What do Early Years Teachers Think About it?

By: Maria Kallery-Vlahos, Aristotle University of Thesaloniki, Greece
vlahos@helios.astro.auth.gr

Animism refers to the tendency one has to regard objects as living and conscious, while the tendency to ascribe to inanimate objects and nonhuman beings not only life, but also human characteristics such as feelings, desires, reasoning, and human capabilities, is called anthropomorphism. While controversial views have been expressed by several researchers and science educators as to whether animism and anthropomorphism should or should not be used in science instruction, teachers' opinions on this issue were never sought. Kallery and Psillos (2004) carried out a research project exploring Greek early years teachers' views on issues concerning the use of such formulations in science instruction, also investigating the reasons behind teachers' use of such constructs. Early years teachers were chosen because issues concerning the teaching of science become more complicated when it comes to children of very young age.

The early years teachers who participated in this study were implementing the national science curriculum for pre-primary education. This targets acquainting young children with science topics that concern properties of matter (e.g., floating and sinking, dissolving in water), atmospheric phenomena (water evaporation, rain, snowfall), concepts of light, sound, and motion, the Earth, Sun, Moon and the phenomenon of day and night, and plants and animals.

The results of the study showed that early years teachers do not share the view of some researchers that anthropomorphism and animism can aid young pupils' comprehension in science. They believe that use of these constructs can cause cognitive and--in special cases--emotional problems in children.

Cognitive problems. Teachers believe that the use of anthropomorphism and animism can confuse young children and cause them to form misconceptions and wrong impressions. They mentioned that, in their experience, very young children frequently find it difficult to make the transition from fiction to fact, and also to interpret metaphoric language.

Emotional issues. Teachers related emotional issues to fears that may be created in children when personification is used to explain devastating natural phenomena, such as earthquakes, tornadoes, and volcanic eruptions.

Teachers expressed the view that young children should be given scientific explanations in scientific language appropriately formulated for their age, and expressed the experience-based view that simulations and analogies could help teachers avoid the use of anthropomorphism and animism and at the same time be effective for presenting or explaining concepts and phenomena to these children.

Findings also showed that, although teachers expressed concerns about the use of animism and anthropomorphism, they do nonetheless use these formulations in the real classroom, either consciously or unconsciously.

Conscious use. Teachers attribute their conscious use to several factors. One is the lack, in the pre-primary schools, of appropriate materials for science instruction. A second factor is their low levels of content knowledge required to successfully carry out science activities for young children (Kallery & Psillos, 2001). Teachers find use of anthropomorphism and animism an easy way out of difficult situations, such as difficult explanations of scientific concepts. A third factor is their lack of knowledge of other appropriate ways to present topics to young children.

Unconscious use. There are two main factors to which teachers attribute their unconscious use of metaphoric constructs. One is everyday language, which, as teachers noted, is full of metaphors. The second relates to personal experiences, such as the way they have acquired their own knowledge of science and the way they have learned to present science concepts and phenomena to young children.

Teachers believe that an improved working knowledge in science will, to a certain extent, help them avoid conscious use of these formulations or, at least, help them create fewer problems in young children. Teachers also believe that improvement of their working knowledge of the subject will also make a difference to their unconscious use of anthropomorphism and animism since, among other things, it will enable them to have a better control of the language they use in science activities with young children. It should be noted, though, that although teachers' specific discipline knowledge is crucial for the successful development and implementation of science activities, "teachers also need to develop a better understanding of the nature of science, since extensive use of animism and anthropomorphism .... may indicate possession of alternative world views incorporating myths that are not consistent with standard science" (Kallery and Psillos, 2004, p. 309).

References

Kallery, M., & Psillos, D. (2004). Anthropomorphism and animism in early years science: Why teachers use them, how they conceptualise them and what are their views on their use. *Research in Science Education*, *34*, 291-311.

Kallery, M., & Psillos, D. (2001). Preschool teachers' content knowledge in science: Their understanding of elementary science concepts and of issues raised by children's questions. *International Journal of Early Years Education*, *9*(3), 165-179.

Experiences and Outcomes of Graduate Courses for Elementary and Middle School Teachers Studied On-Line and On-Campus

By: Wynne Harlen, University of Bristol, UK wynne@torphin.freeserve.co.uk

The experiences of teachers who studied the same course content delivered either on-line or on-campus were reported by Harlen and Doubler (2004). The course, *Try Science*, is the first course of a Master's programme in science education for elementary and middle school teachers. It was developed as an on-line course by a team of scientists and science educators; it was not a transformation of an existing course. In their coursework, participants worked in groups of 6 or 7, reported to members of their group on the tasks they were given, and responded to each other's reports. In the first part of the course, the tasks involved conducting investigations off-line, and in the second part a consideration of children's learning and the teacher's role in inquiry-based science. The on-campus course was created and run specifically for this research. It included thirteen weekly, 3-hour sessions, and was based on the same content, activities, and sequence as the on-line course.

Data were collected using pre-course and post-course instruments about changes in participants' understanding of the science content, of the meaning of inquiry, their view of inquiry teaching, and their confidence in teaching science. Lesson plans developed during the course were analysed for evidence of application of strategies for teaching inquiry. During the course, all the posted messages on the on-line course were collected and analysed, and all sessions of the on-campus course were observed, with three sessions being videotaped in entirety. Semi-structured post-course interviews were held with participants in both courses, and with the course facilitators. The main focus of the Harlen and Doubler (2004) paper was to show how the on-line postings were analysed, and how the experience of participants in the two courses compared. Other findings are also summarized, and can be found in full in Harlen and Altobello (2003).

The experiences of participants in the two courses were compared in terms of categories based on the course aims. These were for participants: to undertake inquiry at their own level; to identify the teacher's role in inquiry-based teaching; to work collaboratively; and to reflect on the nature of inquiry and on their own learning. It was found that in both courses, participants frequently used inquiry skills. The main differences were in categories relating to reflection, where there was a greater incidence in the case of the on-line course. It was suggested that the asynchronous communication on-line, which gave participants time to think and formulate a response in their own time, might have contributed to this. A similar explanation might account for the greater frequency of on-line teachers applying ideas from the course to their own experience and identifying inquiry skills in action. There was a difference in time spent in studying in the two groups, the on-line participants spending on average 7.5 hours per week and the on-campus participants 5.5 hours, including the weekly, 3-hour session.

Other findings, in brief, were that participants in both courses increased their understanding of the science, but the gain was significantly greater for the on-line teachers. The confidence in teaching science of the on-line course teachers also increased more than that of the on-campus course teachers. In other respects, there were little differences between the groups.

References

Harlen, W., & Altobello, C. (2003). *An investigation of "Try Science" studies on-line and face-to-face*. Cambridge, MA: TERC.

Harlen, W., & Doubler, S. (2004). Can teachers learn through enquiry on-line? Studying professional development in science delivered on-line and on-campus. *International Journal of Science Education*, *26*, 1247-1267.

? ? ? ? ? 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!

Evolution and Species

I read recently: "According to Dr Khalid Anees, president of the Islamic Society of Britain, there is no contradiction between what is revealed in the Koran and the idea of natural selection. However, he went on to say that Muslims do not accept that one species can develop from another" (Chapman, 2004, p. 9). How does science presently respond to this position?

Reference: Chapman, B. (2004). Opinion: 4.5 billion versus 4.5 thousand - no contest? *School Science Review*, *85*(313), 8-10.

Science and religion are two different ways of making sense of our world. Science relies solely on empirical evidence, including human observations of ***natural*** processes. As a result, inferences and explanations about natural phenomena are tentative and can change when new evidence or data becomes available. The key here is the idea of empirical evidence--not belief. The majority of scientists around the world agree that evolution occurs among organisms and that the mechanism for evolution, namely natural selection, is responsible for causing speciation (i.e., one species evolving into another). All organisms on Earth, from bacteria to *Homo sapiens* (humans), have undergone speciation, with natural selection being the primary cause. However, scientists are still collecting data on the specific molecular and ecological mechanisms that drive natural selection, and have driven it in the past.

The Koran maintains that God or Allah is responsible for "directing or driving" the processes of natural selection. This position, in and of itself, is a contradiction in science, since the concept of natural selection does not provide for the existence, or non-existence, of a God. It is at this point that science and the Koran diverge. Science does not claim that God does not exist, since it has no empirical evidence to suggest otherwise. However, by the very nature of science as a particular way of knowing, scientists cannot offer Allah's intervention as the driving force of natural selection and speciation.

Scientists must work to provide evidence, of natural occurrences that happened in the past, in the absence of witnesses. They do so by collecting as much evidence--both direct and indirect-- as possible (i.e., the fossil record, geological record, DNA analysis, etc.). Religious explanations are based on belief, not empirical evidence, and as a result are outside the realm of scientific understanding.

Paul Narguizian, California State University, Los Angeles, CA, USA

I think this question exemplifies how unnecessary conflict can appear to arise between science and religion. Both science and religion play important roles in the lives of humans. For example, consider the health benefits that science has delivered, and the fact that a small minority of the world's population are atheists. However, as Paul Narguizian reminds us above, science and religion represent different ways of knowing, with very different methods and purposes ("Science and Religion," 2003), and apparent conflict arises when one comments inappropriately in the realm of the other.

For example, religion "asks for trouble" when it proclaims a geocentric universe, or that the Earth is only a few thousand years old, because it is commenting on nature, which is the province of science. Likewise, science is "out of line" when one of its members declares: "The more the universe seems incomprehensible, the more it seems pointless" (Derry, 1999, p. 127), because this statement has a spiritual dimension--the province of religion.

References

Derry, G. N. (1999). *What science is and how it works*. Princeton, New Jersey: Princeton University Press.
Science and religion: Is conflict necessary? (2003). *The Science Education Review, 2*, 52-53.

Peter Eastwell, Editor

Getting Students' Attention

What way(s) have you found effective for getting all students in a class quiet and listening within 10 seconds? (*Editor:* This question relates to Item 1 of the Inquiry Classroom Management Checklist, p. 27 of this issue.)

My children's school has a technique, standard in all classrooms, that I have seen work effectively year after year. When the teacher wants her/his students quiet and listening, s/he raises her/his right hand high as s/he walks around the room making eye contact. When a child's eye makes contact, the child raises her/his hand also, and stops talking. When everyone's hand is raised, the room is quiet and the teacher has the floor to proceed. I've seen this work in individual classrooms and in a whole school assembly.

Michael L. Bentley, University of Tennessee, Knoxville, TN, USA

I don't use this technique personally, but I have seen it used effectively with over 400 students, aged 6-13 years, in a large theater. Clearly, it is instituted school wide in this case. It consists of a clapping call and response. The rythym can probably be anything, and will certainly be lost in translation: clap, clap, clap-clap-clap. This is done by the teacher, and responded to by the students.

Mark Paetkau, Keyano College, Fort McMurray, Alberta, Canada

I have a recorder (a musical instrument) and start playing. The benefits are that it's attention getting, recorders are very portable, I get my recorder practice in, and the students often have a go at guessing the tune as well. I use this technique with preschool to primary aged students, the tunes vary from nursery rhymes to classical, and usually include the national anthem.

Suzanne Pritchard, NSW, Australia

I ask them who wants to be the last one to leave after the bell. Ninth-grade students hate to be the last one to leave.

Anonymous

I have recently completed prac teaching in two schools, both in the same "poor" area. Initially, I found I could not teach at all, as the students were terribly illiterate and unmotivated, and classroom management was all that my job comprised. At one school, only one method worked for getting all students to pay attention, a method I saw the permanent relief teacher use. She displayed a stopwatch (running it and putting it up in the air for everybody to see), and all students became quiet within 30 seconds (not 10 s unfortunately, but I'm sure this can be worked on). She would then keep them in at lunchtime, for the same length of time it took for all students to be quiet. I gave this method a shot with my three year 9 classes, and it worked! My guess is that it works because it is very visible, but most of all because the relief teacher was very strict with it. She would pluck students from the courtyard at lunchtime, if necessary, even for 1 minute. So basically, routine and consequences are the answers to your question.

Jacky Dahlhaus, Australia

For lower secondary school students, I use the old "Stop, Look, Listen." Students soon learn to turn and listen. When I start with a new class, I usually make it a bit competitive (e.g., that took 5 s, let's try for 3.") They usually respond well to this.

Another strategy, for the beginning of a class, is a quick quiz. As students enter the room, they see the quiz already displayed by my data projector. They sit down and start straight away. This works particularly well for a highly motivated group, such as post-compulsory students aiming to achieve the highest possible mark in an external examination. They really like the quizzes, and it not only helps them to focus, but provides a self-check to make sure they are picking up the appropriate knowledge and skills.

Gail Moriarty, Western Australia

The key to getting silence is silence. You can ask teenagers for silence (although voice projection lessons may help). Primary students usually have some protocol, such as hands-on-heads, fingers-on-lips, or hands-up). But after the attention getter, WAIT in silence for the silence of your students. After they become silent, hold on to it for 1 second before talking.

If you are having trouble with a rowdy room, you could try what worked for a teacher I knew. He acted angry. No yelling, no verbal threats, no depression or defeat, though--just brow folded, sometimes with a sharp intake of breath. If it was really bad, he'd sit down ("Oh boy, we're going to get it now!"). Perhaps it was a game with the class, or perhaps they knew he could boil the scales off a fish with his reprimand if need be--but it rarely came to that.

Joe Ireland, Brisbane, Australia

Simple. Merely stand at the front looking at them, not saying anything, and when the talkers hear that it has gone quiet, they become quiet too. It's the element of surprise--they don't know what is going to happen if they carry on talking. Works for me.

Roy Skinner, Murdoch College, Western Australia

There is a teaching behaviour called Instructor-Expressiveness (IE) that can be employed by a classroom teacher for this purpose. IE is a teaching behaviour that emphasises how a teacher communicates, what he intends to teach, through words, gestures, and looks (Ogunkola, 2000). IE has four observable features: physical movements, voice inflection, eye contact, and humour. For a teacher to maintain good class-control throughout a lesson, and also to restore order to a class after a moment of confusion, the following are crucial:

1. The teacher should use most of the time during a lesson moving from one place to another in the classroom. This allows him to maintain a close distance with all students. The students will therefore quickly obey instructions from him.

2. The teacher should support his explanations with hand gestures and other relevant parts of his body, as well as teaching aids. This focuses the students' attention on him, and whatever he says is promptly obeyed.
3. The teacher should maintain eye contact with the students, concentrating on their faces. Through this, students who are busy violating his orders are discovered and reprimanded.
4. The teacher should speak loud enough for all students to hear (good voice inflection). He should make declaration statements with emphasis on important words.
5. The teacher should create opportunity for relaxation, by smiling or cracking some jokes, in order to relieve tension as teaching proceeds. This makes students happy, encouraged, and relaxed.
6. During the course of a lesson, if there is any moment of confusion or crisis, an expressive teacher (the teacher who uses the features of IE) moves towards the students, supports whatever he is saying with gestures, maintains eye contact with the students, and speaks loudly making declarative statements. All the students will know he is serious and means what he is saying. They will therefore respond promptly by keeping quiet.

The features of IE recommended above are effective because they have stimulus-cueing properties that serve to elicit selective attention. There is a schedule called the Instructor Expressiveness Observation Schedule (INEXOS) (Ogunkola, 2000) to train teachers to be Expressive Instructors.

Reference

Ogunkola, B. J. (2000). *Instructor-expressiveness: Student locus of control and cognitive entry behaviour as measures of students' achievement in, and attitude towards, Biology*. Unpublished doctoral dissertation, University of Ibadan, Ibadan.

Bola Ogunkola, Olabisi Onabanjo University, Ago-Iwoye, Nigeria

Editor: The following responses focus on gaining students' attention at the beginning of a class.

My experience, with 13 to 15-year-olds, is that whenever I entered a class with well-prepared materials for a demonstration lesson, my students became unusually attentive in anticipation of what was to come. I would introduce the lesson with: "Today I am going to demonstrate . . . , and after this I will call those paying attention to come and repeat what I do." The entire class becomes quite, and each individual listens attentively to the introduction and watches the demonstration.

Mawuadem Koku Amedeker

The main thing is to get the students into the lesson early. I usually have something different to start with--a show and tell type thing. It is especially good if it is something they have never seen before. Examples include: crushing a model gantry, Van de Graaff generator, interesting questions (e.g., if you turn your back on a plane mirror do you still make an image?), Puzzlers (e.g., with two balloons on T-piece glass tubing, holding one inflated and the other somewhat deflated, what happens when you let them go? How can you make a ball bounce higher than the position from which it was dropped? [uses a basketball and golf ball falling together]). The key is to get their minds into the lesson, and away from previous distractions.

Tony Ford, Redcliffe State High School, Queensland, Australia

My most effective technique is to start class immediately with a discrepant event--something that catches students off-guard, surprises them, or amazes them. For example, the moment the bell rings to start class, I might dim the overhead lights and light a set of "candles" on my demo table. I call on students to state their observations on similarities and differences, which invariably slide over into inferences based on their prior knowledge. Individuals will comment on differences in color, texture, and height, and infer similarities, like "they're all made of wax." I then pick up a lit "candle" and eat it. If I didn't have everyone's attention before, I certainly do now! And those who were off task are wondering what they missed. Students are then invited to ask 20 yes-or-no questions, one at a time, to try to determine the facts of things. The ensuing discussion can lead to distinguishing between observation and inference, prior conceptions, the nature of science inquiry, and so on. The hidden agenda is that students are left wondering what their teacher is going to do next, and they don't want to miss the start of the next class.

I have also found that hands-on/minds-on inquiry-based activities are motivating in themselves. When students enter the classroom and see sets of intriguing materials ready for use--whether it is scientific apparatus or kitchen-chemistry items--they want to get involved. I inform them that groups that settle into their lab stations, have their homework assignments completed, and are able to listen attentively will get to use the tempting equipment. Groups or classes that have difficulty listening to instructions will not be allowed to risk safety. Or, completed sets of homework will be their "ticket" to pick up a set of lab supplies. Or, groups that are at the ready will be able to pick up their kits. This also evokes peer pressure, as group mates encourage their partners to pay attention and get ready. Groups that cannot manage attentive behavior are assigned a "Plan B" during the class period--a learning activity with less hands-on activity and hence less appeal. Having groups of inattentive or unprepared students working on a book assignment, while students on the other side of the room are mixing and pouring and investigating, motivates for next time.

I found that when I worked with many science classes over the course of the day, initial attention was harder to obtain as the day went on. Classes mixed and talked at lunchtime and would ask what happened in science class that morning. Classes that had their act together could talk about the creative or intriguing activity. Classes that couldn't settle down would report that they didn't get to the activity, so they had a less-appealing--but educational--option. These discussions helped motivate students, and helped add a peer-pressure factor for attentive behavior for afternoon classes.

Respectful attention to substitute teachers is also desired when, say, we need to be absent from teaching for a conference. Prior to my absence, I have shown my students the options in activities we'll do, when I return, to identify and sort characteristics and components of mixtures. One set of mixtures was made of screws, nails, bolts, paper clips--that sort of thing. The other mixture was made of colorful edible items, like candies and marshmallows. I told the classes in advance that groups that had a good report from the substitute teacher would work with (and consume, if desired) the colorful mixture. Without a good report, the class would get the metal mixture. The substitute teacher was thrilled with the students' attentive behavior!

Lynne E. Houtz, Creighton University, Omaha, NE, USA

Editor: The Edible Candle demonstration, together with suggestions for conducting "edible" experiments, will appear in a future issue of *The Science Education Review*.

Further Useful Resources

Science Across the World http://www.scienceacross.org

Primary and secondary students, from schools around the world, exchange information, opinions, and ideas on a variety of topics that include Acid Rain, Domestic Water, Road Safety, and What do You Eat?

ExploreLearning http://www.explorelearning.com

Interactive simulations, for Years 6-12, to promote understanding of a number of natural phenomena, such as high, low, spring, and neap tides.

Primary School Science http://www.primaryschoolscience.com

Lesson plans, worksheets, and other resource for 7 to 11-year-olds.

ImageBank http://bio.ltsn.ac.uk/imagebank/

Free, downloadable bioscience images accompanied by descriptive text.

BBC Science and Nature Hot Topics: Animal Experiments

http://www.bbc.co.uk/science/hottopics/animalexperiments/index.shtml

Includes a quiz on how much you know about animal experiments, the main arguments for, and against, using animals in testing and whether it is morally right to do so, alternative research methods, and a vote on whether animal experimentation is necessary.

A Sense of Scale http://falstad.com/scale/

A visual comparison of various distances.

Chime Molecule Representations

Alphabetical Listing of Molecules
http://www.wellesley.edu/Chemistry/Flick/molecules/newlist.html
Crystal Structural Models http://www.geo.ucalgary.ca/~tmenard/crystal/crystal.html
Molecules for Modern/Cell Biology http://www.biologie.uni-hamburg.de/b-online/ibc99/biochemistry/Molecules.html

CameraScope http://www.teacherlink.org/tools

A tool for capturing digital images, performing measurements on them, and analyzing this data.

The Science Education Review (ISSN 1446 - 6120) is published by ***Science Time***, "Willow Downs," M/S 623, Warwick, Queensland 4370 Australia.

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