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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Geological Timeline

A 24-hour clock may be used to display a geological timeline, representing the period of time from the beginning of the Earth to the present day. On this clock, 1 hour represents about 200 million years, dinosaurs appear about 10.30 p.m., and mankind appears at less than 1 minute to midnight. A geological timeline illustrates the immensity of geological time compared with the relatively short span of life on Earth. Other ideas for displaying a geological timeline include:

- Painted mural on a school wall, on a playground, or in a corridor.
- Painted vertically, or hanging, in a deep stairwell.
- Knots along a long string, stretched across the playground. A student might stand at each knot.
- Toilet roll, or roll of other paper (e.g., in a corridor, or outside on a dry day).
- Spiral cut from large sheet of card. (A spiral shape allows a long timeline to fit into a much smaller space.)
- Line along the longer side of a sheet of A4 paper. (A scale of 1 cm representing 200 million years requires a 23-cm line.)

Science Story

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

The Great Hartford Circus Fire

With 167 people killed, and more than 700 injured, the Great Hartford Circus Fire in Hartford, Connecticut, USA on the afternoon of July 6, 1944 provides a tragic example of the power of combustion. The fire started in a side wall of the big top of the Ringley Brothers and Barnum and Bailey Circus, and rose to engulf the roof. With exits narrow, and many blocked by animal chutes, the collapse of the main support poles saw melted, burning canvas fall on those below, sticking to people’s skin and cremating many of those who were killed.

The cause of the fire remains unknown. Perhaps it was a carelessly thrown match or cigarette? Perhaps it was arson? What is known, though, is that the rapid spread of the fire, and the intense heat, were due mainly to the type of waterproofing used on the tent. Waterproofing the canvas was essential if, in order to maximize profits, shows were to be held in the rain. With World War II on, and the US military needing as many supplies as possible, the circus owners were not able to acquire the safe waterproofing they wanted. Paraffin, though, is a great waterproofing agent. However, being a solid, it needed to be dissolved in gasoline to produce a paste--a very flammable paste!--that could be painted onto the canvas.

Once the fire began, it was virtually impossible to extinguish. Foam extinguishers and modern equipment were not available at that time, and the hoses and buckets of water used were not only ineffective (because water and gasoline do not mix, with the later floating on water) but actually spread the fire even more quickly. The circus paid 10 years' profits to compensate the families of victims.

Source: Rimetz, B. (2005). The great Hartford circus fire. *ChemMatters*, *23*(1), 4-7.

World First MarsLink Mission Participants Learn and Enjoy Science

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Abstract

Students learn and experience the excitement of science by actively participating in the MarsLink Space Mission, an educational component of the National Aeronautics and Space Administration's (NASA) Mars Missions. This Mission has been made possible by Space Explorers, Inc., in collaboration with NASA. In the World's First MarsLink Mission, which includes an international team of students in the United States and Malaysia, participants perform science activities and projects relating to Mars and have opportunities to interact with other teams, educators, and scientists around the world.

Introduction

The World's First MarsLink Mission, organized by the author, includes an international team with members in the United States and Malaysia. It is an ongoing program that involves all available Mars Missions and lots of science. This MarsLink Mission is an educational component to the National Aeronautics and Space Administration's (NASA) Mars Missions. It is sponsored by the Northern New York section of the American Chemical Society, and has support from Space Explorers, Inc. and NASA. MarsLink, available through Space Explorers, Inc. (2004) includes a science curriculum, mission simulation, opportunities to chat online with space scientists, and data analysis.

My program started, at Clarkson University in 2000, with a mission simulation and a linkup to the Mars Global Surveyor Spacecraft via the Internet. Members of the community, as well as news media, were invited to the event. The team enjoyed communicating, by conference phone, with a mission controller and receiving and analyzing live data from the spacecraft. They also learned about mission positions, duties, instruments aboard the spacecraft, and a teamwork approach to solving problems. The positions and duties assigned to MarsLink team members during the mission simulation included the Public Affairs Officer (informing the mission team, spectators, and the general public about mission activities), the Spacecraft Engineer (responsible for spacecraft operations), and the Mission Design Officer (responsible for controlling and navigating the spacecraft).

During 2001, I traveled to Malaysia to visit the Malaysian team comprising Ansted University college students and junior high students from St. Xavier's Institute in Penang. I discussed the mission, described the instruments aboard the spacecraft, and gave instructions for accessing and analyzing incoming data from Mars. Dr Roger Haw, Co-Founder of Ansted University, is coordinating the team's efforts in Malaysia. The US component of the team includes upper elementary level students from St. Mary's School, Canton, New York and junior/senior high school students from Norwood Norfolk Central School, Norwood, New York. Team members exchange ideas, and share information, through email and at their Space Explorers, Inc. website. Photos and details of team activities may also be found at Barry (2005).

Team Activities and Progress

The exploration of Mars can be compared to a large science research project. It is an investigation of the planet's chemical makeup and reactions (Barry, 2001). This information is obtained from sophisticated instruments aboard the spacecrafts (Barry, 2002). The World First MarsLink team became acquainted with some of the equipment. They learned about the magnetometer and electron reflectometer, which measure the magnetic properties of Mars and the interaction of Mars' magnetic field with the local solar wind. Together, these instruments measure the strength of the magnetic field induced in the interior of Mars and the magnetic properties of Mars' crust at the surface. Mars does not have a strong magnetic field. In fact, it is almost non-existent. The students examined diagrams and photos from the thermal emission spectrometer, which measures the thermal infrared energy coming from the surface of Mars. A major purpose of this instrument is to identify minerals on the surface and use this information, along with morphology and other data, to understand the geologic history of Mars. They saw images of the surface of Mars taken by the Mars orbiting camera, which also serves as a weather satellite. This camera records the movement of clouds and the progress of dust storms. Participants also discussed the Mars orbiter laser altimeter (MOLA), an instrument designed to map the planet's topography. MOLA, which consists of an infrared laser and a collecting mirror, maps the heights of volcanoes and the depths of craters on Mars.

In addition, the Malaysian team members take part in many Mars-gazing activities. They use telescopes to view and study the planets and constellations. Also, the students attend and prepare science exhibits and participate in telescope-making workshops, planetarium shows, space-art painting contests, astrophotography, and rocket launching.

The US team members also carry out Mars-gazing activities and science lessons provided at the MarsLink website (Space Explorers, Inc., 2004). They prepared and studied the physical properties of carbon dioxide gas (the gas making up 95% of the planet's atmosphere) and made simulations of impact craters on Mars. This activity is now described.

Impact Crater Simulation Activity

Objective. Students use balls to make impact craters in flour, and determine the effect of drop height on the size (diameter) and depth of craters.

Materials. Plastic spoon, plastic cereal bowl, flour, ruler, ball (or marble), and graph paper.

Procedure. Provide each student, or pair of students, with a plastic cereal bowl filled with flour. Use the plastic spoon to smooth the flour surface before each test. Release the ball from various heights (e.g., 2.5, 5.0, 7.5, 10.0, 12.5, & 15.0 cm) above the bowl's surface and use the ruler to measure the crater depth, and diameter, for each test. Have students record and graph their data (drop height versus crater depth, and drop height versus crater diameter). Discuss the results in class. As an option, have students repeat this activity using a different-sized ball.

Figure 1. Sixth-grade students at St. Mary's School, Canton, New York measure crater depths in flour.

Conclusion

The international World First MarsLink team is making excellent progress. During 2004, this mission program received a national award of excellence, from the American Chemical Society, for it's creative teaching approach. In addition, the students are very happy and excited to have an opportunity to learn science by participating in Mars Missions. Their names are on a disk aboard the 2003 Mars Exploration Rover, which is presently exploring the planet's surface in search of geologic evidence of water in Mars' past. Highlights of this team's progress are displayed at Barry (2005).

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Demonstration

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

Spread of Disease

Needed. One opaque drinking cup for each student, white vinegar, water, and bromothymol blue (BTB) indicator with eyedropper.

Advance preparation. Pour 10 mL vinegar into one cup only, and add 10 mL water. Add 20 mL water into each of the other cups.

Invite students to collect, one at a time, one cup each, instructing them to not smell or drink the contents. Ask them to imagine that the liquid in the cup represents one of their bodily fluids (saliva or blood, say), and that they are about to go to a party where such fluids are exchanged (e.g., sharing drinking cups or needles used for taking illegal drugs, or engaging in unprotected sex, and using an age-appropriate choice), and that they will now simulate this process by mingling with others in the class and sharing liquid with at least three other students. To share liquids, one student pours his or her liquid into another's cup, and this person then pours half the contents back into the first student's cup.

After about 5 minutes, ask students to return to their seats. Tell them that, at the start of the party, one person--and one only--was infected with a disease (perhaps even using a specific example, such as HIV), and ask them to predict the percentage of the class that is now infected. Test for the disease by adding one drop of BTB to each cup, but with students keeping their results secret. Tell them that a yellow resulting liquid indicates infection, whereas a blue result means no infection. Ask for a show of hands by infected students, and compare the percentage infected (the magnitude of which students may find quite scary) with the predictions made earlier.

Subsequent discussion may be promoted by asking how anxious they were while waiting for their test result, and how they felt about the person(s) who may have infected them, and include the consequences of risky behaviour, ways to reduce the risks of infection, and how a particular disease might change the lives of those infected.

Adapted from: Scare them to death. (2003). *Science Scope, 27*(3), 60.

Student Activity

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

Exploring Animals

Needed. A box (or set of boxes) containing pictures of various animals. There needs to be at least one picture for each student in the class and, in addition to the usual favourites, the animals should include fish, insects, dinosaurs, and the like. Toy animals might be used instead of pictures.

While much of the inquiry learning literature focuses on performing experiments, nonlaboratory activities also play a key role in inquiry. For example, asking good questions is a central inquiry skill and is practised in this activity. In addition, the activity promotes lively interactions, acquaints students with their peers, and fosters a student-centred feeling.

Have each student choose, from the box, one picture, view it, but keep it hidden from other students. Working in pairs, and for a period of 2 minutes, students try to identify their partner's animal by asking them yes/no questions (i.e., questions to which they can reply either *yes* or *no*). "I don't know" is an acceptable response, and students record the number of questions they ask. When time is up, have students change partners and repeat the process.

After two, or a few more, rounds invite students to reflect on how many questions were needed to identify an animal, and any trends in this data. They will likely find that, with practice, fewer questions were needed, and they might conclude that they had learned to ask more informative questions in a better order. For example, isn't it better to ask if the animal has wings before asking if it is a chicken?

Ask students to identify the questions they found the most informative, and list them on the board. This also provides an opportunity to categorise the questions as form (e.g., does the animal have legs? Is it a mammal? Is it bigger than a chair?), function (e.g., is it a predator? Does it live in packs?), or environment (e.g., does it live in water?).

Source: Ingram, E., Lehman, E., Love, A. C., & Polacek, K. M. (2004). Fostering inquiry in nonlaboratory settings. *Journal of College Science Teaching*, *34*(1), 39-43.

Do Children Have Similar Models of Understanding for Seeing, Hearing, and Smelling?

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Abstract

The drawings and annotations of 7- to 11-year-old English children suggest that, overall, they seem to use five models for the senses of hearing, smelling, and seeing: the receptor, outreaching, sensing-as-instant, clashing-arrows, and arrows-both-ways models. There is some evidence that children's models are context-driven, in that they often have totally different models for each of their senses.

To read the full text of this article (15 pages), please **click here**.

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.

Touching the Learner, Just-In-Time

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During my first year of teaching at a secondary school, I had to conduct a chemistry practical lesson where each learner needed to shake an Erlenmeyer flask, as required in titration experiments. This was the second experiment and learners were to work individually, unlike during the first one where they worked in groups of 3. As I moved around the class, I noticed that all learners were doing well except George, who was shaking his whole body but not his arm! This seemed bizarre. Before intervening, I watched him for a few moments to be sure that he was not missing the mark. I talked to him, reminding him that according to the instructions, it was the flask that was to be shaken and not his own body. He responded by assuring me that he was indeed shaking the flask. I asked him to shake it again and, to my amazement, he shook his body and not the flask.

I took the flask and shook it, to demonstrate what I meant, and then asked him to do the same. Upon receiving the flask, he again shook his whole body rather than the flask. I immediately sensed that this learner had some central nervous system disorder that might need medical attention. Before advising him to seek such, I decided to hold his arm while shaking the flask. As I shook his arm, I asked him to relax his muscles so I could control the shaking of both his arm and the flask. After a number of trials, his arm was relaxed and we managed to shake the flask with ease. I wondered, as the titration proceeded, about what might be wrong with his arm. Gradually, I decreased my influence on his arm. To my surprise, his arm had gained some momentum, which made my arm shake. I felt as though I had brought life back to his arm and, from that day onwards, titration was no longer a problem for George. Indeed, there were also no major challenges in other practical lessons. Holding a secondary school learner's arm like a pre-school learner was a fascinating experience, at least for me.

Despite George's breakthrough in laboratory work, unlike his classmates he never made admission to a higher institution of learning. This meant that the battle was not yet over. My only hope was that, since George had a good pass in Physics, he would enrol at a Technical School of one kind or another.

Out of school, George continued to study the principles of friction, levers, and gears. He spent time sanding and polishing pulleys, as well as rollers, which he would join together to produce a grass cutter or lawn mower that used no petrol. George focused not only on the scarcity of petrol, but also on its high price in his country. He envisaged that one day he would provide an alternative to lawn mowers that use petrol. He worked on those pulleys and rollers for many months until he was satisfied that he had reduced friction to the lowest possible level. He joined pulleys, rollers, and many other parts together in such a way that the effort applied from the handle could be magnified more than 10 times at the blades of the lawn mower. Three years later, before many of his classmates graduated from colleges and universities, he presented his artwork at the National Agricultural Show. It was well received, being declared a category winner and receiving 0.5 million shillings (140, 000 USD, at the time). George used this money to improve his workshop, and he became an entrepreneur of his own kind.

When I once visited him at his workshop, he reminded me of how I had helped him overcome the titration problem. He cited other incidents, which I had forgotten, where hands-on problem-solving had been required. He appreciated my interventions ("just-in-time") during the practical sessions at that secondary school, because they had made all the difference in his life.

Implications for science educators. Science educators need to reflect on the works of Johnstone and Letton (1988), Johnstone and Su (1994), Tamir (1991), Wellington (1998), and Woolnough (1991), all of whom suggest the importance of practical work (hands-on & minds-on) that results in meaningful learning. Needless to mention, such knowledge is highly likely to be easily transferred to different situations. As such, the knowledge becomes useful to both learners and society, as demonstrated by the case of George.

What was wrong with George's hand, anyway? I do not know. One thing I know, though, is that the panacea for George's stiff hand was an educator's touch, just-in-time. This has far-reaching implications for educators. It could be a conceptual barrier, and an educator would serve best to touch the learner individually, just-in-time.

References

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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 .

The Study of Science

The study of science covers so many things,
Like plants and animals and Saturn's rings.
It's about how and why things act like they do,
About chemicals and potions and other stuff too.

Or solar system is a vast, vast place,
Some people just call it outer space.
Full of stars and planets and black holes too,
Things that are strange to me and to you.

Mixing, measuring, heating this and that,
Using test tubes and beakers and a heatproof mat.
A thermometer, some scales and other equipment too,
Testing chemicals and liquids to find out what they do.

Out of all the things the one I like best,
Is about plants and animals and all the rest.
The things that live all around me,
On the land, in the air and by the sea.

Lauren Sambell, 9 years
Australia

Just Like You!!!

If I could see what I want to see,
I would see the sun right next to me.
I would see the moon dive into sea,
And see a bee; half flea, half bee.

If I could taste what I want to taste,
I would taste zinc with tomato paste.
I would taste tin from chemical waste,
And taste some fruits grown in outer-space.

If I could hear what I want to hear,
I would hear Dolly say: *"Me clone, dear!"*
I would hear a snail's cry loud and clear,
And hear sound waves in the atmosphere.

If I could smell what I want to smell,
I would smell sulphur and be unwell.
I would smell oil an oil tank expel,
And smell the smell of a burning gel.

If I could touch what I want to touch,
I would touch a snake's fangs such and such.
I would touch acid but not too much,
And earn the gift of a Midas touch.

If I could do what I want to do,
I would turn a peach from pink to blue.
I would melt liquid and whoop-de-do,
Cause I'm a mad scientist, just like you!

Pei Shan Chow, 15 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.

Three Senses

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The following activities are based on my research, "Do Children Have Similar Models of Understanding for Seeing, Hearing, and Smelling?" reported on p. 72. The subjects were 7- to 11-year-olds, and the reader is referred to the full research report for a description of the models mentioned.

1. Which of the following statements about **seeing** are correct? (There may be more than one.)

   (a) I see because light from a source is reflected off objects and into my eyes.
   (b) I see because my eyes go out to see things when it is light.
   (c) I see things instantly as soon as there is light.
   (d) I can see things when light comes towards my eyes and my eyes go out to meet it.
   (e) Your eye travels to objects by having to see and then it travels to the eye.
   (f) I see things when light bounces off my eyes and onto things.
   (g) To see your eye needs some light and your vision bounces off the sun to things.
   (h) I have a better idea. (Please explain.)

Comment: Option a represents the receptor model, the scientifically accepted view. Options b-g reflect the outreaching, sensing-as-instant, clashing-arrows, arrows-both-ways, sun-eyes-object, and bounces-off-sun models, respectively.

2. Which of the following statements about **hearing** are correct? (There may be more than one.)

   (a) I hear because sound travels from a source to my ears.
   (b) I hear because my ears reach out and get the sound.
   (c) I hear things instantly when the sound is made.
   (d) I hear because my eardrum beats and comes out of my ear and it bounces together and brings the sound back into your ear.
   (e) I hear because first you hear the whistle and then it travels to your ear.
   (f) I have a better idea. (Please explain.)

Comment: Option a represents the receptor model, the scientifically accepted view. Options b-e reflect the outreaching, sensing-as-instant, clashing-arrows, and arrows-both-ways models, respectively.

3. Which of the following statements about **smelling** are correct? (There may be more than one.)

   (a) I can smell because the vinegar evaporates into the air and travels as a gas to my nose.
   (b) I can smell vinegar with my nose because vinegar has a strong smell and your nose is attracted to it.
   (c) I can smell vinegar because my nose goes out and gets the smell.

(d) I smell instantly as soon as the vinegar is opened.
(e) The smell of the vinegar goes all around the room and your nose goes out and smells it.
(f) I can smell the vinegar because it has a strong smell and when your nose smells it, it comes back and like clicks a trigger in your brain so you can tell what it is.
(g) I have a better idea. (Please explain.)

Comment: Option a represents the receptor model, the scientifically accepted view. Options b and c both represent the outreaching model, while options d-f reflect the sensing-as-instant, clashing-arrows, and arrows-both-ways models, respectively.

Activities to challenge children's conceptions. Regardless of the model that children have for sensing the environment, there must be some attempt to challenge what they perceive to be true, even when they have the accepted scientific model. Such a gathering of supporting evidence enables the scientific model to become more robust. Ideally, all children should end up with a model of passive sensing organs, with stimuli travelling to them from a source.

To challenge the various models of smelling, use a long-stemmed pipette to place vinegar inside a balloon (not inflated), and seal the balloon with a knot. Ask the children to smell the balloon to see if they can smell the vinegar; and they can't. This means that there is an obstacle between them and the smell that cannot be overcome by an outreaching of their sense of smell. Then, add vinegar to balloons, inflate the balloons, and seal them with a knot. This time, when the children smell a balloon, they will be surprised to find that they can smell the vinegar, even with a supposed barrier in the way. How could the smelling involve an outreaching if there is an obstruction in the way? With a little effort, the children might suggest that:

- when blown up, the balloon must have very small holes in its wall that allow the smell to get out. Air must have particles larger than the holes, because it is trapped inside the balloon.
- the liquid must be evaporating and turning into a gas (fumes, smells).
- the gas particles must be very small indeed to get through the holes in the wall of the balloon.
- the gas particles must be smaller than some air particles.
- some of the air can escape through the holes because this is why balloons go down after birthday parties.
- air must be made up of different gases, some having large particles and some with small particles.
- there is nothing between the gas particles that connects them. Otherwise, they would not get through the holes.
- either the liquid particles are stuck together, or larger than the holes, because they did not flow out.
- gas flows from its source to the nose. The nose does not go out to get the smell.
- smelling cannot be instant, because something had to pass through the holes in the balloon and travel to the nose.
- the sense of smell involves receptors that sense their surroundings but do not outreach.

This raises several questions in the children's minds. If we can smell something, does that mean that a gas is being given off? Can solids give off a gas, because we can smell them? Using this method to challenge their models, those children with the sensing-as-instant model find it very difficult to sustain. They come to realise that, if the nose is to respond to a smell, there must be some kind of movement from the source to the nose.

Following successful intervention in one area, take the opportunity to further challenge and intervene by comparing students' models for one sense with those for another. So, for the second challenge focussing on hearing, have children observe the behaviour of a slinky. Tell them that sound travels through the air as a compression wave, and that this is similar to the way the coils in the slinky move. (I do have some reservations, though, with using slinkies to teach the movement of sound, because the children see a linear model rather than concentric spheres of compression waves.) When they realise that sound travels from a source, they then begin to realise that they do not need to outreach with their ears, and this will be particularly so if they are constructing this understanding on the basis of their knowledge about smelling. I use Newton's Cradle to teach sound movement through a solid, although a physicist tells me that it is a dangerous analogy because of the curved motion it produces in the end ball. However, this does not seem to be a problem for the children, and they readily accept the idea of sound travelling through a solid without the movement of the solid to any great degree.

Understanding vision is the most problematic for children, but after developing an understanding of the other two senses, this provides an opportunity to further build on the concept of things travelling to receptive sense organs. Start in a darkened room, and ask students if they can see anything. The response will be "no, because there is no light." Light is needed for vision to occur, but many students will retain the outreaching and sensing-as-instant models. Blindfold the children and switch on the light. With the light now on, ask why they can't see. The answer might come that because their eyes are covered, they cannot see out! Then ask how many can see light seeping into their eyes past the blindfold, and many will likely raise their hand. How can you see this with the blindfold in the way, if the blindfold is a barrier that you can't outreach through? Ask them to remove their blindfolds, but to keep their eyes closed. Ask if they can tell whether the light is on or off, and they will be able to do so easily. So, with eyes closed, they couldn't be outreaching and light must be seeping into their eyes from outside. Then give them coloured acetate spectacles and ask them to open their eyes. Why do their eyes now see everything in one colour only? What has happened to their eyes to make this happen? The only explanation the children will likely consider sensible is that the acetate changes the light seeping into their eyes. However, my experience is that these vision challenges are not as successful as the smelling and hearing ones, and you will still be left with a substantial number of children who are unsure.

Once alternative models are learnt, their decay seems to be very slow. I think that the earlier an alternative model is learnt, the more stable it will be in a child's everyday working knowledge, and the fact that many children are quite happy to have different models for different senses is evidence of this. If this is so, the earlier the intervention the better. I am sure that there are teachers who could build on, modify, and extend these activities to produce even better outcomes.

Teaching Techniques

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

Probable Passage

This before-reading technique requires students to predict what a reading will be about, and helps to activate their prior knowledge. Provide students with a list of key words from a passage, and invite them to use these words to write a prediction about what the reading will be about. Options include asking students to first categorize the words provided, and providing them with a title for the passage. After the reading, students revisit their probable passages and check for accuracy.

Say Something

Use this technique to encourage thinking during reading. Prior to reading, have students mark a set of predetermined stopping points in a passage (e.g., use the points to divide a chapter into 10 sections). Working in small groups, all students read quietly to the first stopping point and then take turns in saying something about that reading. All students are expected to contribute, and the following starters may be provided to prompt responses: a question (e.g., "Why …?" "What does … mean?"), clarification (e.g., "Now I get it." "No, I think it means …."), connection (e.g., "This is like …." "An example is …."), prediction (e.g., "I wonder if …?" "I think that …."), comment (e.g., "This confuses me, because …." "I think that …."), or explanation (e.g., "The main point is that …."). Repeat for each successive stopping point.

Literature Circle

This after-reading technique can help students process their reading and deepen their understanding. To facilitate the discussion to come, ask each student to first prepare a written response to a reading, which might include what they found interesting or confusing, questions, and vocabulary needing explanation. Working in groups of 4-5, students then discuss the reading, either once only after the reading or on several occasions during a longer assignment. Options include requiring each student to prepare a final reflection paper, and having groups prepare a presentation that shares what the group learned and discussed.

Source (of all three techniques): Johnson, J. C., & Martin-Hansen, L. (2005). Improving science reading comprehension. *Science Scope*, *28*(6), 12-15.

Ideas in Brief

Summaries of ideas from key articles in reviewed publications

Tab Posters

To supplement a written paper about the life and work of a scientist, James (2005) has each of her students also construct a tab poster. Eleven, three-sided openings are cut, in a sheet of poster paper, to form lift-up flaps. The flaps are numbered 1 to 10, and under each is pasted paper containing a fact about the scientist aimed at providing a clue to the scientist's identity. The most obscure fact should be under flap 1, moving through to the most obvious under flap 10. A visitor lifts each flap in succession, trying to determine the name of the scientist, which appears under the last, unnumbered flap.

Students are asked to make their posters interesting (e.g., by displaying a quote) and visually appealing (e.g., employing a layout that looks like an atom, with the tabs representing electrons), using for a focus some symbol that represents a feature of the scientist or his or her work. A rubric for the task might contain the following criteria: visual appeal, appropriate facts, use of representative symbol, neatness and readability, and meeting the submission deadline. The posters make a useful hallway or classroom display.

Reference

James, E. (2005). History of science poster challenge. *The Science Teacher*, *72*(2), 54-57.

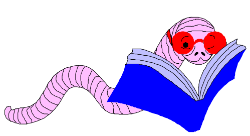
Service Learning

Service learning provides a way to link science education with students' lives. Students construct new knowledge and understanding by researching a topic (including the history of the issue and how it affects the community) and deciding how the project might affect others. The best projects/activities respond to real community needs and, while students' ideas about possible projects should be sought, the following are examples of service learning projects:

- Adopt an endangered species (e.g., a whale at Pacific Whale Foundation http://www.pacificwhale.org) and raise funds to meet the costs.
- Use an area tree survey to recommend future planting and tree care programs.
- Have older students teach a unit to younger children.
- Plant trees (e.g., to serve as a wildlife habitat, windbreak, or beautifier) and observe the habitat during the course of 1 year.
- Clean up, and develop a recycling plan, for a local area.
- Test for water quality and share the results with the community.
- Organise the collection and processing of what would otherwise be a pollutant (e.g., used motor oil).
- Design forest ecosystems in 2-L, plastic drink bottles, observe them for 2 weeks, donate them to a local assisted-living body, and have students correspond with the recipients for the remainder of the school year.
- Seek donations to save rainforests. (See Rainforest Alliance at http://www.rainforestalliance.org for information about rainforests.)

The keeping of journals, class discussion, and small group work after the project can foster reflection about the project. Results should be reported to relevant parties, and assessment can include written reports, reflective journals, and class presentations.

Source: McDonald, J., & Kromer, T. (2005). Service learning: A way to connect science to the community. *Science Scope*, *28*(7), 46-48.



Research in Brief

Summaries of research findings from key articles in reviewed publications

Secondary Science Teachers' Use of Inquiry Science Teaching

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For several decades, there has been a great deal of rhetoric about inquiry teaching in science education reform (National Research Council [NRC], 1996, 2000; Schwab, 1962). However, there is a lack of evidence on how teachers translate the curriculum ideal into actual classroom teaching. Given this need for research on teachers' actual classroom implementation of inquiry teaching, Wallace and Kang (2004) reported the beliefs, of 6 secondary teachers, about inquiry and how those beliefs are enacted out in both the laboratory and the classroom. The 6 teachers followed in the study first participated in a week-long summer workshop about inquiry teaching. They were not teachers who had been recognized for using inquiry methods in the classroom. Rather, they were teachers who had expressed interest in using inquiry techniques in the classroom.

The current US national standards define inquiry in terms of multifaceted activities:

> Inquiry . . . involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 2000, p. 23)

While studies of exemplary teachers' inquiry science teaching demonstrate ways to ideal inquiry science teaching, studies of "regular" science teachers' actual classroom enactment of their ideas about inquiry will inform teacher educators about ways to encourage inquiry science teaching that aligns with curriculum reform ideal. Wallace and Kang (2004) examined how "regular" secondary science teachers embraced inquiry in their classrooms. Based on the literature, they focused their research on three areas: teachers' beliefs about successful science learning, their purposes for using laboratory activities, and their definitions and enactment of inquiry in the classroom.

From the workshop, 6 teachers (Ellen, Tom, Rose, Jerry, Jane, and Pamela) were selected to represent various school settings. The main goal of the workshop was to provide the teachers with opportunities to explicitly reflect upon their beliefs about inquiry in comparison with other teachers in both similar and different teaching contexts. There was no intention to change, or "educate," the teachers about inquiry science teaching. The workshop was therefore not expected to affect teachers' classroom teaching practices.

The teachers were interviewed, and observed, throughout their teaching of a course. In addition, their written reflections and lesson plans, developed during the summer workshop, were analyzed. As a result of the data analysis, Wallace and Kang (2004) described the following ways in which these teachers' used inquiry in the classroom.

Ellen was a biology teacher. To her, "constructing an understanding of science was dependent on engaging in authentic scientific practices" (Wallace & Kang, 2004, p. 945). She put a lot of emphasis on students understanding laboratory procedures, interpreting data, and communicating the results. She used five, or six, long-term inquiry activities during her year-long biology course. In each case, she provided the students with the main question to examine while allowing them to choose the variables they wanted to study. Hence, different groups of students investigated different variables and the class answered the main question as a whole. She defined her inquiry as "guided" because it was the teacher, not the students, who asked the question to be investigated. In reconciliation with the curriculum requirement, Ellen confined her inquiry within the given curriculum by providing students with inquiry questions.

Tom (a physical science/technology teacher) and Rose (a chemistry teacher) held similar views and enacted inquiry teaching in a similar manner. "Both teachers held a primary belief that successful science learning is developing a deep understanding of scientific concepts. They also held a secondary belief that successful science learning involves thinking and problem solving" (Wallace & Kang, 2004, p. 947). They conducted two kinds of laboratories in their classes, a type to meet each of their goals. They differentiated cookbook labs from inquiry labs. The former were used to help students visualize scientific concepts in order to enhance their understanding of the concept, while the latter were to help students think independently. In their inquiry labs, students were given opportunities to devise a method of investigation, and the results did not necessarily have a single answer. In so doing, the teachers expected their students to develop independent thinking skills in doing science. According to Wallace and Kang, "their desire to teach for conceptual understanding and to promote independent scientific thinking may be viewed as competing belief sets, because it is difficult to give students the freedom to develop their own labs yet teach for canonical science understandings simultaneously" (p. 947). In contrast to Ellen, these two teachers tried to overcome curriculum constraint by adopting two different types of science activities for two different goals.

Pamela (a physical science teacher) thought that "successful science learning can be described as explaining everyday phenomena" (Wallace & Kang, 2004, p. 949). "Her teaching goal was to give students as much explanation as possible and to encourage them to use their science knowledge" (p. 950). Pamela also demonstrated a similar tension between teaching canonical science understanding and providing students with opportunities to construct understandings on their own. In reconciliation with the tension, Pamela broadened her definition of inquiry teaching as encouraging student thinking. Therefore, she believed that any activity could be inquiry as long as students had to figure something out. Thus, she thought of demonstrations in which students had to propose an explanation for the observed phenomenon to be inquiry. She also used inquiry laboratory activities in which the students had to figure out parts, or all, of the procedures. Pamela expressed her concern for content coverage. She believed that her definition of inquiry was sufficiently explicit for her to incorporate it into teaching.

Jerry's (physics and chemistry teacher) "main goal of science teaching was to develop scientific habits of mind in his students" (Wallace & Kang, 2004, p. 952). He chose to use labs and classroom discussions to bring up issues of the nature of science, such as the meaning of error and scientific models. Just like the other teachers, he was concerned about covering content. The interesting thing about Jerry was that he tended to differ in his beliefs, and uses of inquiry, between his two classes. He did not tend to use inquiry activities in his chemistry class. He believed that students' maturity and readiness were critical factors for inquiry in the classroom. He thought his chemistry students were not ready to conduct inquiry independently, whereas his physics students were capable of doing inquiry. In his inquiry activities, Jerry promoted thinking and problem-solving skills and fostered students' discovery of relationships in natural phenomena. Jerry believed in students' ability to construct science concepts independently when they were ready, in terms of maturity and prior knowledge.

Jane (a biology teacher) thought that "successful science learning can be described as creative thinking about science" (Wallace & Kang, 2004, p. 955). She "believed that successful science learning involved a synthesis of important ideas or big concepts, which was related to her ideas about creativity" (p. 955). At the beginning of the year, Jane used cookbook labs to get students used to using equipment. Later, she used inquiry-based labs to allow students to develop their creative and independent scientific thinking. Similar to Ellen, Jane gave her students questions to examine in their inquiry labs.

The cases of these 6 "regular" teachers' use of inquiry in science teaching support the literature in that they interpreted the notion of inquiry in various ways and hence, implemented differently. One common theme in their notion of inquiry is its role in promoting student thinking. All the teachers in the study aimed to enhance students' independent thinking through inquiry activities.

The variation in the teachers' inquiry teaching seems to be related to the way they coped with school constraints. In particular, as reported in other research studies, these teachers expressed curriculum constraints on utilizing inquiry teaching. They felt constrained by the amount of content to be covered in the limited time. Efficient content coverage does not necessarily invite student thinking that requires more time on less topics. In reconciliation with the curriculum constraint, the teachers in the study adopted various strategies that ranged from utilizing a limited number of authentic scientific inquiries within teacher-driven questions to broadening the definition of inquiry in compliance with efficient content coverage. Whether these different versions of inquiry are effective for the teachers' goals for science teaching, and in particular for developing students' thinking skills, requires further research.

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Informal Science Education for Girls: Careers in Science and Effective Program Elements

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Abstract

Addressing the need for continued support of after-school and summer science enrichment programs for urban girls and at-risk youth, this paper describes the educational and career paths of a sample of young women who participated in the Women in Natural Sciences (WINS) program during high school. This study also attempts to determine how the program affected the participants' educational and career choices after graduation in order to provide insight into the role informal science education programs play in increasing the participation of women and minorities in science, math, engineering, and technology-related fields. Findings revealed that almost all of the young women enrolled in a college program after completing high school. Careers in medical or health-related fields, followed by careers in science, emerged as the highest-ranking career paths. The majority of the sample perceived having staff to talk to, the job skills learned, and having the museum as a safe place to go as having influenced their educational and career decisions. (This paper is a summary of Fadigan & Hammrich, 2004)

Introduction

Women have a long history of under-representation in science careers that persists to this day. Over the past several decades, educators have designed and implemented numerous activities and programs to encourage the participation of girls in science and to narrow the gender gap.

Evaluations of these programs often reveal an increase in girls' positive attitudes toward, and interest in, science, an increase in content knowledge, and an increase in their knowledge of career opportunities in science immediately following, or a few months after, participation. Unfortunately, it is difficult to assess if the positive effects of science education programs for girls are long lasting. Conducting follow-up evaluations with participants of such programs is not a common practice, often due to financial and time constraints. Thus, it is difficult to determine whether or not girls who participate in science enrichment programs eventually pursue careers in science after high school.

The intent of this paper is to summarize the findings of the study by Fadigan and Hammrich (2004), which tracked a group of young women 3 to 8 years after they completed a science program for girls. The study describes the educational and career pathways of a sample of young women from urban, low-income, single-parent families who participated in a single-sex, informal, science education, enrichment program while in high school. This study also attempts to determine which program elements affected the participants' educational and career choices, to provide insight into the role informal science education programs play in increasing the participation of women in science-related fields.

Background

Females are at risk of not being equally represented in both school science and the workforce. From infancy through adulthood, females and males are treated quite differently (Sadker & Sadker, 1994). Science textbooks and curricula often fail to equally represent females in graphics and text. Science content, when traditionally presented in schools, and especially in the physical sciences, does not have as great a relevancy to real-life experiences for girls as it does for boys. For instance, concepts are frequently presented using male-oriented examples such as guns, sports, and automobiles. Compared to boys, girls often have fewer opportunities to use tools and equipment and participate in out-of-school-time science experiences.

Although students spend a great deal of time learning in the classroom during regular school hours, a large amount of learning also occurs during non-school hours. Learning can take place in a variety of environments including schools, homes, museums, and community centers, to name just a few. Participation in extracurricular activities may help students to improve academically, learn the values of teamwork, competition, and responsibility, and enhance their self-concept (American Association of University Women Educational Foundation [AAUW], 1999; Eccles & Barber, 1999; Nettles, Mucherah, & Jones, 2000; Shmurak, 1998; U.S. Department of Education, 2000).

When out-of-school-time science activities are voluntary and intentionally designed not to be a part of a school's curriculum, they are referred to as informal science education. Informal science education programs conducted by museums and science centers frequently provide opportunities for mentoring, improving science and job skills, and counteracting negative science stereotypes. Science programs designed specifically for girls increase their understanding and perceived value of science (AAUW, 1998), as well as offer opportunities to develop skills they might have otherwise missed out on, such as utilizing science equipment or acquiring job skills (Eccleston, 1999; Pierce & Kite, 1999), and increase feelings of self-concept and empowerment (Baker, 2002).

Program of Study

The Women in Natural Sciences Program (WINS) is a yearlong natural science enrichment program offered for academically talented females. To be eligible, girls must be entering the ninth or tenth grade, be enrolled in public school, maintain a C or better average in all major subjects, live in households where one or both parents are absent, and demonstrate financial need (i.e., be eligible for reduced-price school lunch). Since 1982, the WINS program has been offered free of charge to all participants, and includes materials, admission fees, field trip transportation, bus tokens for travel to and from the museum, and family memberships to the science museum. Approximately 30 young women are selected each year. The ultimate goal of the WINS program is to provide participants with the information, encouragement, and confidence they need to consider pursuing careers in the natural sciences, to make informed decisions, and to shape their own futures.

Over the course of 1 year, students attend classes at the local natural science museum, meet scientists, play science-related games, take field trips to local parks, laboratories, zoos, aquariums, and seashores, and spend 4 nights at an environmental education center. The thematic units presented to the girls include people and the environment, terrestrial ecology, taxonomy, and aquatic ecology.

After completing the yearlong program, approximately 15 to 20 of the WINS students remain involved in the program through participation in a second year program extension known as WINS II. WINS II includes opportunities for paid laboratory or museum positions, travel, and involvement in other established informal science education programs. Other WINS II girls sometimes acquire volunteer or paid positions in other programs and departments within the museum. Acceptance into the second year of the program is based on first year performance, as well as available funding.

After hosting a 15-year reunion for former participants, the WINS staff realized that many of them were attending universities and pursuing science-related careers. This event sparked the idea of a more formal tracking of the girls’ educational and career plans.

Utilizing program records, surveys, and interviews, the researchers conducted a case study to compare the WINS participants' educational and career goals before and after completing the program, and to determine if elements of the WINS program influenced their decision-making. Between 1992 and 1997, 152 young women attended the program for at least 1 year. The majority of the participants described their race or ethnicity as African American or Black (83%). Historical records providing high school completion and college entrance were available for 117 of the original 152 participants. Seventy-eight former participants completed and returned a survey that confirmed this information and provided additional details about educational and career trajectories. Of the 78 women who returned a completed survey, a sub-sample comprising 12 survey respondents was asked to participate in an interview.

Plans Before the Program

As part of the original application form, participants answered the question: “What are your current education and career plans once you graduate from high school?” The majority of participants (92%) indicated a desire to enroll in a college or university. Medicine and health-related career choices were most popular career plans (42%), followed by choices falling into the science, technology, engineering, and math (STEM) category (25%). Law and education were the third and fourth most popular desired careers, respectively.

Even though a high number of students desired science-related careers, their choices were not always specific. Many girls listed general careers such as scientist or doctor. This may hint that, in early adolescence, girls are uncertain of their career plans or may be lacking adequate career information (AAUW, 1999). If girls knew more about science careers before high school, a crucial drop-off point for many, they may have a better chance of staying in the science pipeline.

It is also important to note that the top four career choice categories, medicine and health, STEM, law, and education, can be identified as careers that enable the individual to help others. This finding is consistent with the work of Baker and Leary (1995) and Shmurak (1998), who found that girls in each of their studies selected science-related careers based upon a desire to help people, animals, plants, and the earth.

Progress After the Program

Information regarding educational paths was available for a total of 117 of the 152 original participants. Not only did all 117 participants in this case study graduate from high school, but 93% of these women also enrolled in some type of college program after high school. Originally, 67% of the careers listed by the 117 participants on their application forms were science-related (including medicine and health). Historical records and surveys provide data regarding the careers that 100 of these 117 participants pursued, and show that 45 % of the 100 actually pursued a career in a science-related field.

Careers in medical or health-related fields (pre-med/biology and nursing) rank highest with 25 students (25%) employed in, or pursuing a career in, this area. Careers in science (biology, computer science, and chemistry) fields rank second with 20 students (20%) working or studying in these areas. None of the women in this study are pursuing physics or math. The under-representation of these women in the physical sciences is similar to that reported by the National Science Foundation (2000). It is also worthwhile to note that 2 of the participants who selected careers in education are concentrating on science education.

Thirteen participants are pursuing graduate studies: 6 in a science-related discipline and 2 in secondary science education. The other graduate-level participants are studying in the fields of business, elementary education, law, psychology, and rehabilitative counseling.

Effective Program Elements

One particular question on the WINS survey directly addresses the participants' perceptions of which program elements affected their educational and career paths. The question lists different program components to which participants could respond. The results of this survey question, together with the data from the 12 interviews used to further explore participants' perceptions of each program component they identified as influential, provide insight into the ways in which the women perceive the WINS program as having affected their lives.

Three to 8 years after their involvement in the WINS program, the majority of participants perceived the **science classes and content** they learned in WINS as having an influence on their education and career decisions. Interviews revealed that the structure of the WINS classes--the hands-on nature of activities, the frequent opportunity for discussion and debate, the guest speakers, and the number of different scientific fields and topics covered--were important to these participants. During the interviews, the young women indicated that the science information they acquired in the WINS program later aided them with high school or college science courses. Seana felt she had an advantage in her schoolwork "because when I took biology and everything I understood what was going on." Fatimah shared similar thoughts, exclaiming: "It was good that I went to WINS because I actually learned it before I got to high school." Research tells us that informal science education programs for girls (and boys) can affect students' attitudes toward science, their achievement in science (Lee-Pearce, Plowman, & Touchstone, 1998), and their perceptions of scientists, but the literature has not yet indicated these programs directly affect students' education and career decision-making.

All the interviewees, as well as the majority of survey respondents, indicated that **going on field trips** influenced their educational or career decisions. These women remembered the trips as fun, educational opportunities to escape the fast pace of life in the city. Maureen recalled her experience, noting: "I hadn't really been out of the city, as far as going out to the middle of nowhere and just experiencing nature and the beauty of nature."

Over the years, WINS II participants have travelled to many parts of the world. Many WINS II students participated in other science enrichment programs, attended youth summits, and shadowed teens from other science institutions. The majority of respondents indicated an **opportunity to travel or attend other science programs in the second year of the program** influenced their educational or career decisions. The interviewees discussed how travel provided focus and direction for participants.

Almost half of the young women indicated that **career information** learned while in the program and **meeting scientists** at the museum influenced their education or careers decisions. The interviewees spoke of careers they learned about or scientists they met while in WINS, claiming that outside of the WINS program they did not have many opportunities to meet scientists. Bobbi summed this up by saying: "Well, beside your science teacher, who do you know that you can actually meet that knows that much about science?"

In the WINS program, students met girls from all parts of the city with whom they shared many commonalities, one of which being their enjoyment of learning science. Forty-three of the 78 survey respondents (55%) indicated that **the friends they made** in WINS influenced their educational or career decisions. For interviewees, it was important to have friends with whom they shared similar interests in science. Arlene stated: "It was nice to find somebody that shared some of the same interests as me so I didn't feel like the outcast in school." She added: "Since I had all these high interests in science, it's nice to find people that were just as determined as I was to make their goals and their dreams come true." Maureen articulated her perception of the importance of the friends she made in WINS by saying:

> They have similar interests, so when I start talking about something science-related they don't look it me like I'm speaking another language. They understand. A lot of them came from similar socio-economic backgrounds that I did, similar parts of the city that I did where the crime rate tends to be up, violence tends to be a big factor there, single-parent homes. To be able to have people that understand you in that way and to connect with you in that way tends to be very helpful, tends to kind of provide a safety net for you to lean back on. To have somebody there encouraging you when you kind of get discouraged by what you see around you.

WINS staff encouraged participants to pursue post-secondary education by planning activities to assist in preparing students for selecting, visiting, applying to, financing, and succeeding in college. Thirty-eight of the 78 respondents (49%) indicated the **college information** they learned in WINS influenced their educational or career decisions. Three of the participants mentioned the lack of resources available at their high schools. They mentioned the heavy workload of the few counselors prevented any intense or personalized attention to their needs.

Teamwork, leadership, responsibility, cooperation, punctuality, and communication are skills stressed during the first year of the program. Forty-seven of the 78 survey respondents (60%) indicated the **job skills** they learned in WINS influenced their educational or career decisions. During the interviews, the young women most frequently spoke about the development of their communication skills, especially the ability to speak in front of groups of peers or adults. Being part of the WINS program also instilled a positive work ethic and sense of pride in participants.

Reinforcing the need for more out-of-school time programming for high school-aged teens, the majority of survey respondents (53%) indicated that **having the museum as a safe place to go** influenced their education or career decisions. Considering participants' low-income and single-parent family status, their perception of the WINS program as providing a secure, stable environment is worth further attention. The interviewees described the museum as a fun place where you always could learn something new, hang out with friends, or just take time out to sit and think. Interviewees perceived the museum as providing an opportunity to escape their sometimes dangerous neighborhoods or family or emotional problems. Maureen said: "It was definitely really helpful in helping me to put myself in an ambitious mind set, to know that there's a lot more for me out there then just dodging bullets." Similarly, Arlene commented: "I don't have to worry about a drive-by [shooting]. That's always good."

Fifty of the 78 survey respondents (64%) indicated that **having staff available to talk to** influenced their educational or career decisions. The interviewees described the WINS staff as approachable role models who took time out to answer their questions, offer advice, and help out with homework. They said they felt as though they were treated as individuals and as young adults, rather than children. Fatimah described the staff as:

> more like friends instead of just mentors or adults that are there telling you what to do. They were sitting there right beside you, and even if they already knew the things you were learning, they were still interested in it, and they were like learning new things as they went along, working with us. So it was like, they weren't really adults. They were just older kids.

Some participants described the staff as being like an extended family to them. Sereeta commented: "If we were having a problem we all knew that we could go and talk to somebody about it. So, it made it a little bit, it was more of like a kind of a friendly, family-like atmosphere." Bobbi also described the program as being "like a new family to me." The women often felt that they could easily relate to the staff, especially when it came to their interest in science. Salina exclaimed: "I never really met anyone who was a science nerd like I wanted to be and it was really cool having someone that was knowledgeable." Several of the women also talked about the lasting effects of their relationships with staff members. They acknowledged they are still able to rely on the staff for advice. Bobbi considered the relationships to be "lifelong."

Implications for Science Educators

The WINS program provided participants with an assortment of positive experiences. In the eyes of the participants, WINS offered mentoring relationships with adult staff, a safe and stable place to call their own, job skills, and socialization experiences with like-minded peers. The participants' positive perceptions of the program elements raise the question of what type of role informal science education programs for girls can serve in narrowing the gap for women and minorities in SMET-related fields.

In the area of career education, especially within the science-related fields, it appears that students need to be exposed to the variety of different potential careers long before they reach high school. Students need opportunities to explore their options and learn more about the training requirements and the day-to-day responsibilities associated with science-related careers. For instance, students need to discover the rigorous requirements for a career as a doctor early on in their education so that they may take the necessary course work in high school.

In addition, careers in the physical sciences, more so than careers in life sciences, continue to be dominated by men. Based on WINS participants' interests in careers in which they are able to help people, perhaps women do not perceive physical science careers as having that characteristic. Career educators and science teachers can present these fields to girls in a new light, and allow them to see the dual possibility of both studying physical science and helping others.

Conclusion

Although the trajectory of not every member of the sample has led to a career in science, these women, each in her own individual way, have achieved success and overcome barriers associated with the risk factors of gender, race, and low socioeconomic status. In early adolescence, the majority of the sample displayed a high-level interest in science-related fields, valuing human interaction and opportunities to help others. In adulthood, over half the sample in this study maintained their aspirations for science-related careers. Their interest in occupations stressing human interaction and opportunities to offer assistance to others persisted as well.

Informal science education programs can play an immense role in the lives of young women and low-income students. When the duration of intervention is long enough to allow participants to form relationships with staff, feel they are in a safe, stable environment, and acquire skills for adulthood, participants benefit by gaining the confidence and support needed to succeed in science careers. Efforts to provide youth with a safe and supportive environment are crucial. This does not mean merely providing youth with a physical space. Youth needed to be treated with respect and made to feel they belong. Additional studies, including action research by teachers, of science education programs for girls are much needed in order to narrow in on the most effective strategies for keeping girls interested in science throughout their lives.

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Readers' Forum

Recreating Cuthbert's Experiment

In my role as a reviewer for this journal, I was privileged to read Anthony Cuthbert's paper (see p. 72) about English children's models for hearing, smelling, and seeing, and just as I was about to teach a very similar topic to my own Year 7 class of 25 13-year-old Australians of mainly Anglo-Celtic or World War II European immigrant background. I decided to use his test to discover what models my students were using, and to then design teaching and learning to help them reconstruct their understanding of how stimuli are received by receptors.

Using diagrams similar to those used by Cuthbert, I instructed the students to find a way to display how they believed we hear things, smell things, and see things by writing notes, and/or drawing, on the diagrams. Unlike Cuthbert, I did not encourage them to use arrows to complete the diagrams. I kept the results, also not telling the students that this test was to be repeated at the completion of the unit.

Interestingly, my students held the same range of models as Cuthbert's students, despite being on the other side of the globe. While the majority of the class was using either one or two models to explain the three related phenomena, only 20% of my students using one model only were using the preferred western science model.

Following this initial test, I explained how western science explains the three phenomena and wrote the explanations, as three separate hypotheses, on the whiteboard. I then invited the students to create experiments to test one of the hypotheses. For homework, they investigated aspects of their chosen hypothesis and planned experiments. The experiments included an eye dissection, touch test, reaction time test, and use of a cathode ray oscilloscope and flutes, lasers or torches, mirrors and dust, smelly objects (flowers, perfumes, cheeses, and detergents), flasks with stoppers, and blindfolds.

We spent four lessons (320 minutes over 2 weeks) investigating hearing, smelling, seeing, tasting, touching, and the nervous system, and each student then wrote a report. The students were able to display a sound understanding of scientific methodologies as they implemented controls and tried to control sources of error. The experiments proved much more difficult to plan and carry out than we had originally envisaged, though, and, in many cases, the experiment performed did not really test the hypothesis chosen. However, the students were able to discuss this in their reports.

Students then repeated the original test, and both completed tests were returned to students for discussion. The results were very encouraging, indicating that my students had been able to successfully reconstruct their understanding of how humans receive stimuli from their environment. Ninety-two percent of the class was now using only one model to explain the three senses, and 88% of the class was using the preferred western science models. Only 3 students in the class retained an outreaching model, and all 3 have recognised learning difficulties. One wears hearing aids, and used the accepted model for hearing but an outreaching model for seeing and smelling.

Some questions remain, though. I certainly feel that having identified students' prior models for scientific phenomena, discussed the western view of the phenomena, and then asked students to design and perform experiments to test the western view has been effective in having students question their personal constructions. However, how lasting are the new conceptions? And, have the students replaced their previous constructions, or are they simply holding two conceptions that they are able to use in different settings? Answering these questions would require further investigation.

I would highly recommend using tests like Anthony Cuthbert's to discover what models students are currently using, as a starting point for developing units of work that cause students to question their constructions of science and change them to a construction more like the western science tradition.

Gary Simpson, Woodleigh School, Victoria, Australia

? ? ? ? ? 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!

Group Roles

What group roles might I assign to students in an inquiry classroom? (*Editor:* This question relates to Items 7 and 8 of the Inquiry Classroom Management Checklist, p. 27 of this volume.)

In the *Primary Investigations* (PI) programme (http://www.science.org.au/pi/index.htm), students are assigned one of the following three roles: Director (not the team leader, but making sure the team understands and completes what is required), Manager (collecting and returning materials), and Speaker (communicating with the teacher and other teams' speakers, which includes asking for help). All students share in leadership responsibilities, the investigative work, and cleaning up. Any team member might report his or her team's results to the class.

Richard Cooper, Allora State School, Queensland, Australia

I suggest an equipment manager, timekeeper, manager or facilitator, and recorder.

Jennifer Echtle, USA

I generally divide students into groups of 4, and assign the following roles based on the letters S-A-F-E, which stresses safety.

S = Scientist. This person does the bulk of the hands-on parts of the experiment. If more than one set of hands is needed, the Facilitator will assign a helper, or helpers, as required.

A = Archivist. This person is the recorder for the group, making sure the results are recorded and questions answered. They also record any additional questions or comments the group might like to add. Each student leaves the activity with a copy of this information.

F = Facilitator. This person is responsible for reading the directions for the experiment and making sure they are carried out properly. Also, if any questions arise, this is the only person in the group allowed to ask the teacher. This prevents 30 children converging on the teacher with the same question, thus reducing foot traffic in the room. This person also assigns helpers to the scientist as needed.

E = Equipment Engineer. This person is solely responsible for collecting all of the necessary supplies for the experiment and returning them intact at the end of the experiment. Supplies for each experiment are grouped together in bins or boxes prior to class, so the Equipment Engineer generally only has to make one trip to obtain the supplies and one trip back to put them away. If equipment needs cleaning, the Equipment Engineer will do it. The Facilitator and Scientist help clean the work area where the experiment was performed.

The groups are set at the beginning of the semester and remain so for the whole semester, unless circumstances occur that require a change. Students rotate the roles so each student has a chance to be a Scientist, an Archivist, a Facilitator, and an Equipment Engineer.

Terry Keck, USA

Electric Fence Shock

A student told me that, when he held an electric fence with one hand and the hand of a friend with the other, his friend experienced a bigger shock than he did. How could this be the case?

I think I appreciate your interest in this situation because, if both students were identical, one might expect each to feel a similar shock because they form parallel components in the part of the circuit between the electric fence wire and ground, with each of these parallel pathways having roughly the same resistance and therefore carrying similar currents. (Actually, while the internal resistance of the human body is quite low, the resistance of skin can be high, so the pathway to ground through the second student [student B] would have a somewhat higher resistance than the parallel path through student A, due to the skin resistance associated with them holding hands.)

So, to observe the reported effect, I think student A needs to be wearing better-insulating shoes than B, and the bigger the difference the better. Consider the limiting case of A having perfectly insulating shoes and B being barefoot. Because A and B are now in series, the current in them must be the same. However, the magnitude of the current is only one of a number of factors that determine the form and severity of the effect of an electric shock, with another being the pathway that the current takes through the body (i.e., which parts of the body are affected). The current in A will pass through only arms and chest, whereas B experiences the same current in an arm and most of the trunk. Ouch! Not only will the latter affect more tissues in the body, but these tissues perhaps also contain structures that are more sensitive to electric currents. Reducing this difference in resistance between the students’ footwear would see relatively more current in the trunk of student A.

Peter Eastwell (Editor)

Heat Energy Changes Associated With Dissolving

Are there any rules/generalities about temperature changes associated with substances dissolving?

When a substance dissolves, there are three processes to consider. First, the solute particles must be separated, and this is an endothermic process (i.e., it absorbs heat energy). Second, the solvent molecules must be separated to make room for the solute particles, and this is also an endothermic process. Finally, the solute and solvent particles must mix together--that is, be attracted--and these attractions release energy in an exothermic process.

The sum of these three processes determines whether the overall dissolving process is endothermic, exothermic, or neither [and this is difficult to predict--*Editor*]. If the attractions between the solvent and solute particles are sufficiently exothermic (that is, release more energy than the two endothermic processes absorb), the dissolving process is exothermic and the solution gets warmer (e.g., sodium hydroxide dissolving in water). If the dissolving process is overall endothermic, the solution gets colder (e.g., ammonium nitrate dissolving in water). If the heat energy absorbed equals the heat energy released, there is no temperature change associated with dissolving.

Rosemary Carlson, Pana High School, Pana, IL, USA

Here is a rather interesting interactive demonstration site: http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/thermochem/heat_soln.html .

Terry Keck, USA

Further Useful Resources

Mayhem in the Middle: How Middle Schools Have Failed America--and how to Make Them Work (http://www.edexcellence.net/doc/2960_MayhemFINAL.pdf) Argues that middle schoolism is based on pseudo-scientific theories and downplays academic achievement, and that it is time for a thorough reform of middle grade education, including a new focus on high standards, discipline, and accountability for student achievement. Suggestions are provided for planning and implementing the transition to a K-8 model and for sustaining success.

Icons of Evolution? Why Much of What Jonathan Wells Writes About Evolution is Wrong (http://www.ncseweb.org/icons/index.htm) Alan D. Gishlick responds to Jonathan Wells' (2000) attempt to overthrow the paradigm of evolution.

Reference: Wells, J. (2000). *Icons of evolution: Science or myth? Why much of what we teach about evolution is wrong.* Washington, DC: Regnery.

Wonderwise: Women in Science Learning Series (http://net.unl.edu/wonderwise/) Introduces 9 women who have made science their career.

NSDL Middle School Portal (http://nsdl.enc.org/) A direct path to selective online resources, for instruction and professional development, from the National Science Digital Library.

Using the History of Science in the Chemistry Classroom
(http://cse.edc.org/products/historyscience) Aims to help teachers incorporate the history of science in chemistry and physical science classrooms. The fifteen biographical profiles connect science to students' lives, and imbue it with human character.

Astronomical Pseudo-Science: A Skeptic's Resource List
(http://www.astrosociety.org/education/resources/pseudobib.html) For those who want to examine, with a skeptical eye, some of the claims at the fringes of science that seem connected to astronomy. Topics include moon hoaxes, UFOs, astrology, crop circles, and faces on the planets. Does a full moon cause crazy behaviour? Could the universe be less than 10,000 years old? Did an alien spaceship land at Roswell, New Mexico?

SCIPs Partnership Project (http://www.scips-asta.edu.au/home) This School Community Industry Partnerships in science (SCIPs) program saw parties working together to design and implement small, innovative, science-based projects that promoted scientific literacy in their communities.

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Contributions are welcome, as are expressions of interest in joining the Editorial Review Board. The latter role requires the periodic review of submitted contributions, and is not onerous. Comments, questions, and article proposals may be sent to The Editor, Dr Peter H. Eastwell, at editor@ScienceEducationReview.com .

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