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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Robert Millikan

As a struggling junior researcher nearing 40 years of age, and at a time when physics was at its most exhilarating, Robert Millikan was probably very well aware that he could establish a reputation for himself if he could measure the charge on the electron. With his water drop experiments proving unsuccessful as a result of the water evaporating too readily, he set Harvey Fletcher, his doctoral student, the task of trying to use oil drops instead. Together, they refined the technique to the point where it seemed it was going to work.

Then, in what looks to be an act of enormous selfishness, he “pushed” Fletcher off the project, promising to give him full credit for some other work. As Fletcher later wrote, but only after Millikan’s death: “I did not like this, but I could see no other way out, so I agreed.”

Source: Brooks, M. (2011). *Free radicals: The secret anarchy of science*. London: Profile Books.

Teaching Ideas

Techniques, demonstrations, activities, alternative conceptions, critical incidents, stories, and other ideas

Does Air Have Weight?

Invitation. Invite students to consider the following question, without any discussion, and take a class vote:

> Consider an inflated football. If more air is pumped into the ball, the ball will:
>
> A. become heavier.
> B. become lighter.
> C. weigh the same as before.

Invite students to discuss and revise their responses and then take another vote, noting any effect that the discussion may have had on their thinking.

Exploration. Invite students to design an investigation to answer the following question: "Does air have weight?" Have students share and discuss their investigative designs, possibly provide for any that show promise to be carried out, but also guide the class towards the following demonstration.

Take a 2-litre, plastic soft drink bottle and fit it firmly with a rubber stopper through which a metal needle, of the kind used to inflate balls, has been tightly fitted. Place the bottle on a balance that is capable of reading to the nearest 0.1 gram and tare the balance. Then, remove the bottle from the balance, connect a bicycle pump to the needle, and use a sufficient number of pumps to add about 1 gram of air to the bottle. (The number of strokes required to achieve this, which will vary with the type of pump used, needs to be determined prior to the class.) Disconnect the pump and place the bottle back on the scale to demonstrate that the mass has increased by about 1 g. Students will see that the evidence suggests that air does indeed have weight and that the correct answer to the question that introduced this activity is Choice A. To reinforce the point even more effectively, the stopper can also have a short piece of glass tubing inserted and to which is connected, on the outside of the bottle, a short length of rubber tubing that is clamped to seal it. With the inflated bottle on the balance, loosening the clamp a little will allow the students to hear the air hissing out of the bottle as they also observe the balance reading slowly decreasing. With the balance linked to a computer, the balance readings can be displayed clearly on an interactive whiteboard.

Hold up a piece of pre-prepared plasticine having a mass of 1 g to help students "get a feel for" the weight of the air that was added to the bottle. For comparison, hold up another piece of plasticine having a mass of 2.4 g and tell students that this represents the weight of the air that was in the plastic bottle originally. (Older students may be asked to calculate this value themselves on the basis that the density of air at 1 atmosphere pressure is 1.2 kg/m^3, or 1.2 g/L.) Also, it might be noted that if the roughly 2 g of air in the bottle produces a pressure of 1 atmosphere, the addition of a further 1 g of air would have resulted in a pressure of about 1.5 atmospheres in the bottle. This can be compared with the typical pressure of 2 atmospheres in an unopened bottle of soft drink and the pressure of about 12 atmospheres required to explode such a bottle.

Concept introduction. How can it be, though, that the air inside the bottle can have weight, given that the air particles are widely spread out and spend very little time in contact with the balloon? How can the balance possibly "know" that more air has been added to the bottle? While it is true that the air particles spend very little time in contact with the balloon, an answer to these questions comes from considering what happens when the air particles do indeed bounce off the inside of the balloon.

As an air particle moves upward inside the balloon, the force of gravity acting on it tends to slow it down. Conversely, as the same particle moves downwards, gravity acts to speed it up. So, each air particle actually strikes the bottom of the balloon faster than it strikes the top of the balloon, and this difference over all molecules gives rise to a net force downwards, which we call the weight of the air in the bottle. The more air particles in the bottle, the greater will be this net difference and hence the greater the weight of the air.

A further thought. During the student investigative design process to determine whether or not air has weight, guard against students wanting to evacuate the plastic bottle, which will cause it to collapse, and comparing the weights of the bottle before and after evacuation. With older students who have studied buoyancy, the following question could be used to address this situation.

Alternatively, the question could be used with such students as an engagement question to introduce the study of buoyancy.

> A sealed plastic soft drink/soda bottle containing air at atmospheric pressure is placed on a balance and the reading noted. The bottle is now evacuated, causing it to be crushed, and re-weighed. The bottle will now weigh:
>
> A. less
> B. more
> C. the same.

Originally, the weight of air in the bottle will be cancelled by the upthrust on the bottle due to it being immersed in air, so the balance reading will represent the weight of the bottle only; that is, it will not include the weight of the air. (This analysis assumes that the volume of the plastic that comprises the bottle is negligible. In reality, this finite volume will displace its volume of air and experience a corresponding upthrust, and thus the real weight of the bottle plastic would be slightly greater than the reading shown on the balance.) So, the correct answer to the question above is Choice C.

Adapted from: Ross, K. (2011). Do footballs get heavier when you pump them up hard? Implications for climate change. *School Science Review*, *93*(342), 13-15.

Cloud Computing

Cloud computing, which is in its infancy, refers to a computing environment in which software and data are stored on one or more servers (i.e., on "the cloud"). When connected to the internet, a user can access the latest version of an application. In some cloud-based storage options, information is stored both on a server and also in synchronized folders on one's personal computer. The following exemplify cloud-based services that allow information to be organized and shared:

- Google Docs (https://docs.google.com) Documents, presentations, spreadsheets, drawings, and tables can be stored as web pages and accessed by anyone with the URL. Permission can be granted for a reader to edit a web page, with the changes appearing almost instantaneously on the page.
- Box (http://box.net) Documents, videos, podcasts (i.e., audio files), pictures, and folders can all be stored on the cloud only and accessed by those with the URL.
- Dropbox (www.dropbox.com) Content stored in a folder on a personal computer is backed up on the cloud (free up to 2 GB). Changes made to the folder on the personal computer are also made to the folder on the cloud when this computer is online, and the content of the cloud folder is available to any other computer that is logged in to the particular Dropbox account.
- Picasa (http://picasa.google.com) A free, downloadable program that scans a personal computer for images and creates photo albums either locally or on the cloud. Share, for example, photos from a field trip or other learning experience.

Source: Brunsell, E., & Horejsi, M. (2011). Science teaching and "the cloud." *The Science Teacher*, *78*(6), 14.

Archiving Whiteboard Work

In courses in which student-generated work is a critical component (e.g., small groups responding to prompts, recording their work, and sharing it with the whole class), it is highly desirable to be able to store the content students produce. Price, Tsui, Hart, and Saucedo (2011) have used two techniques to archive student work, both of which students found useful and frequently used. Tablet PCs and Ubiquitous Presenter acted as digital whiteboards, but the Tablets are expensive, technologically complex, and relatively small in size.

A simple, low-cost alternative was to have students produce their work on whiteboards, photograph the boards using digital cameras, and archive the photographs on the photo-sharing website Flickr (http://www.flickr.com/). Whiteboards have the advantage of being much larger than Tablets (at least three times the dimensions, say, which provides for at least nine times the area), and among the features available on Flickr are that images can be organized into hierarchical collections that match the structure of a course, tags and comments are supported (thus allowing questions about an image to be asked and discussed), and the instructor can be emailed when a comment is made on an image (thus facilitating a prompt response).

Reference

Price, E., Tsui, S., Hart, A., & Saucedo, L. (2011). Don’t erase that whiteboard! Archiving student work on a photo-sharing website. *The Physics Teacher*, *49*, 426-428.

Using Technology in the Classroom

Students love using technology, and capitalizing on this can help them learn science content and improve their vocabulary and collaborative/communication skills. Campbell and Williams-Rossi (2012) describe the use of the following free software or web applications:

- *CMAP Tools* (http://cmap.ihmc.us/) The gold standard of concept mapping that can be downloaded and used by students individually or collaboratively. Students respond to a focus question posted by the teacher by brainstorming and writing words related to the question, ordering the words from general to specific, identifying potential propositions that answer the focus question, and using the CMAP tools to create a concept map. Small groups may then be used to provide peer feedback on, and discussion about, the concept maps as a basis for students revising their maps.
- *Prezi* (http://prezi.com/index/) Cloud-based software that provides for the creation of non-linear, slideless presentations with zooming capabilities on a canvas. Import PowerPoint or Keynote presentations and download a presentation to a computer or mobile device. Up to 10 students can collaborate in real time.
- *VoiceThread* (http://voicethread.com/) Group conversations from anywhere in the world are collected and shared on the web. This collaborative, multimedia slide show holds images, documents, and videos and allows people to navigate slides and leave comments in five ways: using voice (with a microphone or telephone), text, audio file, or video (via a webcam). Comments may also be recorded.
- *Museum Box* (http://museumbox.e2bn.org/) Developed for social science classrooms, may be used to store and organize anything from a text file to a movie in trays. One can also view and comment on the museum boxes submitted by others.

- *Webspiration Classroom* (http://www.inspiration.com/WebspirationClassroom) An online diagramming, graphic organizer, mind mapping, and outlining tool for writing, brainstorming and collaboration.
- *Tagxedo* (http://www.tagxedo.com/) Creates visually dramatic word clouds using shapes such as a flower, footprint, or umbrella. The words used can come from a student's own text or from a website, news article, or other source.

Rather than being program experts, teachers can rely on the expertise of students to help peers in need of guidance.

Reference

Campbell, L. O., & Williams-Rossi, D. (2012). The way they want to learn: Using technology to build students' literacy across the science disciplines. *The Science Teacher*, *79*(1), 52-56.

Science Poetry

Reading and/or listening to poems 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 .

Veronica James Science [Workshop] for the Hearing-Impaired

In 2008 my mum was searching online
For a science class since my marks weren't so fine
There seemed to be nothing at all out there
Until she came across science for the hearing impaired

At first I wasn't all that keen
When I looked at the lessons they made me scream
I didn't want to dissect a pig's eye or a brain
It made me feel sick and I thought it was lame

There were topics that sounded pretty good though
When I heard about air cannons I said I would go
It sounded kind of radical so I thought I'd try
They said we'd get freebies and meals supplied

On the day I rocked up I was really amazed
No longer was I nervous and I wasn't fazed
There were so many kids who were hearing impaired
Kids and teachers were nice - there was nothing to fear

We did this lesson called the active earth
An adjudicator named Gordon taught us 'bout the universe
He did a volcano experiment - it nearly blew up the room
I thought it was going to propel us to the moon!

We attended a class called projectile motion
To understand it took a lot of devotion
We launched a ball bearing off some type of contraption
And observed its gravitational acceleration

I studied many different types of rocks
Marble, sandstone, granite, lots and lots
At the end of the class we made our own chocolate stone
I can tell you that mine didn't make it home!

I would say it's not all bad to be hearing impaired
The experience wasn't as bad as I'd previously feared
My attitude toward science will never be the same
Going to Sydney Uni with other deaf kids forced me to use my brain

After four years of experience participating
Science is not at all frustrating
Do not be afraid of learning about science
This subject and I have made an alliance

Zaidyn Melrose, 11 years
Australia

The Chemistry of Life

It was known by scientists far and wide
That DNA was comprised of nucleotides
These contained a base and phosphate group
A sugar sweetener completed the loop

And if life's secret was only one chain
The real treasure I'd not obtain
For I sought to unravel the great mystery
What was DNA's true chemistry?

I had a friend, dear Francis Crick
Our minds worked as one - that was the trick
We wanted to know how a single chain
Of nucleotides could combine and retain

The code of life from cell to cell
From father to son - what was the spell?
The race was on with Dr Pauling
We had to work fast - no time for stalling!

Then Wilkins showed me a picture fine
From poor Rosalind Franklin - it was divine
“A helix” I cried, “Not three you fool!”
The strands must align - that's Chargaff's rule

And so with pins and pipes and clay
He worked all night and every day
To construct the double chain proud and true
For every C a G, and A a T too

Now these were joined by hydrogen bonds
The rest forms the backbone long and strong
And so much praise and accolades
Came to us on the world-wide stage

We received prizes far and wide
A Nobel prize, to my great pride
“Great Scott!” they cried “Golly gosh, By Jove!
They've unveiled a treasure trove”

Of scientific wonders, a true delight
I can't believe they got it right!
“We’re famous!” I cried “This is the life!
Now time to go and get myself a wife!"

And the secrets that were sealed
Inside DNA, we revealed
How one chain was the complement
Of the other - so simple, no adjustment

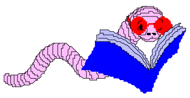
"So it's two! lt's two!" I proclaimed
The double helix, would bring me fame
But we were not done with this quandary
We still had to try and see

How one strand would make more
Of itself and then we saw
That the bases A T C and G
Were the key to this mystery

Was needed to carry the code of life
From parent to child, I told my new wife
"Just open it up and soon you'll see
How the A can find a brand new T!"

And thus a cell can readily build
A new double helix so its nucleus is filled
Hence from bug to bird to dog and tree
The chemistry of life was revealed by me!

J. D. Watson
Courtesy of Domenic Quail, 12 years
Australia



Research in Brief

Research findings from key articles in reviewed publications

What Makes an Exemplary Science Teacher?

The teacher is a crucial factor in engaging students in the study of science. Wilson and Mant (2011) first identified exemplary science teachers in this regard and then determined the features of these teachers' classrooms that were significantly different to the classrooms of others. However, while previous studies of exemplary science teaching have been typically small-scale and have used fellow professionals to identify exemplary teachers, this large-scale study used the judgements of students to both identify exemplary science teachers and to explore their practice. In particular, exemplary science teachers were considered to be those who students reported as being strong in making science fun, in having students who looked forward to attending their classes, and in offering interesting lessons.

Questionnaire data were collected from 5044 Year 8 students (12-year-olds) from 203 classes across 32 Oxfordshire (a county in Southern England) state secondary schools. Eleven classes characterised by having students who were particularly positive about their science classes were identified, and the teachers from six of these classes who were able to attend a planned subsequent teacher forum (for further research on the topic) were then labelled the exemplary teachers whose classroom features were to be further explored. The researchers recognised that these 6 teachers may have simply had students who were more positive about studying science than the norm, but also felt that this was unlikely since the exemplary teachers' students spanned a wide ability range, these teachers were working in a range of different schools, and each came from a different school.

The key features of the classrooms of exemplary teachers that were identified by students were:

- The teacher being a good explainer.
- Encouragement of thinking and discussion.
- Students engaged in practical work.
- Contextualisation (i.e., students being aware of the everyday relevance of what was being learned).

Reference

Wilson, H., & Mant, J. (2011). What makes an exemplary teacher of science? The pupils' perspective. *School Science Review*, *93*(342), 121-125.

The Benefits of Residential Fieldwork for Inner-City Students

The London Challenge was a government-funded initiative during 2004-2008 that provided fully-funded residential fieldwork experiences for 11- to 14-year-old state secondary school students from socially-deprived areas in inner-city London. Amos and Reiss (2012) evaluated the programme using questionnaires, interviews, and observational data from 2,706 participating students, 70 teachers, and 869 parent/carers from 46 schools.

The experiences, which promoted authentic inquiry, did facilitate cognitive gains in students, although these gains were revealed more by interviews than by having students complete survey items. For example, the courses helped students in "doing science" and positively impacted students' environmental behaviours, as evidenced by those who proceeded to question their schools' wasting of energy and/or change their own energy-saving behaviours.

However, the greatest impact of the programme was in the social and affective domains, with students improving their collaborative/teamwork and socialization/interpersonal skills. Students found themselves doing and learning science in a way that was not common in schools, where science classes rarely involved opportunities for collaborative work and where even opportunities for informal collaboration (e.g., lunch breaks) has, during recent decades, commonly been curtailed in an effort to minimize anti-social behavior. Importantly, though, students on curriculum-only field courses were less enthusiastic about their experiences than those who undertook combined curriculum-physical adventure courses.

At a time when financial constraints, pressures on curriculum time, and heightened concerns over student safety are tending to curtail residential experiences in the UK, the results of this study suggest that the opposite should be the case. Such real-world, residential learning experiences can enhance the social and affective skills of students and also help to reverse student dissatisfaction with school science, and the formal and informal education sectors would do well to look for ways to work together to further facilitate such. Combined curriculum-adventure courses incorporating literacy and numeracy, as well as science, are also showing promise.

Reference

Amos, R., & Reiss, M. (2012). The benefits of residential fieldwork for school science: Insights from a five-year initiative for inner-city students in the UK. *International Journal of Science Education*, *34*, 485- 511.

Can Dynamic Visualizations Improve Understanding?

Ryoo and Linn (2012) found that while both static illustrations and dynamic visualizations improved Year 7 students' understanding of the abstract concept of energy transformation in photosynthesis, the latter had significant advantages. In particular, the students who experienced dynamic visualizations were more successful in articulating the process of energy transformation in the context of chemical reactions during photosynthesis, and also demonstrated a more integrated understanding of energy in photosynthesis by linking their ideas about energy transformation to other energy ideas and observable phenomena of photosynthesis.

Reference

Ryoo, K., & Linn, M. C. (2012). Can dynamic visualizations improve middle school students' understanding of energy in photosynthesis? *Journal of Research in Science Teaching, 49,* 218-243.

Readers' Forum

The Scientific Method

I agree with Jonathan Osborne (2011) that scientists do not use the scientific method in all pieces of work, but must protest his subsequent dismissal of the notion of a scientific method. A better solution to overcoming the confusion that he mentions being associated with how science is done is to recognize that scientists can ask two very different types of questions, causal and non-causal, and that each needs to be investigated in a different way. A causal question typically asks (particularly in the school context) about the cause of a puzzling observation (e.g., "why do the plants grow much better here than over there?"). It is answered using the scientific method (or hypothetico-deductive [HD] approach), which requires the generation and testing of a hypothesis, where a hypothesis is a proposed explanation to answer the causal question (and typically, a proposed explanation for a puzzling observation).

In contrast, the investigation of a non-causal question (e.g., "how does the solubility of this chemical vary with changing temperature?") does not require the scientific method and hence does not require a hypothesis, because there is nothing to explain. For an elaboration of the scientific method, the different ways in which causal and non-causal questions need to be investigated, and misconceptions in this area, please see Eastwell (2010b), which is freely available online. Eastwell (2010a) took this reasoning further to explain why the reports of investigations of causal and non-causal questions need to have different section headings.

We can now appreciate the importance of the scientific method to the field of science. At its core, science is about seeking explanations for natural phenomena and it is the scientific method that provides the mechanism for doing so. The scientific method is therefore central to the way science is done and to the way the field of science progresses, and an understanding of the scientific method is fundamental to an understanding of the nature of science. The scientific method needs to be honoured! At the same time, though, it is also a reasoning pattern that is not specific to science (Lawson, 2010). Indeed, HD reasoning really just reflects the common-sense reasoning that humans use in their everyday lives; our brains appear to be hard-wired for it.

Returning to Osborne's (2011) paper, the scientific practices that are discussed may be selected from and applied, and in any order, that best suits the purposes of the work at hand. However, in the context of answering a causal question, the scientific method provides a neat organising framework for them.

Last, a recommendation for school science curricula can be made. What I think presently confuses the landscape is that science textbooks generally outline the scientific method (HD approach) at the beginning, stress how important it is, but then never--or very rarely, at least--provide opportunities for students to use it after that because the investigative questions posed throughout the text are non-causal ones. This is surely no way to effectively communicate the centrality of the scientific method to how science progresses. So, as Lawson (2010) argued, the more explicit and frequent use of causal questions in science classrooms would be highly desirable for the better development of scientific literacy.

References

Eastwell, P. H. (2010a). Headings in scientific reports [Readers' Forum]. *The Science Education Review*, *9*, 89-90.
Eastwell, P. H. (2010b). The scientific method: Critical yet misunderstood [Readers' Forum]. *The Science Education Review*, *9*, 8-12. Available from http://www.scienceeducationreview.com/open_access/index.html .
Lawson, A. E. (2010). Basic inferences of scientific reasoning, argumentation, and discovery. *Science Education*, *94*, 336-364.
Osborne, J. (2011). Science teaching methods: A rationale for practices. *School Science Review*, *93*(343), 93-103.

Peter Eastwell, Science Time Education, Queensland, Australia

Structured Abstracts in **Research in Science & Technological Education** *Papers*

The journal *Research in Science & Technological Education* has recently introduced structured abstracts, an innovation aimed at providing readers with more ready access to key information about articles, and the following heading structure appears typical: background, purpose, sample, design and method, results, and conclusions. I wish to suggest a modification to this structure that I think would better reflect the nature of science, make life less confusing for authors, and likely impact positively on the quality of both research efforts and the reports of them.

Like research in science proper, science education research can address either causal or non-causal questions. A causal question asks about the cause of a puzzling observation (e.g., "why does the interest and enjoyment of students being involved in science decline during the early years of secondary school?"). It is answered using the scientific method (or hypothetico-deductive [HD] approach), which requires the generation and testing of one or more hypotheses, where a hypothesis is a proposed explanation to answer the causal question (i.e., a proposed explanation for the puzzling observation).

In contrast, the investigation of a non-causal question (e.g., "how does the interest and enjoyment of students being involved in science change during the early years of secondary school?") does not require the scientific method and hence does not require a hypothesis, because there is nothing to explain. For an elaboration of the scientific method, the different ways in which causal and non-causal questions need to be investigated, and misconceptions in this area, please see Eastwell (2010b), which is freely available online.

Based on this reasoning, Eastwell (2010a) explained why the reports of investigations of causal and non-causal questions need to have different section headings. By reflecting the steps of the scientific method, a report on a causal question will feature one or more hypotheses and a conclusion, defined as a statement or statements that summarize the extent to which the tested hypothesis or theory has been supported or contradicted by the observed results (Lawson, 2010a), whereas a report on a non-causal question will feature neither of these but rather have a summary of results instead of a conclusion.

On this basis, then, I suggest that the structured abstracts being used by *Research in Science & Technological Education* for research reports might well be revised to have the following headings, depending upon what type of question is being addressed:

- *Causal question*: Background, question (instead of purpose), hypothesis(es) (including a statement of the planned test[s] and predicted result[s]), sample, design and method, results, and conclusion.
- *Non-causal question*: Background, question, sample, design and method, and results.

For some papers, it may even be that the optional abstract heading *Implications* would serve a useful purpose.

The present situation that sees authors trying to write both results and a conclusion in a paper that addresses a non-causal question, when a conclusion is not necessary, must surely cause confusion, because the best they will likely be able to do is repeat content under both headings, as exemplified in Basey and Francis (2011) and Parsons, Miles, and Petersen (2011), and I think this is an unnecessary duplication that would best be avoided. I'm hypothesisng that it was confusion over such potential repetition that led Barak and Asad (2012) to adopt a single, combined *Results and Conclusions* heading and Ogan-Bekiroglu and Sengul-Turgut (2011) to not even use a *Results* heading to summarise the results of their study but to put their results under the heading *Conclusion*.

In addition to better reflecting the nature of science and averting confusion, the suggested revision of the headings in the structured abstracts may help facilitate another useful outcome. Carey and Smith (1993) posited that there are three levels of science epistemologies: descriptive (i.e., non-causal, and not involving the generation of hypotheses), hypothesis generation and test (where knowledge comprises well-supported hypotheses), and theory driven (i.e., theories are generated and their postulates tested, and theories are used to generate specific hypotheses that are tested). Applying this to, and for the betterment of, the field of science education, Lawson (2010b) has suggested that science education researchers have a way to go in desirably progressing the field towards Level 3. While much research in science education is at the descriptive level, it is common for researchers working at a higher level and who do understand the scientific method to generate and test hypotheses in a largely implicit way. However, the more conscious and explicit use of the scientific (HD) method by science education researchers should result in vastly improved research efforts and reports (Lawson, 2010a).

References

Barak, M., & Asad, K. (2012). Teaching image-processing concepts in junior high school: Boys' and girls' achievements and attitudes towards technology. *Research in Science & Technological Education, 30,* 81-105.

Basey, J. M., & Francis, C. D. (2011). Design of inquiry-oriented science labs: Impacts on students' attitudes. *Research in Science & Technological Education, 29,* 241-255.

Carey, S., & Smith, C. (1993). On understanding the nature of scientific knowledge. *Educational Psychologist, 28,* 235-251.

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Ogan-Bekiroglu, F., & Sengul-Turgut, G. (2011). Students' general and physics epistemological beliefs: A twofold phenomenon. *Research in Science & Technological Education, 29,* 291-314.

Parsons, E. C., Miles, R., & Petersen, M. (2011). High school students' implicit theories of what facilitates science learning. *Research in Science & Technological Education, 29,* 257-274.

? ? ? ? ? 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!

Chemical Bonding

What engaging activities may be used to teach chemical bonding?

Magnets of various sizes and colours can be used to represent the atoms in ionic bonds. Students might then explain how the bonds were formed.

N. O. Nwankpa, Nwafor Orizu College of Education, Nsugbe, Nigeria

Types of Chemical Bonding

To some teachers, bonding is just another chapter in a book, or topic in a course, that must be taught. There are a few definitions and a few rules for how electrons behave. For others among us, this is the stuff of which the universe is made, and so it never loses its magic. Getting students, and especially those who are not our best students, to appreciate the wonder of bonding is a never-ending challenge.

First, dividing the subject of bonding into a few broad categories, we should arrive at the following:

1. *Lewis structures*. This usually implies covalent bonds formed by at least two electrons in one orbital sharing their electron density.
2. *Ionic bonding*. Some texts start with ionic bonding and work towards covalent (Brady, Russell, & Holum, 2000; Johll, 2007; McMurry, Castellion, & Ballantine, 2007; Zumdahl & DeCoste, 2008), while others work in reverse (Munowitz, 2000). One easy definition of ionic bonding, meaning one that students understand quickly, is the loss of an electron or electrons from one atom and gain by another.
3. *Coordinate covalent bonding*. This is always presented after covalent bonding, and the point is made that two electrons are supplied into a bond from one atom, while the other atom in the bond supplies no electrons (Munowitz, 2000, provides an excellent treatment).
4. *Metallic bonding*. The term "electron sea" appears to have faded from most textbooks, but the idea is still a fair representation of how valence electrons move in metals. The full idea is that the nuclei of the metal atoms act as fixed points in a three-dimensional matrix, with valence electrons free to move from one point to another, over and over again.

Just What is an Electron?

This question may seem astonishingly simple, but if we dig into it in some detail, we find a complexity unlike many other concepts in chemistry and science in general.

1. *Little particles whizzing along "really fast?"* This is the comfortable, layman's definition of an electron. It's easy to grasp the concept of a small, atomic-scale pea or speck whizzing around a bigger nucleus, also made of atomic-sized peas. It's easy to think of all atomic items as little peas; little particles. Even the term *orbital*, meaning a portion of

space in which an electron exists, sounds like the word *orbit* and implies a body going around another body. Thus, it's easy to think of the little pea rushing about in this sub-atomic space. Further, the image seems to be supported by such phenomena as Rutherford's now famous gold foil scattering experiment. Alpha particles--not electrons, but still four little peas all clumped together--were projected onto a foil, and some of them bounced back.

2. *A standing wave*. Here's where the definition of an electron gets sticky. Since there are s, p, d, and f orbitals, all of which have different shapes, we--students and teachers alike--tend to think of electrons as little peas rushing about in these different-shaped orbitals. But how then can we describe two electrons in a pi bond? Or, even harder, how can we describe one electron in a pi bond or molecular orbital? Does it exist on one side of the orbital, then the other, over and over, hopping back and forth in some eternal, sub-microscopic dance?

   No. The answer is that we have to start getting the concept into students' heads that a single electron can exist as a standing wave; a zone in space that is a particular shape. Now an electron is not a particle, or at least does not function like one. It is a wave; and weirder, it is a wave that doesn't move.

How to Teach Each Type of Bonding

Now that we have quite a few definitions and assumptions out of the way, how do we teach this and have some fun? Slower students in particular are most likely to learn more if the experience is fun.

1. *Lewis Structures*

   a. *Computer simulations*. It is recognized that this journal is read world-wide, and that some readers simply do not have the money or resources to teach their students with computers, or have sufficient computers that each student has his or her own. But, for those who do, there are plenty of free software applications available that concentrate on Lewis structures. One for which I have in the past sounded like a walking advertisement is found at www.ACDLabs.com . The program is quick to load, and it has enormous teaching possibilities for what effectively is a primer in organic chemistry. Draw some simple structures, and for a fun twist, draw them in ridiculous configurations. Students the world over get a laugh when they think the teacher has made a mistake. But the ACDLabs package has a button that cleans the structure (as do many others). Draw your bizarrely-angled cyclohexane, then click the "clean structure" button. Students will get a kick out of the quick rearrangement.

   b. *Play dough balls*. In this model, a single ball represents a single atom. Squeeze them partially together and you've represented the covalent bonding. Children at the middle school level will find this appealing, but students at any level who do not learn well in a traditional setting are often kinesthetic and tactile learners. They like to move and feel things. This activity allows them to do that.

   c. *Gum drops and toothpicks* (or marshmallows and toothpicks). Food and learning do go together. There are many organic chemistry modeling kits available throughout the world, but if you use something like gum drops, spice drops, or marshmallows as atoms, then toothpicks as bonds, you have a hands-on demonstration that most students will enjoy, and that is safe to eat. Using food gets their attention, even of the students who are considered of lower capability, and is a treat for the better students as well.

d. *Drawing in three dimensions*. This may be the hardest aspect of Lewis structures, and of getting students to understand them, that there is. Beginning to use a wedge and a dashed wedge to represent bonds can be confusing, even to high-achieving students. It is important to teach, though. One way to do so is to combine the food ideas, just mentioned, with student drawing. When the students can see a gum drop at the end of a bond, that is now closer to them, they can make the connection with the fat end of the wedge being out of the plane of the paper or the board. Start with something as simple as methane or ethane. Models of each will show three-dimensionality, and can be drawn. This may also prove to be a point at which a low-achiever suddenly excels. Some students do not process information written on a board particularly well, but are rather right-brained learners and thus draw and sketch very well.

e. *Racing the students in drawing structures*. This may seem odd, but can be a lot of fun. Once your students have the basics of Lewis structures and covalent bonding mastered, challenge them to small competitions. For instance, have one of them race you in drawing the two different three-dimensional structural configurations for ethane. Or, have one compete against you in drawing all the isomers of C_5H_{12}. If your class is very large, allow students to put their names on pieces of paper and have a lottery for who will race the teacher. Of course, have some fun prize (personal experience has indicated that free chocolate bars are better received than, say, a free, multi-colored, laminated periodic table).

2. *Ionic Bonding*

a. *Those play dough balls again*. Teaching about an ionic bond, as opposed to a covalent one, is really a matter of making sure students understand that an ionic bond involves the actual loss and gain of electrons between atoms. When we present some visual representation of the ionic bond, it cannot really help but look like its covalent "sibling." So, if we choose to use play dough balls, tear a small portion of the dough off of one atom, and smear it onto the other. Students love destroying things, or appearing to destroy things; even the high-performing ones. Ripping up the atoms gives them such a feel. Plus, it's fun.

b. *Still using gum drops and toothpicks*. Like the play dough example we just discussed, this is still the same presentation of atoms and bonds, with the gum drops or marshmallows now being the ions, and the toothpicks simply the connections to make an overall formula unit. Here is where the graphic depiction of the material breaks down a bit. What used to be two-electron bonds are now just a series of connections. If students, and even those who do not normally achieve particularly well, understand that, they've got the concept. Then, it's still fun to eat the formula unit when the lesson is complete.

3. *Coordinate Covalent Bonding*

Where do the electrons come from and, in a gum drop and toothpick model, what do the toothpicks mean? This is the same question that we have already asked about the ionic bonded material, but now the answer is different, because the toothpicks are back to being two-electron bonds; it is just that the two electrons are each coming from one atom. The caveat is the same as before; get the idea across to the students. Don't let the fun factor involved in edible models overwhelm the idea that the electrons are directed from one orbital.

4. *Metallic Bonding*
   a. *An atomic matrix* (yes, more gumdrops and toothpicks). This can be the same presentation as those listed above. Marshmallows or gum drops can represent the atomic nuclei, and this is helpful for students who like to touch and handle the material as they learn, but there are a couple of better ways to convey the idea of electron movements in a metal, as follows.
   b. *Wide board with nails evenly spaced in it*. If you use a piece of wood that is 1cm x 500cm x 500cm, and pound small nails into it in even lines, staggered from one line to the next, forming a matrix, you have a two-dimensional array that represents the atomic nuclei and inner electrons of a metal. If you then place it at an angle, and drop a lot of small gumballs down the incline, it will make a lot of noise, get a few laughs, and show the students how electrons move through a material like a metal. Try 100 hard gum balls; several bags from a candy or grocery store will make for a lot of noise and fun.
   c. *Plum pudding models*. One of the older models for atomic structure is the plum pudding model. I don’t know if this description works in most of the English speaking world, but in the United States, plum consumption isn’t huge, and the word “pudding” means a creamy dessert confection only. I believe that in Britain, and some other parts of the world, the word “pudding” means any dessert course. In the United States, several colleagues have thus changed this analogy to a description of marshmallows in gelatin desserts. The idea is still the same: the atomic nuclei are the marshmallows, and the gelatin represents the electrons that can move between the atoms. Bring in some of this material and hold it while giving the presentation, making sure it wobbles almost dangerously. This too will get a few laughs. Plus, if your class is a small one, you and your students can eat the “metal” you have discussed as the class ends.

Common Links for Best Approaches

Two of the common ideas throughout this discussion are to use a model to get the students laughing a bit, and to use materials they can eat. It may seem odd to make such connections, but they have worked in the past (and proof that the little kid in us never dies is that I’m teaching with such models and techniques at a college level). Even the slower students pay more attention when there is a laugh or two interspersed into the discussion. Importantly, all students seem to like a class where they are allowed to make and hold models, then eat them when they have finished.

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Laboratory Safety Guidelines

This section presents a series of 40 laboratory safety guidelines kindly provided by Dr James A. Kaufman, President, The Laboratory Safety Institute (LSI), USA. Please visit http://www.labsafety.org for further information, products, services, and publications.

#16 of 40. *Extend the Safety Program Beyond the Laboratory to the Automobile and the Home*

The effectiveness of safety programs depends on their ability to motivate people to care about their health and safety. When people view this caring process as part of their whole life, and not just part of their job, it becomes all the more effective. In fact, the same hazards exist outside of work and school as exist within.

Help your students/employees to understand the importance of safety throughout all of their lives. Most of the nearly 100,000 accidental deaths and 20,000,000 disabling injuries that occur each year in the United States do not happen in the workplace. The injury is just as severe and the loss of resources and productivity is nevertheless just as great.

Many small, inexpensive safety reminders are available that can help to deliver this message. For example, the EPA has a Read the Label campaign. There are four brochures on protecting your pet, your garden, your kids, and your household. They are available on request or can be downloaded from http://www.epa.gov/opptintr/labeling/campaign.htm . The LSI publications "Sources of Handouts" ($2.00) and "Laboratory and Occupational Safety Bibliography" ($10.00) list many free and inexpensive materials you could use to enrich your safety program.

Further Useful Resources

FreeMind (http://freemind.sourceforge.net/wiki/index.php/Main_Page) Free, downloadable mind-mapping software written in Java. The products can be exported into many different programs.

TED: Ideas Worth Spreading (http://www.ted.com/) Free videos, featuring guest speakers at TED (Technology, Entertainment, and Design) conferences who are instructed to offer insights and novel information, that can teach lessons and stimulate creativity.

Build a Faraday Motor With Your Students! (https://tinyurl.com/csfaradaymotor) A video showing a recreation of Michael Faraday’s original motor using salt water to replace the toxic mercury.

Oresome Resources: Minerals and Energy Education
(http://www.oresomeresources.com/) Current resources and teacher professional development on minerals and energy education coordinated by Queensland Resources Council (Australia).

Science Issues and the National Curriculum
(http://www.scienceissues.org.uk/overview.htm) A multimedia learning package to help students understand the scientific ideas behind a wide range of environmental issues, including pollution, biotechnology, global warming, habitat loss, fossil fuels, nuclear power, agriculture, your home,

the way your body works, and transport. Developed originally in CD-ROM format, these self-study resources are now available as a free download.

Google Science Fair (http://www.google.com/events/sciencefair/) A worldwide science fair that invites students to carry out a scientific investigation into a real-world problem or issue that interests them and share their work online using a Google Site. There are three age categories (13-14, 15-16, and 17-18 years), and students may enter either as individuals or as a member of a team of up to 3 persons.

The Archimedes Initiative (http://www.archimedesinitiative.org/index.html) A free, online video archive of students addressing their peers at science fairs in the United States. While about one half of the video content provides practical, how-to information for completing projects, such as how to decide on a project, the videos may also be used in the classroom to promote scientific literacy by augmenting classroom discussion and independent research on how scientists work. Directors of fairs could even use one or more videos from the "What's in it for me?" theme, either in a classroom or at an assembly, to encourage participation in a fair. Other online science fair resources include the Intel International Science and Engineering Fair (http://www.societyforscience.org/isef) and Science Buddies (http://www.sciencebuddies.org/).

Ecological Intelligence and Environmental Education: My Journey

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Abstract

Many of us are intentional in considering the environment when performing our daily tasks. But how many of us really know the true impacts of our "green" behaviors on the environment? Indeed, is it possible that engaging in green efforts can actually be counterproductive or detrimental to the environment? In his book, *Ecological Intelligence: How Knowing the Hidden Impacts of What We Buy can Change Everything*, Daniel Goleman (2009) suggests metacognition is critical to our overall ability to engage in environmental care. Yet, critically thinking about the outcomes of our actions demands that we have a strong knowledge base and a level of care or empathy sufficient for us to both gather that knowledge and then act on it. The application of ecological intelligence to environmental education is the focus of this article.

After hearing about its publication, I went out to purchase *Ecological Intelligence: How Knowing the Hidden Impacts of What We Buy can Change Everything* by Daniel Goleman (2009). As a teacher educator, I have been mindful to share his earlier works, *Emotional Intelligence* (Goleman, 2006) and *Social Intelligence* (Goleman, 2007), with students. In these publications he pluralized the definition of intelligence to include factors such as motivation and interpersonal skills. For this reason, and the fact that I had just spent a semester on sabbatical in a second-grade classroom focusing on literacy and environmental education, I was immediately drawn to this new book.

The primary purpose of my sabbatical leave was to explore the role of children's literature as an impetus for helping children to think critically about pressing environmental issues and develop their relationship with nature. I was interested in how reading children's literature with critical discourse might encourage them to be more empowered and efficacious to work collectively towards environmental care. I was focused on ways to sensitively and positively deepen children's understanding of texts, themselves, and their world, and especially understanding related to the environment.

The children's responses were revealing, insightful, and powerful. By the end of the semester, we had explored nature and environmental concerns together. We had learned a great deal about ourselves and our behaviors and views, as well as the global environment. We worked collectively to better the environment and shared personal feelings about our environmental fears. Since I was purposeful in choosing children's books that depict nature in a way that I thought children would relate to (mostly fiction that was aesthetically pleasing and relevant to their lives), we often engaged in critical discourse and thinking. Many times this led to action, at times child-initiated and at other times initiated by me. Either way, we worked together to better our understanding of both global warming and of ways to reduce our carbon footprints. Consequently, we heightened our self-efficacy to be change agents and developed deeper relationships with nature. Numerous, specific examples of these developments, together with a summary of my work, may be found in Bouley (2009).

The intent of this article is to discuss Goleman's theory of ecological intelligence and the practicability and applicability of his theory to elementary classrooms. Goleman sent me on a journey. While reading *Ecological Intelligence* (Goleman, 2009), I began to wonder whether or not my entire semester was spent in vain. I began to question everything: Did my work actually increase the ecological intelligence of these 18 second graders? Will the environment benefit in any way from our work? Did I actually do these children and the environment a disservice? While Goleman's discussion on ecological intelligence got me thinking critically about my recent going-green efforts, by the time I had actually finished his book my feelings of having made an impact had been restored.

Ecological Intelligence

As a child, I got the idea somewhere that it was better to leave the light on for a certain period of time than to shut it off. I specifically remember thinking that every time I hit the light switch on or off it would cost my mother 5 cents. I must have decided countless times that, since I would soon return to the room, it would be better to leave the light on. I was remembering this recently when my daughter and I were discussing a "No Idling" sign. She was wondering whether it takes more fuel to shut off, and turn back on, the motor than to have it idle and, if so, how long you need to idle to use the same amount of gas it takes to restart the vehicle. Such a lack of knowledge about the impact of our actions on the environment is the focus of Goleman's (2009) *Ecological Intelligence*, in which he examines how we can collectively "become more intelligent about the ecological impacts of how we live" (p. 3). He makes the case that awareness and knowledge of the impact of one's actions on the environment is critical, yet he emphasizes collectivism and the need to "build the human store of shared ecological intelligence" (p. 3). He states that it is our knowledge, our ecological intelligence, that will "guide our decisions in better directions" (p. 3). While Goleman's focus is consumerism and knowing the carbon footprint or Life Cycle Assessment (LCA) of the items we buy, this way of thinking demands that we reflect on the impact of all of our actions. Even when we act in purposefully green ways, do we really know the impact of our actions on the environment? Goleman believes that a "fundamental disconnect resides within our awareness between what we do, and how it matters" (p. 31).

According to Goleman (2009), one demonstrates ecological intelligence when he or she actively learns about the connection between their actions and the environment and applies what has been learned to "do less harm and live sustainably" (p. 44). The ecologically intelligent being sees "the interconnections between our actions and their hidden impacts on the planet, our health, and our social system" (p. 44). Equally important to cognitive skills, says Goleman, is developing a sense of empathy and compassion for nature. Because this knowledge is immense, he calls for collectivity; a dissemination of knowledge that leads to shared empathy and collaborative action "for the greater good" (p. 49). Goleman establishes the following collective ecological rules to follow: "Know your impacts, favor improvements and share what you learn" (p. 50).

The very impetus for my research was to take a different approach to environmental education. I did not want to focus on the popular topics such as the 3 R's (reduce, reuse, recycle), polar bears, or animal extinction and rain forest depletion. I wanted to take a deeper approach and help children to develop a love for nature and a deep connection to the environment while understanding the consequences of their everyday actions. I had hoped to do this by tapping into children's keen sense of empathy, compassion, and fairness (which has been discussed so often as the basis of multicultural education) as an effective way for children to truly understand the term environmental care. I wanted to avoid exactly what Goleman (2009) sights as a hindrance; the false sense that we are doing enough when we are engaging in action that's only green in appearance. In other words, thinking we are doing some good when in actuality we are not. Goleman suggests that we do not know the impacts of what we do and buy and, what is worse, that we don't know that we don't know. As he says: "Failing to know what we do not notice is the essence of self-deception" (p. 30). One way in which he demonstrates this is by looking at an area that is growing in popularity as a green act; buying local foods. Goleman makes us question whether local is even local at all as he tracks a "local" tomato in Quebec back to France, where the research and development associated with it was conducted, to China, where the seeds were grown, and back to France, where they were treated and shipped to Ontario to be sprouted, before the seedbeds were finally trucked to Quebec to be cultivated and harvested and labeled local. Everything has a Life Cycle Assessment (LCA) and we must learn to look beyond the label, learn more, favor changes, and inform others.

Cognition: Life Cycle Assessment (LCA) Awareness and Metacognition

While reading *Ecological Intelligence* (Goleman, 2009) I began to think differently about everything I did. Most often these thoughts involved a sense of doubt that my environmental actions served a purpose. During these times I realized that my ecological intelligence was lacking in many ways. At times this even led to a period of panic. One day I was on my usual run when this panic set in. I'm not sure if it was a truck or a bus or a series of cars that sent out the fumes that choked me, literally and figuratively. What if this act of running, something that is healthy and good for me, isn't good at all? Or worse, maybe my regular runs outdoors are counterproductive to my health. How much emission gas do I inhale while running on these streets? Do the benefits of running outweigh the harm of breathing in pollution? Exactly how much pollution do I breathe in on a single run? I didn't know. I simply didn't have the ecological intelligence, but what I did have was a higher level of consciousness that made me question the hidden consequences of my actions. In my panic I opened Goleman's book and read about something called Disability Adjusted Life Years (DALY) that "measures the amount of healthy life lost due to impacts from particulate emissions, toxins, etc." (p. 63). I knew it was up to me to do some research on emission absorption while running (know your impacts), make necessary changes (favor improvements), and share what I learned with other runners (share what you know).

It is this level of consciousness that I wanted the children to have, and after reading this I began questioning whether or not this was something we achieved at all. As I scanned over the semester I was flooded with examples of how we researched product origins and thought critically about the potential effects of our actions. I remember one young boy discussing the school's recent efforts to get children to walk to school. He said that while it was good they were walking to school, there was no difference in the distance the buses ran as they stayed on the same routes to pick up children who didn't walk. He suggested that they should sign up for those days so the buses would know how to change their routes and save in pollution. I suggested he share his thinking with the Principal. This is a great example of how easy it is to feel good about something (walking to school) when it actually has no favorable impact to the environment (although it does get children outdoors and exercising). It is easy to see how using Goleman's suggested model of know your impact (how much bus pollution can we save), make necessary changes (change the bus routes to accommodate for walkers), and inform others (share with the Principal, bus services, families, etc.) can lead towards collectivity and powerful change. On another day, and when discussing how far products travel before we purchase them, an insightful girl just got up from my group, walked over to get the globe, tracked the trip of a product from China to her home, and started estimating mileage. She walked around the room with the globe showing everyone and suggested that we use string to show the trip's distance. She later told her parents that they should be careful to buy only products labeled "Made in the USA." Not stopping at that, she suggested we buy fewer products and only buy things we absolutely need. This started a trend of children looking around their houses for items that they could recycle to make other items, for either simple fun or useful purposes. At this time I introduced the readings of various books that could help the children to discuss and further act on this new feeling of compassionate consumerism. During readings of *The Lorax* (Dr. Seuss, 1971) and *The Gift of Nothing* (McDonnell, 2009) the children engaged in critical discourse regarding the environmental impacts of consumerism and were able to apply the author's message to their own lives by thinking about, and listing, things they needed and things they did not.

These were great examples of children thinking about their ecological knowledge and actions (metacognition) and developing the basic awareness of life cycle assessments; that everything has a carbon footprint. Further, children demonstrated they understood collective action by the consistent sharing of what they learned. As they were developing the ability to see and share the interconnectedness between human activity and the flow of nature and make the necessary changes, they were becoming more ecologically intelligent. I realized that my fear of actually being counter-productive, causing the children to have an inflated and/or uneducated view of the impact of their actions, was unfounded. I believe we focused more on thinking beyond our actions than simply engaging in apparent go-green behavior. In fact, I once brought in a card with a picture of a polar bear and the saying "Everything is Connected." When I asked the children what this meant they said, in unspecific but clear terms, that everything we buy, eat, or use has created pollution somewhere and this affects everything; even the polar bear. Goleman cites Gregory Norris's reminder that everything is connected and his warning that "every product's life cycle is linked to the release of at least trace quantities of pollutants somewhere far back in the supply chain" (p. 64). This reminds us that, even if something says it is a green product, it still contributes to pollution. Goleman suggests that as we learn more about products' LCA we will be entering an era he calls "radical transparency" (p. 6). This new knowledge will impact how we shop, which in turn will dictate how products are made, all ultimately leading to positive change. These children were insightful in their thinking and on their way into this radical transparency era. Interestingly, the children also seemed to exhibit a natural desire to share what they had learned. Whenever an issue of environmental concern arose, the children would share with each other, their families, other classrooms, and beyond as they wrote numerous letters to companies, restaurants, politicians, and President Obama. They demanded to be heard and clearly saw the urgency in sharing their new information, as well as its potential to facilitate the necessary change.

I was able to make many other connections between Goleman's work and my own. I soon realized that he provided the language and rules of thinking, or protocol, for doing what I had started. So often when reading his book, my sabbatical experience came to mind. After reading *Ecological Intelligence* my first concern was whether or not I helped the children to think and know about life cycle assessments and be sufficiently informed to accurately know the impact of their actions. A second major connection I made had to do with the notion that empathy plays a critical role in environmental education, action, and care. This has always been evident and a concern to me as I set out to accomplish my goals. My objective was to cradle children's natural sense of empathy and use it to empower them rather than disempower by filling them with sadness and fear.

Empathy: Interactions and Feelings

While the cognitive abilities to identify, understand, and problem-solve the interconnectedness between human activity and nature is an important aspect of being ecologically intelligent, ecological intelligence must "meld these cognitive skills with empathy for all of life" (Goleman, 2009, p. 44). In his earlier works, Goleman (2006, 2007) suggests that, in addition to cognitive intelligence, people must develop their emotional intelligence and their social intelligence, respectively, as this would allow them to better understand the perspectives of others and demonstrate motivation, empathy, and compassion. Howard Gardner (2006) also pluralizes intelligence and suggests that there are numerous forms of intelligence that, depending on one's life experiences, can become strengths or weaknesses. Gardner suggests that those who develop a positive sense of nature have an ability to connect with nature and a deep sense of empathy for the earth; a naturalistic intelligence. Goleman (2009) sees this as a necessity to ecological intelligence and writes: "We display such empathy whenever we feel distress at a sign of the 'pain' of the planet or resolve to make things better." (p. 44).

Upon entering my research I was explicit in my intention to help children tap into their sense of empathy and use it as a motivator to be change agents. Since children are too often disconnected from the environment, I expected to see what Richard Louv (2005) calls nature deficit disorder, which involves "the human costs of alienation from nature" (p. 34). These children had limited regular interactions with nature. They often reported not having a favorite place outside to play and instead stated indoor activities as being typical. In fact, some children stated that they either do not like, or are not allowed to go, outside. Clearly, increasing children's connection to nature would be important in establishing empathy towards environmental care. We must facilitate this personal relationship with nature as "we no longer can rely on our astute attunement to our natural world nor the passing on through generations of the local wisdom that lets native peoples find ways to live in harmony with their patch of the planet" (Goleman, 2009, p. 45).

Interestingly enough, children's literature played a big role in heightening children's awareness of different aspects of nature. For example, after enjoying a reading of Patricia MacLachlan's (1994) book *All the Places to Love*, in which the characters go to, and share, their favorite places to love outdoors in a beautiful poetic prose, we went outside with science observation journals to investigate and get to know nature. The connections that children made between nature in the book and the nature they were experiencing were powerful. The book reading seemed to make the children keenly aware of the sights, sounds, and smells of nature. What I quickly learned as these children became aware of, and interested in, the natural world around them was they were equally aware and deeply concerned with the state of the environment. These children clearly felt "distressed at the 'pain' of the planet" and had an incredibly strong "resolve to make things better" (Goleman, 2009, p. 44).

I also learned that their emotional responses needed an audience, that they needed to talk about these feelings of concern, and that they needed help to focus these emotions. This was exactly what I set out to do. If left unattended, these observations and concerns could eventually lead to a sense of disempowerment and disconnect. Often times we discuss big issues with children but don't allow for the time to bring their feelings full circle. For instance, when we were out we saw a tremendous amount of garbage in the woods. The children were immediately perplexed as to why someone would throw garbage there. They needed to share their feelings, to have time to talk about their concerns. They then needed to take action, to organize picking it up. They decided next that it would be important to let other people know why we should not litter and make an appeal to people to stop such behavior. To me, asking children to notice the garbage but then not give them the space and time to move through this process could be disempowering, in the least.

These were all important steps in developing ecological intelligence, and their deep feelings of empathy motivated them to become change agents. These children set out to work together towards the greater good (in fact, they gave up their recess time to do so). They understood the importance, and principles, of collective action. Most importantly, they believed their actions could make a difference. These children already knew what Colin Beavan (2009) learned after spending a year attempting to "save the planet." He concluded that while we must pay more attention to educating ourselves on the state of the earth and the impact of our actions, before we do we have to actually believe that we can make a difference. Beavan states: "That, by the way, is one of the most important results of the project: that I've come to believe that I can make a difference" (p. 223). A second conclusion he made is that changing the people around him was the "unforeseen consequence of individual action" (p. 224) and it is by changing ourselves and sharing what we know that "we can change the people around us" (p. 224). These children already seemed to understand these concepts of self-efficacy and collectivity that took Beavan a long, hard year to discover or confirm.

Conclusion

The notion of radical transparency implies that we are given a great amount of data based on scientific findings that can help us to know what is safe and to make wise decisions as consumers (Goleman, 2009). It is Goleman's perspective that "what eventually may become a learned emotional reaction must begin with intellectual comprehension" (p. 47). The students in this second-grade classroom are well on their way to building, sharing, and acting on this knowledge. We all need to become better researchers and trace the history, or LCA, of the products we buy and be diligent in finding ways to share this information. We, like these children, have to engage in this on-going process to be compassionate and smart consumers and to engage in activities that have the least negative impact on our environment. If Goleman is correct, as our store of information grows so will our emotional response, and personally, I have found this to be true. If nothing else, what I have learned from these young children is the power of caring, of empathy, and of compassion. Vivian Paley, an early childhood educator/writer once said: "The role of the teacher is to be nice; to set the model for niceness; to be nice to all children all the time. This allows children to take the risk of being nice themselves" (Bullard, Carnes, Hofer, Polk, & Hernandez Sheets, 1997). I wonder; if it is a risk to be nice to each other, is it an even greater risk to be nice to the earth? Yet, I know firsthand that even very young children understand what is, and what is not, fair. They understand social justice and they feel empathy. Children can, and should, be a model for us. Let us allow this to be the motivation to increase our ecological intelligence, move into the era of radical transparency, and use consumer power to change our relationship to our planet. We don't have to be drastic and strive to obtain "no impact" status, but we do need to act soon, as Goleman suggests: "A boost in ecological intelligence seems essential for our species to adapt to the singular challenges of these times" (p. 246). Yes, time is of the essence. Let's not only be deliberate in sharing all that we know with the children in our lives, but listen to them carefully as it appears they are emotionally wise, intellectually capable, and highly motivated to work together towards change.

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