Volume 5, Issue 4 - 2006

THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

# Did you Know?

### *Annoying Mobile Phone Users*

There is no need to speak so loudly, and annoy those around us, when using a mobile phone. We tend to do so because we are used to using landline phones which employ a technology called side tone, where part of the signal from your mouthpiece is sent to your earpiece. Because we can hear our own voice, we tend to adjust our voice level to match our listening level. However, mobiles don't have side tone. Because we can't hear what we are saying in the earpiece, we tend to think we need to speak louder. Another reason for mobile users speaking loudly is that the earpiece is not being held directly to the ear. Because the sound from the earpiece then sounds softer than it really is, the user thinks he or she needs to shout.

In any case, shouting into a mobile phone makes no difference to what is heard by a receiver, because mobiles typically have a technology called automatic gain control (AGC). If you shout, the AGC reduces the signal from the mouthpiece, and if you whisper, the AGC amplifies this signal. Speaking with a normal voice level, during which time the AGC will be largely inactive, produces the same listening effect for the receiver. To reduce the effect of background noise, simply bring the mobile phone mouthpiece closer to your mouth (which increases the level of your voice relative to the background level) and/or wrap a hand around the mouthpiece to shield it from the background noise.

*Source*

Kruszelnicki, K. (2006). *It ain't necessarily so . . . bro*. Sydney: HarperCollins*Publishers*.

# The Magic Liquid: A Science Story About Acids and Bases

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***Abstract***

A science story can teach pupils about scientific phenomena in an indirect way. While this story involves animals, the danger that it exposes applies equally to humans.

***Introduction***

Children of all ages find stories interesting, and stories can provide a good way to teach children the content of different subjects and to explain phenomena (Howe, 1993; Huck, 2003). A story can create enthusiasm in children and stimulate them to learn. It can also promote the functional perception of information and improve the skills of scientific thinking among children (Bliss, 1995).

The teacher is advised not to exaggerate the imaginative points in a story, and to ask clever questions at the end that lead to appropriate conclusions. The teacher's role is highly significant in guiding children and assisting them to understand the events and theme of a story through effective ways of thinking.

The following story provides a way for students to learn about materials that look similar, and is an alternative to the approach that uses the senses of taste or smell (Hugerat & Basheer, 2001). The focus is the scientific idea that not all materials having a similar appearance are necessarily the same. A person must therefore be very careful.

***The Story***

The Magic Liquid

The farm of uncle Sami is beautiful. It is green all over, with lots of colored flowers. In the farm, a dog, a cat, ducks, geese, and hens live peacefully. Uncle Sami wakes up early, works hard in his farm, cultivates the land, waters the vegetables, and feeds the animals.

One day, uncle Sami felt severe pain in his feet that made him stay in bed. The dog called all the farm animals for a meeting in order to help uncle Sami in running the farm jobs. The hen Lulo gathered her chicks and said: "I am going to look for grain in the surrounding fields. Please, stay inside the farm with the dog and the cat." She pointed to the troublesome chick and said: "You make sure to stay with your siblings and near the pen." The chicks replied: "We promise you, Mammy."

The chicks began to hop around, and the cat started to meow. Suddenly, the cat noticed that the troublesome chick was not present. She rushed to look for him. She heard a cry. "It is the troublesome chick!" the cat said. She went toward the sound and there he was. The troublesome chick was coughing and crying: "Ku . . Ku . . Ku." "What happened to you?" the cat asked. "I felt thirsty; I went to look for water and . . . ." Before he could even finish his sentence, he fell on the ground.

"Help! Help!" the cat screamed. Everyone in the farm hurried to help. They knew the chick was in some kind of danger. The rooster, who was a doctor, came over and examined him. He recommended transferring the chick to the hospital. The hen felt very sad and prayed to God to be merciful for her little chick. The chick remained 3 days in the intensive care unit.

After 1 whole week, he recovered and came home safely to the farm. Everyone in the farm came to congratulate the little chick on his recovery. Dr Rooster stood and asked everyone to pay attention. He brought three glasses filled with clear liquid and asked: "What do you see inside the glasses?"

All of them were surprised by his question. They began to whisper between themselves: "Of course, water! All the glasses are filled with water!" Dr Rooster then asked the rabbit to put some leaves of red cabbage in a glass filled with boiling water. The color of the liquid turned purple, and Dr Rooster poured a few drops of the purple liquid into the three glasses. Wow! Everyone screamed loudly. "Purple . . . red . . . green!" Dr Rooster is a great magician.

Dr Rooster replied in a loud voice: "No, no, I am no magician. The cabbage's purple liquid is an indicator. It shows the nature of the clear liquid. Look carefully! The purple color has not changed in the first glass, because it has water in it and water is neutral. But it has changed in the other two glasses. This shows that the liquids in the other two glasses are not water. We obtained a red color in the acidic liquid (vinegar) and a green color in the alkaline liquid (baking soda solution). Therefore, we must not be deceived and think that every clear liquid is water. This is what happened to our friend, the troublesome chick. The clear liquid he drank was not water. It was one of the dangerous pesticides that Uncle Sami uses on the farm." Dr Rooster added in a firm voice: "My dear friends, you must be very careful when you drink, because **not every clear liquid is water**!"

### *Using the Story*

The story provides an indirect way for children to learn new information. The presentation of this story, which warns against drinking any clear liquid, could be tailored to fit a wide range of ages; 5- to 15-year-olds, say. The story might also form the basis of a game to be played or a drama to be acted out in the classroom.

Some children will also learn that it is not so good to be like the troublesome chick, and that you should therefore listen to the advice of adults and be careful not to touch strange or unknown things. Some will appreciate the good role model of Dr Rooster in helping other people.

The science story can activate the imagination of the child and support new elements of imagination. In this story, in which the animals behave like people, the child makes the connection between imagination and reality. Children of all ages adore stories, and science stories are a valuable tool for teaching aspects of scientific knowledge.

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# The "Magical" Sphere: Uncovering the Secret


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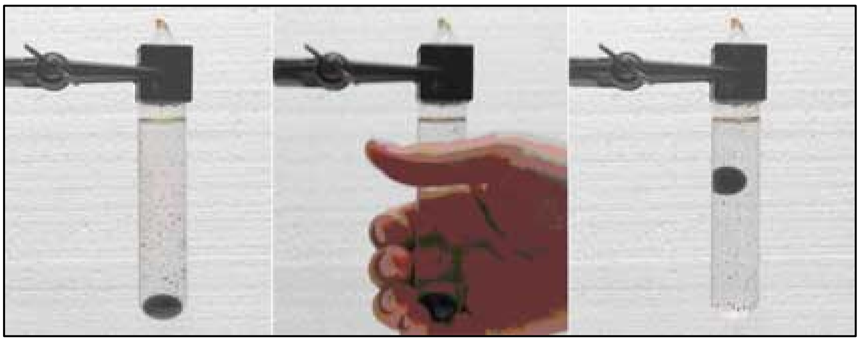
### *Abstract*

A red sphere is seen at the bottom of a sealed glass tube filled with a colorless, transparent liquid. Holding the tube for a short period makes the sphere rise slowly from the bottom until it finally floats on the surface of the liquid. Instructions for preparing the demonstration are given, together with an explanation of the phenomenon. A similarity with the Galileo thermometer is pointed to. An example of guiding the discussion with students in the course of uncovering the secret behind the behaviour of the sphere is also given in the form of Socratic dialogue, relying on carefully selected questions that stimulate the students to think in a scientific way. The latter may also serve as an example of a teacher's approach during inquiry-based learning.


### *The "Magical" Sphere Demonstration*

A sealed tube containing a transparent, colourless liquid was fastened on a stand. A red sphere could be seen at the bottom of the tube (Figure 1a). Students were invited to observe it for a minute or so.

The "magician" (instructor) approached the demonstration table and announced that he will make the sphere float in the liquid. He placed his hand over the lower part of the tube, where the red sphere was at rest, and held it for about 15 seconds (Figure 1b). The magician removed his hand from the tube. The audience witnessed the red sphere moving slowly through the colourless liquid, towards the top of the tube (Figure 1c). “True magic, isn't it?” concluded the magician. The instructor then initiated discussion with the students aimed at answering the questions: (1) What is inside the tube? (2) How does it work?



(a) (b) (c)

*Figure 1*. The red sphere rests at the bottom of a sealed tube (a). After holding the tube for about 15 seconds (b), the sphere slowly rises (c).

### *Construction Details*

The sealed tube is made of a large test-tube. First, by strong heating (Bunsen burner was used), the open end of the test tube was stretched and partially closed to form a narrow-neck ampoule. The ampoule was about two-thirds filled with a water solution of ammonium chloride (although ordinary salt [sodium chloride] could also be used as a much cheaper and more readily available alternative) and about 1 to 1.5 mL of liquid aniline was added.

The concentration of the ammonium chloride solution was chosen so that its density was just slightly lower than the density of liquid aniline. The easiest way to accomplish this would be to first prepare a solution of ammonium chloride with $w(NH_4Cl) = 9$ %, or a solution of sodium chloride with $w(NaCl) = 4$ %. This solution is then carefully diluted until its density is such that the pink aniline sphere slowly sinks to the bottom of the ampoule. Finally, the ampoule is sealed using the Bunsen burner.

### *Explanation of the Phenomenon*

The density of pure aniline ($\rho \approx 1.02$ g cm$^{-3}$) is somewhat higher than the density of pure water ($\rho \approx 1.00$ g cm$^{-3}$) (Weast, 1987). However, upon dissolving salts (like the above mentioned ammonium chloride or sodium chloride) in water, the density of the solution increases. It is thus fairly easy to prepare a water solution of table salt that will be of slightly lower density than the added aniline. The aniline, having the shape of a slightly deformed sphere, will sink to the bottom of the vessel.

When the liquids are warmed slightly, things change gradually, with the densities of both the water solution of salt and aniline decreasing. However, the rates of these changes are markedly different. For temperatures close to room temperature (≈ 20 °C), there exist data (e.g., Engineers Edge, 2006) that enable one to calculate the temperature coefficients of the densities,

$$\frac{\Delta\rho_{\text{water}}}{\Delta T} \approx -0.2\ \text{mg cm}^{-3}\ \text{K}^{-1} \quad \text{and} \quad \frac{\Delta\rho_{\text{aniline}}}{\Delta T} \approx -0.9\ \text{mg cm}^{-3}\ \text{K}^{-1}.$$

This means that, if initially $\rho_{\text{water}} < \rho_{\text{aniline}}$, a temperature change of a few degrees might result in $\rho_{\text{water}} > \rho_{\text{aniline}}$, and the red sphere (aniline) will slowly rise and travel through the solution until it eventually reaches the top.

The phenomenon bears resemblance with the Galileo thermometer (Figure 2). The Galileo thermometer is a sealed glass cylinder (height ≈ 30 to 35 cm and diameter ≈ 4 to 5 cm). It is filled with a non-toxic liquid (mineral oil) of practically uniform density (an excellent approximation, given that liquids are practically incompressible). There are multi-coloured globes inside the thermometer (they all have the same volume and shape, but each one is of different weight). The globes have gold tags that read the temperature in 2 °C increments. As the temperature increases, the density of the surrounding liquid decreases and the globes sink, one by one, to the bottom of the vessel, a behaviour opposite to that described in the present demonstration.

### *Hints for the Discussion*

There are virtually unlimited possibilities as to how the ensuing discussion might be guided in the classroom, including asking students to describe what they see, propose possible reasons behind the phenomenon, make decisions, and draw conclusions. The idea is to keep the information given to students to a bare minimum, so that they are "forced" to think about the problem (the "magic") and to arrive at an explanation. The text that follows provides an example. For simplicity, it is presented in the form of a conversation between the instructor and a student, although in reality an instructor would be interacting with a group of students.

*Figure 2*. A Galileo thermometer.

*Instructor*: Alright. Let's try now to look "behind the magic." First, can you describe what we saw?
*Student*: Yes. Soon after you put your hand over the tube, the sphere started to rise.
*Instructor*: Correct. Now, what does it mean?
*Student*: Well . . . I'm not sure, what is the question?
*Instructor*: The sphere rests at the bottom, in the beginning of the "magic." Right?
*Student*: Right.
*Instructor*: So, what about its density? Is it higher or lower than the density of the surrounding liquid?
*Student*: It must be higher.
*Instructor*: And after I removed my hand, the sphere slowly rose. Can you explain that?
*Student*: Well, it must have changed somehow and its density is lower now . . . .

*Instructor*: Correct again. Look now at the transparent liquid in the tube. Any idea what it is?
*Student*: It is colourless . . . might be water?
*Instructor*: It might be. But can you tell water from sugar solution?
*Student*: I can, by taste. But not by sight . . . so it could be a solution of sugar.
*Instructor*: It surely could be. It could also be a solution of salt, or for that matter of any colourless material. This one here is a solution of salt. What about the red sphere?
*Student*: It is obvious now that it is also a liquid . . . we could not be sure about it when it was sinking and moving through the liquid. But it is coloured.
*Instructor*: Any idea about its nature?
*Student*: Sorry, I have no clue.
*Instructor*: Is it possible that it is also water? Coloured water?
*Student*: Yes, it could . . . No! It can't be. Coloured water would mix with the other water and soon it would become pink.
*Instructor*: Very good. Now, would you agree if I say that it is some liquid that is not miscible with water?
*Student*: I think I would.
*Instructor*: OK. The liquid is called aniline. It is used in the production of dyes. Now, what can we say about the temperature effect on liquids?
*Student*: They are heated?
*Instructor*: Actually, when liquids are heated, their temperature increases. But what is the effect of the temperature?
*Student*: I don't understand the question.
*Instructor*: Think about a common thermometer. A mercury or alcohol one will do. What do you see when you heat the thermometer? How can you confirm that the temperature really increases?
*Student*: Oh, you mean the liquid expands?
*Instructor*: I mean exactly that. Now, upon expansion, will the mass of the liquid change?
*Student*: No. It is just its volume becoming larger.
*Instructor*: And what about its density? Does it change?
*Student*: The density is the ratio of the mass to the volume. And the mass is a constant . . . so the density actually decreases.
*Instructor*: Excellent! That was the point. It is quite a general rule that the density of a liquid decreases upon heating. The important exception is water, in the temperature interval between 0 and 4 °C. Are you familiar with that?
*Student*: Sure. Actually, this is the known anomaly of water. It makes life possible in water during cold periods, because below the ice there is liquid water.
*Instructor*: Right. Now, back to our problem. Knowing that the density of a liquid decreases upon heating, can you offer some explanation of what we saw?
*Student*: I think I can. Your hand had the role of a heater. Upon heating, the density of the red liquid decreases and it moves upward.
*Instructor*: That is almost perfect. However, there is another liquid in the tube; the solution of salt surrounding the aniline sphere. Don't you expect that this liquid will also expand upon heating?
*Student*: Hmmm . . . yes I would. But if both liquids expand, then the density of both will decrease.
*Instructor*: Very well. Please continue.
*Student*: In that case, the density of aniline will still be higher than the density of the water solution of salt, unless . . . .
*Instructor*: Unless?
*Student*: Is it possible that the density of aniline decreases more than the density of the solution?

*Instructor*: Surely it is possible! And this is actually the solution here. Well done!

*Note*: A video-clip of the demonstration (~ 6.5 Mb) is available upon request from the authors.

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# Critical Incident

## *An Invitation*

Readers are invited to send, to the Editor at editor@ScienceEducationReview.com , a summary of a critical incident in which you have been involved. A critical incident is an event, or situation, that marks a significant turning point, or change, for a teacher. The majority of critical incidents are not dramatic or obvious, but are rendered critical through the analysis of the teacher (see Volume 3, p. 13 for further detail). You might describe the educational context and the incident (please use pseudonyms), analyse the incident (e.g., provide reasons to explain your observations), and reflect on the impact the incident made on your views about the learning and teaching process. Upon request, authors may remain anonymous.

We have undoubtedly all done things about which we were very pleased, and perhaps done other things about which we did not feel so pleased, and we all need to remain reflexive of our practice. While teachers will view an incident through the lenses of their own professional experiences, and may therefore explain it differently, this does not detract from the potential benefits to be gained from our willingness to share our experiences and thus better inform the practice of other teachers.

## *A Critical Incident Leads to Classroom Success With "Homebrew" Radio Kits*


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After reading the definition of a critical incident is a pervious edition of *The Science Education Review*, I recalled several events of this kind that took place during my teaching career. These events changed not only the way I teach, but also the way I view the process of teaching. In this article, I'll describe the most recent such critical incident, during a unit on electricity and magnetism pedagogy, when a student told me: "I'll never understand this!" Perhaps something similar has happened to you.

*The instructional context.* The elementary education students in my teaching methods classes generally feel the least comfortable about their content knowledge and teaching abilities in the physical sciences. Much like the well-known phenomenon of math anxiety, I've observed over the years that many elementary education students have science anxiety, particularly in regard to anything they consider to be in the arena of the physical sciences. It was not a surprise to me to find that physical sciences are the least taught science topic in elementary schools in the United States, a phenomenon evident to both educational researchers and casual observers. Thus, I make it one of my personal instructional goals to engage elementary education students in learning physical science content and pedagogy via interesting, hands-on activities in the hope that they will be more willing to teach it themselves.

While working with activities in a unit on teaching electricity and magnetism, I decided to extend our inquiry into the area of electromagnetism. To do this, I thought we could study how a simple radio receiver works, since it is a device for detecting electromagnetic energy in the form of radio waves and transforming it to an observable form of energy. I asked students, working as a class, to develop a concept map on how a radio works. Starting with this concept, I added and linked terms they associated with how a radio works to our class map. The results of this class concept map were revealing. While the students were able to add terms like AM/FM, speaker, radio station, music, speaker, and tuning dial to the concept map, essential elements about how a radio works were missing. Further interviews with the students revealed none of them were able to accurately explain how a radio works, even in a basic way. The concept map the students developed, and the explanations they offered, lacked reference to electromagnetic radiation and how it was captured and transformed by a radio receiver. Further, other than the speaker and tuning dial, they made no reference to the fundamental components of a radio receiver.

*The instructional problem and first solution*. This lead to the instructional problem of how to engage my elementary education students in learning how a radio receiver works in a way they could use to teach their own future students. I wanted to avoid using only abstract presentations of the concept of how a radio receiver works, such as verbal explanations or extensive readings from textbooks or Internet websites. So I decided I would have the students build and test their own radio receivers. I located some suitable crystal radio kits that could be purchased for around 6 USD each. These kits included all the parts, step-by-step assembly instructions, and a brief explanation of the theory of operation of a radio receiver. Great, I thought; now they can build the kits and learn how the kits work.

I bought a couple of cases of the kits and anxiously awaited their arrival. When the kits arrived, I built and tested one myself. I found that a much more substantial antenna and ground system was needed than that provided in the kit. But with a suitable antenna system, the receiver seemed to work well indeed. So to prepare for the lesson, I strung a long antenna wire out a third-floor window of the school building and connected a ground wire to a copper cold water pipe under the sink in the classroom. Now everything was set up for the students to build and test the radio kits.

When the lesson got underway, I found that the students, working in groups of 3 or 4, were able to build the radio kits in about 30 minutes or so. They positioned and connected the radio components (tuning capacitor, ferrite bar, diode) to its chassis per directions and completed the wiring without difficulty. One-by-one, each group tested their crystal radio by hooking it up to the antenna and ground system and an earpiece. Some radios didn't work at first, but the students were able to quickly repair them by comparing the non-working sets to working ones. Eventually students in each group were able to tune in and listen to several local AM broadcast stations on their crystal radio. I gave the groups additional class time to read and discuss the theory of operation information that came with the kits and try to develop an explanation of how a radio works. As a homework assignment, they were also asked to do Internet research on how a radio works.

*The critical incident*. Students really enjoyed building the radios. The activity met affective and process objectives of the lesson beyond my expectations. So, were the students able to develop an explanation of how a radio works based on the kit-building lesson and related homework; in other words, were the content objectives of the lesson met? The answer, to my surprise, was a resounding NO. In fact, one student told me she "could build and study 10 of the kits and still not have a clue about how a radio works." Then she added with assurance: "I'll never understand this!" Her statements were for me the critical incident watershed.

Was the student right? If so, how could I improve my teaching so that students would learn how a radio works via a hands-on activity instructional approach? To investigate these questions, I had another class of elementary education students build the crystal radio kits and this time carefully observed their reactions. Building the kits did not seem to help the students in the second class any more than it did those in the first class. Even when they completed building the kits, the crystal radios seemed only to be a confusing jumble of strange parts to the students. The theory of operation information provided with the kits didn't seem to help the students learn how a radio works either. Evidently, they were missing some important fundamental ideas. Students didn't seem to view the radio as an electrical circuit nor could they trace the flow of, and change of, energy through the crystal radio. The functions of the components of the radio was not evident to them as a result of their kit building experience, nor did they see the radio, antenna, ground system, and earpiece as parts of a complete system.

It was apparent to me by this time that the commercially purchased kits were not adequate as initial teaching tools on how a radio works. I decided the radios students built needed to be simplified, using as few parts as possible. Based on an Internet search of crystal radio designs, I fashioned a plan for a "homebrew" radio kit using only three essential components (apart from the antenna, ground system, and earphone): a coil, diode, and a tuning arm. The coil is made by winding magnet wire numerous times around a cardboard paper roll, the tuning arm is a piece of aluminum flashing cut into a 2 cm by 10 cm strip, and the diode is a semiconductor that is purchased. These components can be mounted on a wooden, or thick cardboard, base using pushpins or small screws. You can find many similar designs on the Internet. I suggest you look at a website like that of The Xtal Set Society (2006) as a starting point.

*Success with homebrew kits*. So what instructional results did I get with the simplified, homebrew radio kits? Had the challenge posed to me during the critical incident been met? Would students indeed learn how a radio works when using the simplified crystal radio kits?

Students found it easier to build and diagnose problems with the homebrew radio kits. These kits were also preferable as initial models for learning about how a radio works. When a homebrew radio kit is assembled, students can trace, with the point of a pencil, the flow of current through the radio circuit from antenna to ground. Electromagnetic radiation passing through the antenna induces a current in the antenna wire. This current is "pulled" from the antenna into the coil and through the diode to ground. This is a fundamental idea they did not gather from the commercial kit. The number and locations of wires in the commercial kit made tracing this current difficult to do.

Students were also more easily able to focus on the two major components in the homebrew kits; the coil and the diode. They related rather easily to the large coils they constructed as devices that "ring" with radio frequency energy like a tuning fork rings to produce sound energy. And having previously worked with diodes in simple circuits, they knew the action of diodes as one-way gates, in this case cutting the radio frequency wave in half allowing for extraction of transmitted voice or music. With these things in mind, and after reviewing and discussing radio theory of operation information included with the original commercial kits, students were able to make reasonable explanations of how a radio works. Frankly, I'd never been able to help them get that far without the critical incident experience and the resulting homebrew radio kits that were developed.

*More success with homebrew kits*. With the success using the homebrew crystal radio kits I've moved on to developing and using other simplified kits that demonstrate the abstract and somewhat difficult concept of electromagnetism. Recently my elementary education students have been building pie pan speakers, from aluminum pie pans, magnets, and coiled magnet wire. The pie pan speakers allow students to observe the operation of a simplified speaker system first hand, and even test the effects of variables in the system by altering components such as container and coil size. The homebrew speaker kits have also recently been used in an area middle school classroom with good results. Our next project is to build a simplified electric motor kit as we've found some of the commercial educational motor kits to be tedious and touchy to build leading to more frustration rather than learning.

Perhaps you have some ideas for homebrew science kits you can develop to use in your classroom. Focus on designing a kit that illustrates a science concept, one that students can build from simple materials and one that uses the fewest possible number of parts. Incorporate in your lesson elements such as group work, various informational resources, guiding questions and concept mapping to facilitate student learning. If your experience is anything like ours this will be a thought provoking and enjoyable experience for both you and your students.

*Reference*

The Xtal Set Society. (2006). *The Xtal Set Society*. Retrieved October 10, 2006, from http://www.midnightscience.com/ .

# 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 .

## Nanotechnology

Nanotechnology is as small as ever,
The people who invented it must be clever!
Doctors will use nanotechnology to cure,
And people will feel healthy and pure.

People's windows will clean themselves,
So will microwaves, ovens and shelves!
These little things will clean the lot,
Appliances will be spick and span, won't
miss a spot!

Now down to a logical matter,
Not all that girly housework chatter.
If we learn about nanotechnology in schools,

## Ode to Nuclear Fusion

The second isotope of hydrogen is deuterium
When reacted with tritium, it makes helium
The energy released
Is enough to wake the deceased
But it doesn't make beryllium.

This process is known as nuclear fusion
If you're not careful it might give you a contusion
It's extremely efficient
Unless its deuterium deficient
And that's hardly an illusion.

Deuterium diffusion
May cause confusion

We will improve our materials and tools.

*Sarah England, 11 years*
*Australia*

In this way water
May power a mortar
Through deuterium-tritium nuclear infusion.

Though this process appears in stars
It doesn't appear on Mars
It is hard to understand
And difficult to command
But maybe one day we'll use it in cars.

*Chris Ryba, 13 years*
*Australia*

# To What Extent can Concept Mapping Motivate Students to Take a More Meaningful Approach to Learning Biology?

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***Abstract***

Concept mapping was investigated as a learning strategy to motivate 82 high-ability, 10th-grade students to take a more meaningful approach to learning biology. The study employed a quasi-experimental, pre-post mixed methodology design to assess the relationship between concept-mapping proficiency and changes in motivational and learning strategies use profiles using the Motivated Strategies For Learning Questionnaire (MSLQ). The qualitative and quantitative findings suggest a mixed motivational response by learners in taking a more meaningful approach to learning biology using concept mapping. Specifically, the findings revealed that concept mapping may play a supportive role in contributing to a more meaningful approach to learning biology, as indicated by positive and statistically significant effects on students' test performance, as well as adaptive and statistically significant fall-to-spring changes in motivational and learning strategy use profiles in direct relation to the level of mapping proficiency. This dichotomous relationship appears to be a consequence of whether learners' perceive that concept mapping can provide them with a more effective learning strategy than those utilized in the past and, more importantly, upon their willingness to put in the requisite time and effort to develop proficiency in using mapping to take a more self-regulated and meaningful approach to their learning. Thus, it behooves the educator interested in using concept mapping to consider students' receptiveness to using concept mapping and encourage them to perceive the value of becoming sufficiently proficient in its use.

To read the full text of this article (23 pages), please **click here**.

# Influencing College Chemistry Success Through High School Chemistry Teaching

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### *Abstract*

The connection between high school chemistry pedagogical experiences and introductory college chemistry performance has been a topic researched in published science education literature since the 1920s. However, analysis techniques have limited the generalizability of these results. This review discusses the findings of a large-scale, multi-institutional research study addressing many of these previous limitations. The findings reveal that high school experiences are significantly associated with college performance. The implications indicate that high school chemistry teachers may have a positive impact in preparing their students for future success in introductory-level college chemistry. (This paper is a summary of Tai, Sadler, & Loehr, 2005)

### *Introduction*

Preparation for college is a goal shared by many high school students and their high school teachers. For many teachers, preparation for introductory college science is an important consideration in their decisions about what and how to teach. An analysis of trends in college performance associated with particular high school teaching and learning experiences may therefore offer some insights for high school teachers seeking better preparation of their students for introductory college chemistry courses as one of their instructional goals. In fact, this connection has been explored in chemical education research as early as the 1920s, in the *Journal of Chemical Education*. However, despite repeated analyses of this connection over the past 9 decades, the existing studies typically studied only students at a single college or university, making the results specific to these particular college courses.

To address this issue, we performed a study that surveyed 1,531 introductory college chemistry students from 12 different baccalaureate-granting colleges and universities from across the United States (Tai, Sadler, & Loehr, 2005). Using a statistical technique called multiple linear regression analysis with course-wise identifiers to account for differences in grading practices across colleges, we were able to account for students' demographic differences to offer results that are a step closer than previously existing research. For those readers seeking more details regarding our research study and analytical approach, please refer to our published study. In this manuscript, we offer a discussion of our findings and their implications for high school chemistry teaching and learning.

### *Overview of Our Data Set*

We begin with a brief overview of the data we used to perform our analysis. We administered a self-report survey to introductory college chemistry students, asking them about their high school chemistry learning experiences. This survey technique took advantage of two important characteristics of introductory college chemistry students. First, students were surveyed during their college chemistry course time, a period of time in which the relevance of the questions we were asking them on the survey was evident and in many cases at the forefront of their minds. Second, students were surveyed in the Fall semester, which for 63 % of our survey participants was their first semester in college and therefore the earliest time possible between high school chemistry experiences and college chemistry performance.

As the outcome for our study, we chose to use final course grades which were provided by the students' college instructors. While grades are certainly limited in their capacity to reflect deep understanding, there is little doubt regarding their impact on students' future career options. This fact is readily apparent to all students taking introductory college science courses in general and, as a result, we expect that most students will make concerted efforts to succeed in these courses. Since we surveyed 12 different colleges, we needed to account for differences in grading practices across schools. We accomplished this task by including a variable in our analysis to absorb these institutional differences, a technique common to the analytical approach we chose for our study. In the end, nearly 60 % of the students in our survey were from highly-selective colleges (based on institutional, standardized, admissions test scores), 87 % were enrolled in public colleges, and 67 % were from colleges enrolling more than 15,000 undergraduate students.

With regard to student demographics, our sample was 53 % female, 64 % Freshman, and 74 % white. In terms of high school mathematics backgrounds, 52 % of our surveyed students had taken some form of high school calculus.

### *Findings and Implications*

Next, we turn our attention to the primary analysis searching for associations between high school chemistry pedagogical experiences and college chemistry performance. Here we used statistical techniques that allow for inferential analysis, which means that our findings may be interpreted in term of associations and trends between the outcome variable (introductory college chemistry final grades) and the predictor variables that included both the student background variables discussed in the previous section and the high school chemistry pedagogical experiences, to follow. Simultaneously accounting for a variety of predictors in a model of college grades offers the opportunity to compare the relative impact of the predictors on their capacity to inform the outcome. However, the approach we took in this analysis offers a broad, comparative overview of these predictors. For a more in-depth statistical analysis, offering greater detail on the associations between college performance and high school chemistry experiences, we have undertaken more focused analyses (Tai & Sadler, 2006; Tai, Sadler, & Mintzes, 2006; Tai, Ward, & Sadler, 2006).

Our survey asked students a variety of questions regarding their instructional experiences in high school chemistry that included practical work, independent projects, typical quantity and type of assigned problems, and high school chemistry content. After developing a set of significant predictors based on students' demographic and general educational backgrounds, we included variables accounting for these particular instructional experiences. Our final statistical model included 10 variables describing various pedagogical experiences in high school, which fall into 5 areas which we label in this manuscript as 1) general classroom instruction, 2) practical work and laboratory experiences, 3) independent projects, 4) problems on assignments and tests, and 5) chemistry content topics.

*Concerning general classroom instruction.* In this category, we considered several different overarching approaches to instruction and daily classroom practice. This category represents a mix of pedagogical practices that did not appear to us to fit neatly into the other four categories. Our survey queried students on how frequently they recalled working in groups, individually, or as a whole class. Our analysis revealed that students who reported working more frequently on an individual basis were predicted to earn lower college grades, while differences in frequencies related to group work and whole-class work did not appear to be significant. In addition, we asked students to report on the emphasis their high school class placed on rote memorization of facts versus development of full understanding of concepts. We found that students reporting a focus on the development of full understanding of concepts were more likely to earn higher college grades, while high school courses emphasizing rote memorization typically earned lower grades.

*Practical work and laboratory experiences.* Our analysis of practical work included a variety of different pedagogical approaches. We considered the various instructional phases of practical work and developed survey questions to pursue student experiences in these areas. We began with general aspects such as the typical number of laboratory experiences student recalled having each month. In our understanding, most high school science teachers typically follow patterns in their practice, choosing to use similar procedures in introducing, carrying through, and debriefing from laboratory activities. As a result, we asked questions regarding the implementation of laboratory experiences beginning with preparation and proceeding through to debriefing and post-laboratory activities.

Our analysis revealed three variables significantly associated with college performance: reading and discussing lab procedures the day before, students' reported understanding of laboratory procedures, and frequency of repeating laboratories for furthering understanding. The first two variables reveal an emphasis on practical work procedures in high school chemistry and the results indicated that students reporting greater emphasis on procedure tended to have lower grades in introductory college chemistry. On the other hand, students reporting greater frequencies of repeating labs to enhance understanding tended to earn higher college grades.

*Independent projects.* Our survey included questions aimed at gathering information on the frequency of independent projects in high school chemistry. We found that students reported being assigned greater numbers of independent projects typically earned lower grades in college chemistry. This result should give pause to teachers seeking to shift their teaching practices to emphasize project work over teacher-guided learning. However, this result is not evidence that independent projects are somehow counter productive experiences for students in their preparation for college chemistry. Instead, a general trend of lower performance with greater frequency of independent projects indicates that we should turn our attention toward how independent projects are implemented as a pedagogical practice.

*Problems on assignments and tests.* Most high school chemistry courses require students to solve a variety of problems, ranging from multiple-choice/true-false questions to those requiring calculations to be clearly shown, to receive full credit. These problems commonly appear on tests and homework assignments. Our analysis discovered two types of problems to be significantly and positively associated with college performance: the number of assigned problems with calculations and test questions requiring memorization of terms/facts. This result seems to be counter intuitive, unless one takes the view that proficiency in both calculations and recall of facts/terms are important. Note that we did not find that taking class time to promote memorization was positively associated with college performance. Rather, we found that holding students responsible for recalling facts and terms on tests was valuable. In fact, there are instances when holding students to account for the recall of particular facts and terms pushes them to pay closer attention to their work and tests are the most common venue for this type of accountability. Regardless, it appears that requiring students in high school chemistry to perform calculations and holding them responsible for possessing knowledge of facts and terms appears to be useful preparation.

*Chemistry content topics.* Against the backdrop of pedagogy and classroom structure stands the content of high school chemistry. Questions regarding what to teach inform responses about how to teach. In our study, we asked students to estimate the emphasis their high school chemistry courses placed on a series of content topics which included Atoms and the Periodic Table, Chemical Reactions and Equations, Solutions, Gases and Gas Laws, Stoichiometry, Nuclear Reactions, Biochemistry, and History/People of Chemistry. Among these eight general content topic areas, we found two significant associations. Students reporting greater emphasis on stoichiometry typically earned higher grades, while students reporting greater emphasis on nuclear reactions typically earned lower grades in college. We did not find significant associations among the other topics. This non-finding may have been due to a number of reasons. For example, regarding very common topics, such as Atoms and the Periodic Table and Chemical Reactions & Equations, there was very little variation, since all students reported having a relatively strong emphasis on these topics compared with the other topics.

### Conclusions

Linking these results into a cohesive chain offers a picture of how particular high school chemistry instructional practices may impact college chemistry performance. The results most striking when juxtaposed are the findings that, on the one hand, rote memorization of facts is negatively associated with college performance and, on the other hand, that emphasis on test questions requiring memorization of terms and facts is positively associated, appear to be contradictory. However, consider the case of teachers who focus class time on developing students' full understanding, using the facts and terms of chemistry as one would use a "language." Students being held accountable for learning the words of the language, and then coming to classes where the language is used as a means for developing deeper understandings, would respond positively to both questions and it seems not unlikely that these students would be very well prepared for the rigors of college chemistry. Therefore, an initially contradictory result offers a clue to a subtlety of effective pedagogy.

The negative results regarding lab procedure instructional practices and frequency of independent projects suggests that there appears to exist a middle ground for most effective guidance in pedagogical practice. Overemphasis on procedure may alleviate the responsibility of students to actually understand the purpose of the steps in a laboratory experiment, leading to an algorithmic exercise in direction following. On the other side, independent projects offer students a great deal of freedom. However, freedom to explore without the experience to take advantage of this latitude may only lead to confusion. Our analysis suggests a middle ground of guided learning with opportunities for independent exploration. The negative association of higher frequencies of individual work also suggests that guidance may not only come from teachers, but from peers as well.

The significance of stoichiometry as a positive predictor, and nuclear reactions as a negative predictor, suggest that greater emphasis on fundamental skills over a faster-paced approach covering many topics is more useful. The imbedded characteristic of calculations in understanding stoichiometry matches well with the focus on higher frequencies of class problems using calculations.

These results offer evidence for the long-term impact of high school chemistry. It appears that high school chemistry instruction does have some significant association with college chemistry performance and our analysis suggests that a definition of rigor in high school chemistry includes: 1) an emphasis on fundamental topics, 2) a facility with calculations, 3) opportunities for independent investigations after well-grounded guidance as opposed to algorithmic procedures, and 4) a requirement that students know the "language" of chemistry.

***References***


Tai, R. H., & Sadler, P. M. (2006). Factors influencing college science success. In J. J. Mintzes & W. Leonard (Eds.), *Handbook of College Science Teaching* (pp. 359-367). Arlington, VA: National Science Teachers Association Press.

Tai, R. H., Sadler, P. M., & Loehr, J. F. (2005). Factors influencing success in introductory college chemistry. *Journal of Research in Science Teaching*, *42*, 987-1012.

Tai, R. H., Sadler, P. M., & Mintzes, J. J. (2006). Factors influencing college science success. *Journal of College Science Teaching*, *35*(8), 56-60.

Tai, R. H., Ward, R. B., & Sadler, P. M. (2006). High school chemistry content background of introductory college chemistry students and its association with college chemistry grades. *Journal of Chemical Education*, *83*, 1703-1711.


# 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.

## *Cloning*

For each of the following, please indicate if you *agree*, *disagree*, or are *not sure*.

A. Cloned organisms are grown in a laboratory.
B. Human clones are produced to supply transplant organs for the donor.
C. When a clone is produced, it is the same age as the donor.
D. A clone has the memory of the host and/or acts the same as the host.
E. It is possible to clone extinct, prehistoric species.
F. Cloning is a relatively easy, and highly successful, process.

*Commentary.* All of the above are false, yet these misconceptions are being communicated by popular media such as the following films: *Alien Resurrection*, *Star Wars Episode II: Attack of the Clones*, *The Island*, *Multiplicity*, *Parts: The Clonus Horror*, *Godsend*, and *Jurassic Park*.

Cloned animals are gestated within a surrogate animal. While whole-organ cloning is in the experimental stages, it does not involve growing tissues or organs within a human clone for transplanting to the donor human. Like any other animal, cloned animals are born as infants, and no technology exists for ageing clones more rapidly than the natural ageing process. Scientists widely dispute the concept of cellular memory, whereby cells--or a DNA sample, in this case--have the memory of the donor. While a clone and donor are genetically identical (nature), a significant proportion of personality and behaviour is due to environmental influences (nurture). The DNA required for cloning must be preserved extremely well. So, while species that have become extinct relatively recently may be cloned (e.g., after their cells have been preserved by freezing) if a closely-related species is available to act as a surrogate mother, very few, if any, prehistoric species are likely to be cloned. Cloning is a very difficult and costly task (e.g., cloning a domestic cat might cost 32,000 USD) and, if it is achieved, is typically the result of hundreds--if not thousands--of attempts made over several years.

*Source*

Miller, R. G. (2006). Cloning: A critical analysis of myths and media. *Science Scope*, *29*(6), 70-74.

# Teaching Techniques

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

## *Talking Cards*

Hughes (2006) finds the use of talking cards very useful for encouraging student participation in class (either orally or in writing), establishing expectations for good class discussion, and helping to build a trusting classroom environment. A talking card is simply an index card that is supplied to each student at the beginning of a lesson, and upon which each student writes his or her name.

During the lesson, a student hands to the teacher his or her card after they ask a thoughtful question or respond to a teacher or student question in a thoughtful way. Near the end of the lesson, students who still have a card must write, on the card, a question they still have about the topic or a summary of what they have learned during the lesson.

At the end of the lesson, the teacher uses the handed-in cards to complete the class attendance record, thus pressuring students to ensure their cards are handed in. After frequent initial use to achieve the objectives mentioned above, a teacher might choose to stop using the cards.

*Reference*

Hughes, S. (2006). Getting your students to speak up. *The Physics Teacher*, *44*, 554-555.

# Ideas in Brief

Summaries of ideas from key articles in reviewed publications

## *Teaching to Learning Styles: A Myth*

Given that different people have different preferred intelligences, it might seem reasonable that learning would be enhanced by first testing students for learning style and then providing for them to learn using their stronger intelligence(s) (e.g., providing kinesthetic activities for kinesthetic learners). However, Olson (2006) concludes that not only is there no valid evidence that teaching towards students' preferred learning styles results in any learning benefits, but that it may even lead to reduced effort and achievement.

Salomon (1984), for example, showed that students who learned using their preferred style performed both poorly on tests of the material and worse than a comparison group who learned using a style other than their preferred one! What appears critical to achievement is the amount of effort students put into their learning, and using a non-preferred learning style can, by making a task appear more difficult, motivate students to try even harder and learn more as a result. Other recommendations made by Olson (2006) include:

- Become aware of students' prior knowledge and provide opportunities for students to test these ideas.
- Use concrete representations before abstractions (e.g., in the learning cycle model for inquiry, real experiences precede the development of more abstract concepts).
- Choose the way of representing material that best suits the content itself (e.g., use sound to learn about sound).

*Reference*

Olson, J. K. (2006). The myth of catering to learning styles. *Science and Children*, *44*(2), 56-57.
Salomon, G. (1984). Television is "easy" and print is "tough": The differential investment of mental effort in learning as a function of perceptions and attributions. *Journal of Educational Psychology*, *76*, 647-658.

## *Using Concept-Mapping to Enhance PowerPoint Presentations*

Lectures in higher education are commonly supported by PowerPoint presentations. However, the weaknesses of PowerPoint include the following:

- Encourages student passivity.
- Overreliance on PowerPoint limits the desirable variation in teaching approaches.
- Overemphasises a linear structure of knowledge.
- An idea may need to straddle two slides, thus portraying an artificial break in the idea.
- The typical six-slides-per-page handout can portray a false hierarchy of ideas rather than linking ideas explicitly.

As a result, PowerPoint presentations can impact negatively on the quality of the teaching and learning process, portraying learning as being best achieved by rote memorization rather than deep understanding.

Kinchin (2006) suggests that the learning experience can be enhanced by presenting key slides as nodes in a concept map that appears on the front page of a handout that supports a presentation, as the opening slide of a presentation (acting as an advance organizer), or as a summary slide. Alternatively, in cases where this is likely to lead to information overload for students, one might use a build sequence of slides (i.e., adding slides incrementally) to also show the stages in constructing a concept map.

One way to manipulate slides is to select a desired slide in the thumbnails view of PowerPoint, copy it and paste it into a text box in a Word file, select the text box and paste it into a PowerPoint slide, resize and reposition it like any other image, and then use the PowerPoint drawing tools to add connections and other labels. References can also be added, near any of the constituent slides, to key pages of the textbook, related lectures, and/or page numbers in the more detailed accompanying handout, which may or may not be in the form of PowerPoint slides.

*Reference*

Kinchin, I. M. (2006). Concept-mapping, PowerPoint, and a pedagogy of access. *Journal of Biological Education*, *40*(2), 79-83.

# ? ? ? ? ? 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!

## *Displays*

*May I please have some ideas for good static models to be displayed in a science exhibition.*

Let me suggest the following:

1. You can display a model of a balanced diet. Your options include:

    a. Having different shelves named proteins, carbohydrates, fats, etc. arranged to display real objects or clay models. You should take care to include more of the locally available food items. You could also include shelves showing foods that should be avoided.
    b. Making a wheel showing the percentage of proteins, carbohydrates, etc. needed in a normal diet. Colour each section differently, and stick on pictures of food items containing the particular nutrients.

    You can also make similar models focusing on just the various vitamins, their sources, and related deficiency diseases.

2. You can make a model of the structure of DNA using wires and beads of different colours.

3. You can make your own ecosystem (specifying desert, land, forest, water, and so on) by filling large trays with sand and planting miniature plants, and adding tiny models of animals, found in these areas. You could also depict the influence of modernization on the ecosystem.

*Sunitha*

I think a static model of a properly-oriented globe (i.e., one having the same orientation as the Earth) makes a very useful science exhibit in an open space. We proposed and explained this idea in Bozic, Pantelic, Vuskovic, Nikolic, and Majic (2005). Students can observe the position of the day-night line on the Earth at a particular instant of time, and how this line moves during the day. One needs to have the local horizon of the observer parallel to the tangent plane at the corresponding point on the globe, and the north-south axis of the globe pointing towards the celestial north pole.

*Reference*

Bozic, M., Pantelic, D., Vuskovic, L., Nikolic, S., & Majic, V. (2005). School architecture and physics education. *The Physics Teacher*, *43*, 608-611.

*Mirjana Bozic, Institute of Physics, Belgrade, Serbia*

In a science education exhibition, one needs relatively simple, yet exciting, devices that will impress visitors and make them ask/think: "How does this work?" My favourite list of such devices (listed alphabetically, and with prices varying from about 3 to < 30 USD) is as follows:

1. Diffraction Goggles (use a laser pointer).
2. Drinking Bird (using distilled water is preferred, as this avoids the build-up of a precipitate on the mouth of the bird that can otherwise occur after prolonged use, and which can detract from the aesthetic appeal of the device).
3. Ferrofluid (use a magnet).
4. Fickle Foam Panel (to demonstrate the behaviour of liquid crystals).
5. HT Superconductor (used with small Sm-magnet; liquid nitrogen needed).
6. Newton's Cradle (try also the attractive variant of coupled magnetic pendula).
7. Plasma Sphere (to demonstrate the principle of the Tesla coil).
8. Radiometer Ball (use a light bulb as a source).
9. Solar Motor (often used with a diffraction disk to enhance the impression).

The above are the standard names for the models/toys. I have tried all of them (and many others as well) and claim the results are amazing; and not only at first sight! For a more detailed explanation of what can be demonstrated with the above, and how, do not hesitate to contact me. Also, a valuable source of a virtually unlimited number of models, toys, exhibits, devices, and the like is Edmund Scientific's *Scientifics* (n.d.).

*Reference*

*Scientifics*. (n.d.). Retrieved January 3, 2007, from http://scientificsonline.com .

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# Further Useful Resources

***Dihydrogen Monoxide: DHMO*** (http://www.dhmo.org) Use the materials from this website to demonstrate that data needs to be given a context before sensible use can be made of it. (*Editor*: DHMO is also called water!)

***Genomics Analogy Model for Educators (G.A.M.E.)*** (http://www.entm.purdue.edu/extensiongenomics/GAME/) Resources for teaching genomics, for especially educators who do not have a molecular biology background.

***Strategic Literacy Initiative at WestEd*** (http://wested.org/stratlit) Follow the *Resources* link to find tools and projects for promoting more active reading in science. Includes Metacognitive Logs, Science in the News, writing a children's science book, presenting an interactive historical vignette, reading a fiction book with good science content, and participating in a book club.

***Google for Educators*** (http://www.google.com/educators/index.html) Support for teachers that includes Google tools for the classroom. Sign up for the quarterly newsletter to receive updates about how Google is working with teachers.

***Google Earth*** (http://earth.google.com) Download free software to explore Earth using aerial and satellite imagery.

***GIS.com: The Guide to Geographic Information Systems*** (http://www.gis.com) An excellent alternative to one-dimensional, static maps that combines visual images with statistical data.

***biochem4schools*** (http://www.biochem4schools.org) An "umbrella" site containing links to biochemistry resources.

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

***The Science Education Review*** (*SER*) is an international, peer-reviewed periodical aiming to provide primary and high school teachers with the latest, and best, ideas in science education from around the world. *SER* also publishes original articles, including research articles, and much more.

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