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Year 3 Kids Can Understand Quantum Mechanics

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Credit: ABC 7:30 Report

If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis that all things are made of atoms-little particles that that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.
In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied.

Richard Feynman

Over the past 3 years I have developed a method at our local primary school for teaching kids advanced scientific concepts centered on atomic theory that we usually leave till years 10 and 11. This programme has been recently covered by 'The Australian' and the ABC 7:30 Report.

I have been privileged enough to teach alongside a dedicated and informed, though non-specialist classroom teacher, Adrian Quinn, who was keen to explore how far we could conceptually stretch his primary school students. In the process Adrian has also advanced his knowledge of atomic theory to the point where he is now able to deliver this course solo. I was also fortunate to have a Principal, Richard Nash, who openly supported the introduction of this innovation into his school.

This method puts the big concepts first! When students understand atomic theory, they can then tackle the "branch" subjects of biology, geology, genetics, and astronomy with confidence, as atomic theory underlies much within those domains. It puts in place a coherent learning progression that students can build upon over time. They can return to it throughout their schooling and build more elaborate conceptual versions as they mature. (I think this is called "spiralling" in education-speak.) Importantly, students can then connect their observable macroscopic world around them to the invisible microscopic world of atoms and molecules.

We taught ALL students these concepts, not just the bright few. Even Year 1 students understood the principles behind the Periodic Table, which is a kind of alphabet of the universe. We teach them the linguistic alphabet before they go to primary school, so why not the universe's alphabet at the same time?

Year 3 and 4 students learned the basics of atomic structure and how it resulted in different kinds of bonding between elements. They learned the chemical formulae of important common substances such as hydrogen (H2) oxygen (O2), water (H2O), ammonia (NH3), methane (CH4) and carbon dioxide (CO2), and constructed models of complex molecules like amino acids. Apart from playing a key part in chemical theory, these special molecules are important in our everyday lives, and a couple of them play a centre-stage role in our modern political economy (CH4 is called natural gas, alternatively known as 'coal seam gas; while CO2 is earth's principal greenhouse gas). Furthermore, they understood these formulae in terms of the electron configurations and bonding rules of each element, which in turn was based on their atomic structure.

They comprehended that electron quantum leaps between electron shells (energy levels) resulted in the emission or absorption of light. They also constructed complex molecular models involving single, double and triple bonds. By playing with the models they discovered by themselves that some molecules can be cyclic in structure.

Students from Years 5 and 6 observed and understood why energy changes occur when chemical bonds are broken and reformed in chemical reactions. They developed the concept of a balanced chemical equation and were able to consider mass conservation during chemical change. Writing balanced basic chemical equations was also covered. This is particularly relevant to Queensland as an energy state.

Developmental Stages

We have found that year 3 is a comfortable age for students to handle atomic structure (protons, neutrons, electrons, nucleus and electrons shells). Atomic structure is normally delayed and separated from teaching bonding and molecules as it is considered too difficult. We decided, however, that from a concept mapping perspective, atomic structure precedes the other concepts, so we decided to bite the bullet and taught it in this sequence. In the process we found that the kids found it surprisingly easy to understand because they had some prior exposure to the ideas from other sources. Further, an understanding of electron configuration both explains and simplifies the layout of the Periodic Table's groups and rows. Another example is that the formation of covalent and ionic bonds makes more sense with a prior understanding of electron configurations. This means that the extra time and effort taken in grappling with atomic structure first was refunded to the students in the formation of downstream concepts.

The notion that atomic theory is too difficult for early primary school is curious. Where does it come from?

Most researchers consider that even year 5 and 6 is pushing the boundaries of teaching atomic theory, so testing whether even younger kids can get science seems out of the question in current pedagogical circles. Piaget's developmental stage theory might account for much of the collective conviction to constrain teaching advanced conceptual science early in school, but while the world has moved in to technological overdrive in the past 50 years, primary school kids are still being taught as though they are locked in 1950's preoperational and concrete operational stage pigeon holes, and learning 10th century science. In spite of this, kids are still acquiring scientific understanding incidentally from TV, video games, internet searches and possibly discussions in the playground than they are from the classroom. Has atomic theory replaced sex education as the taboo subject in early educational curricula? My anecdotal observation is that kids already arrive in early primary school classrooms with many preconceived notions about atoms, molecules and DNA from CSI and similar TV shows. Some researchers are now confirming this incidental learning, and others see concepts of atoms and molecules as contemporary cultural artifacts. Even though many conceptual models of atoms and molecules that kids bring into the classroom are wrong or incomplete, most are nevertheless useful and fluid enough to adjust and create a platform to build more accurate concepts.

92 Kinds of Atoms

We first spent too much time introducing the idea that matter was particulate rather than continuous in nature. This turned out to be counterproductive because the kids already knew that, and we risked boring them by offering this to them as a new concept. Instead, we moved on quickly to discuss the 92 different types of naturally occurring atoms about which they were keen to know, and about which there was some confusion in their minds.

The best handle for describing the difference between the different types of atoms was to use their size and, in particular, their weight. At this point we had not introduced the topic of protons in the nucleus, so the definition of the atomic number as equating to the number of nuclear protons was not an option. However, the ranking of the increasing atomic weights is well correlated to the proton count, so this served as a good proxy for atomic number. After all, Mendeleev also used weights to rank elements, and to group them into families and posit periodicity.

So we started by saying, simplistically, that if we list the different kinds of atoms from the lightest atom (hydrogen) to the heaviest (uranium), and number them from 1 to 92, then those numbers are called the atom's atomic number. The atomic number is just a statement of weight rank at this stage. And since scientists are lazy (we say), they like to use a shorthand method of writing the type of atom, for example H for hydrogen. This is its symbol.

Credit: ABC 7:30 Report

Scientists have noticed that some elements have some properties in common, and so put them in vertical groups to show that.

We found that if students could observe palpably light and heavy elements, like hydrogen and helium at one extreme, and gold, mercury and lead at the other. When they handled the elements they got an immediate "feel" for atoms of different weights and their corresponding position in the Periodic Table.

Visit http://www.youtube.com/watch?v=KTSbMczur88 for a 10-minute introduction of atoms and elements that reflects our classroom approach.

Our collection of more than 20 elements also showed students that each type of atom had its own "personality" i.e. unique set of properties. One of the activities involved students recording the state, colour, shininess, density and magnetism of each element. Students were expected to know that each element has its own name, symbol, atomic number, group, row and "personality".

Microscopic & Macroscopic

We decided to introduce the distinction between the microscopic (atomic) and macroscopic (elemental) perspectives early. Again, we found that kids had been mulling over this notion of scale informally, and they quickly acknowledged that assignment of properties to quadrillions of incredible tiny particles observed in their everyday world might have different rules to that of a single invisible atom. Connecting the microscopic and macroscopic worlds, and differentiating the language between them as well as the language they have in common, was one a focus of our early approach. For example, when we speak of "carbon", we could mean a microscopic atom of carbon, or a macroscopic sample of the element carbon. The element carbon may be black in colour, but is a single atom of carbon black? The subtle semantics is worth discussing and clarifying early and makes future discussions clearer.

To underline the importance of the microscopic/macroscopic divide, we asked students to do three thought experiments and imagine the size of an atom. The first and simplest was to imagine that a human hair was about a million atoms thick. In the second way, students were asked to imagine an atom being magnified to the size of an apple. If this magnification were applied to the apple itself, then it would then become the size of planet Earth. This gives students a view from the other end of the microscope, and some students found this useful. In the third way, students were given a metre ruler that was divided into a thousand millimetres, and reminded that a flea is about a millimetre in size. They were then asked to imagine that one of those millimetres itself was divided into a thousand tiny lengths. Each one of those tiny lengths would then be called a micrometre, which is about the size of a virus. Repeating the process, the students then imagined dividing a micrometre into a thousand even tinier lengths. One of those very tiny lengths would then be called a nanometre, which is at the atomic scale, atoms being about 1/2 to 1/10th of a nanometre in diameter. This last method had the advantage of introducing formal microscopic units of measurement- the micrometre and the nanometre. It also launched interesting class discussions about nanotechnology, molecular machines and medical micro-robots, which tied in well with TV documentaries that many students had seen.

Year 3 students picked this method of scaling up in less than 5 minutes, as it started with a concrete exponential magnification that they could directly see (metres --> millimetres) then proceeded to an abstract magnification that they could partially see (millimetres --> micrometres) and finally to an abstract magnification that was entirely invisible to them (micrometres --> nanometres). We chose to scale in lots of 1,000 because we could refer to a physical example of objects at each scale that were familiar to them, if only in their imagination. They have probably seen a flea in real life, and they know that a virus is something so small that it is invisible to the eye.

Which model of the atom to use?

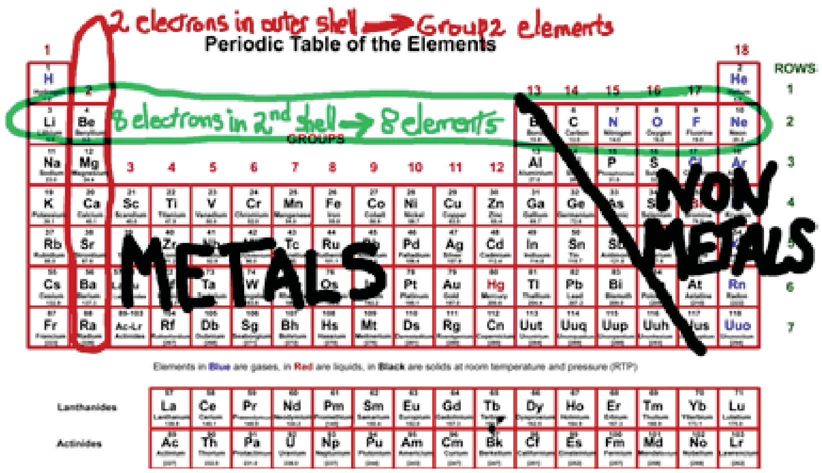
How did we handle which "model" of the atom to use- the planetary model, the hard sphere model, or the fuzzy ball model? (The last model is probably the most accurate, or least inaccurate, view of an atom. The first is downright wrong and misleading, yet prevalent in popular science publications.) First, we discussed what a "model" was - a temporary analogy that is useful for a particular purpose. To illustrate this we showed the class a 30 cm high model of a dinosaur, and asked them what it was? They replied "a dinosaur". We then pointed out that real dinosaurs (Brontosauruses) were about 4 metres tall, and their skin was elastic, not hard plastic. The kids then quickly corrected themselves and said that it was a model of a dinosaur, and also said (correctly) that it was a trick question. This was a good way of developing metacognition; that is, the concept of a concept! We then showed them another model of the skeleton of the same Brontosaurus, to make the point that different models of the same object could be used, that models were fluid and we could change them according to new evidence or our particular purpose - for example, whether we wanted to study the outside or the inside of the dinosaur.

Credit: ABC 7:30 Report

This was a good analogy because we subsequently developed an "inside" model of the atom (protons, electrons and neutrons) and an "outside" view of the atom using polystyrene balls to represent the hypothetical (and non-existent) atomic surface. Because our atomic structure teaching materials involving spinning wire circles around a central "nucleus" implied a kind of planetary model which was questionable, we pointed out that electrons in real atoms were "all over the map", but that they spent most of their time near a particular radius, and that we were using our spinning ring or wire to represent that radius. But we did not harp on about this, and students seemed to accept the model deficiency and moved on, not returning to the issue in an attempt to resolve any conceptual roadblocks. The spinning wire circle does have some analogical advantages however, because, although it misrepresents the position of the electrons, it parallels the energy of electron shells quite well. Despite an electron's nomadic lifestyle, it does possess a precise quantum energy level when occupying a particular orbital, within the limits of quantum uncertainty. We used this feature of the circular wire model to discuss electrons undergoing quantum leaps between different electron shells, and the accompanying energy emissions or absorptions, and demonstrated this using a plasma ball that excited electrons to higher energy states, allowing them to fall back to lower states and emit light of specific wavelengths. This brief excursion into quantum mechanics was not over their heads, at least within the confines of the model we used. (Although I hope Schrödinger does not read this article.) Our overall view was that we should use any and many models that were fit for purpose, with the proviso that the limits of each model was articulated at the time. The use of multiple models encourages students to develop plasticity in their use, both in terms of scale and meaning. Scientists do it all the time!

Atomic Structure

Like atoms, students came to class already armed with a vague knowledge of protons, electrons, neutrons as well as the nucleus. I was again surprised that I had to move quickly or risk boring them as they considered this to be repetition. The charges on each sub-atomic particle was either known, or recalled, or the idea was "bought" by them after the activity involving electrostatic charges, using a charged plastic ruler to manipulate a small piece of paper, and to bend a fine stream of water. Students needed to know that like charges repel and unlike charges attract, and although we did not perform formal electrostatic experiments, the charged ruler activity sufficiently convinced them of this. Further, many students knew this, and also that unlike magnetic poles attract and like poles repel. There is an opportunity to expand student activity at this stage to explicitly show like charges repelling, for example using two balloons, but we have not explored this yet.



The Periodic Table - Edited with class by Ian Stuart

The relative masses of the sub-atomic particles was not familiar to students, but we only mentioned it in passing as the charge is the most important sub-atomic particle property at this stage of their concept development. After all, it is the charge that determines the elemental identity and its chemical behaviour.

It was logical to the kids that the simplest and lightest kind of atom, hydrogen, would possess one proton and one electron, and that the next kind of atom, helium would have two protons and two electrons. We now mentioned that, because protons both carry positive charges, another particle, neutrons, were needed to stave off the repellent forces to keep them apart and act as a kind of nuclear "glue". No mention was made of the "strong nuclear force", and we made the strategic decision to remove the role of neutrons from further models from this point in time, until a later point in their conceptual development (indeed, a later year) , as students could then focus on the electrical aspects that determine the layout of the Periodic Table. This simplification proved to be a good decision and allowed students to consolidate the principles of electron transfer and sharing in more depth.

The notion that electrons were wrapped around the nucleus in shells was also vaguely known (perhaps because of the pervasive image of electrons whizzing around the nucleus), but the rules of electron occupancy for each shell, that is, a maximum of 2 in the 1st shell and a maximum of 8 in the 2nd shell etc. required careful articulation. Yet this needed to be stated only once or twice, and then they "got it".

Of course, the great power of teaching atomic structure is that it has enormous explanatory power and condenses the disparate aspects of atomic theory into a simpler, coherent system. This also demonstrates one of science's most majestic characteristics- the search to explain and simplify seemingly unrelated data!

Periodic Table

Once atomic structure is understood, the periodic rable can be seen in a new light. The atomic number corresponds exactly to the number of protons in the nucleus, the rows correspond to the filling of the electron shells (1st row from filling the 1st shell and so on), the number of elements in each row corresponding to the maximum number of electrons in each shell, and the groups correspond to the number of electrons in the outer electron shell. Trends can also be discussed, like the increasingly metallic properties of elements to the left of the Periodic Table.

This breathtaking simplicity is worth the effort of its achievement, and it is a false economy to separate and delay the connection. This is like a universal key that students can carry forward into their future studies. I am particularly proud of the year 3 and 4 students of Mr Quinn's class at Ithaca Creek State School who have arrived at this intellectual milestone.

Visit http://www.youtube.com/watch?v=NXQZjKdlvgc to see a 2-minute animation making the connection between atomic structure and the Periodic Table (neutrons are excluded at this stage of teaching). As we were showing this animation in class the kids chanted the names of each element as it was "built" from protons and electrons. We found this amusing

It became a badge of honour that our students learn the first 10 elements of the Periodic Table by heart. In fact, even the younger siblings of class members are now learning them. The Periodic Table is going viral!

Covalent and Ionic Bonding

I wanted to skim over the reasoning behind electron sharing to form covalent bonds, because I thought it would unnecessarily complicate the conceptual landscape (and because I rarely picture covalent bonds as electron sharing when creating chemical or structural formulae ... I just use the bonding rules without thinking, much like you put a comma after a phrase in a sentence). However, because Adrian was not familiar with the reasoning behind electron sharing, he wanted this explained explicitly to himself, and he felt that students would also be helped by having this conceptual connection before moving formulae. He turned out to be right, and the students could see the basis of covalency without a beat.

The inclusion of ionic bonding in the course was a pedagogical accident. We were having a class discussion using wire-circle atomic structure models - one was set up for lithium and the other for fluorine. A student asked if the outer electrons could be shared in this case, expecting the same answer between a metal and a non-metal as between two non-metals as with covalent bonding? This opened up the topic of electron transfer - a thief atom and a victim atom - and the conversion of neutral atoms into positive and negative ions, with the resultant ionic bond between them. The concept formation was surprisingly robust as it was flippant. Later, we returned to the idea of ions and found that students retained the idea to a high degree of fidelity. We have not extended ionic bonding to the macroscopic level by discussing ionic lattices and the fact that all ionic substances are solids, electrolytes, etc... but that would be an easy enough step down the track.

Valency, Molecules, Chemical Formulae - Let's dance!

The notion of bonding power or an element followed from the above treatment of atomic structure and electron configuration. Despite the success in our previous "accidental" treatment of ions, we narrowed the topic of chemical formulae to covalent bonding in molecular compounds only, starting with water (H_2O), ammonia (NH_3), methane (CH_4) and carbon dioxide (CO_2). Rather than working out electron sharing arrangements for each compound, we now switched to simple "bonding rule" method of determining a formula.

An early analogy to represent a molecule and formula was the joining of dogs (D) with a "valency" of 1, humans (Hu) with a "valency" of 2 and an octopus (Oc) with a valency of 4. The resultant combinations followed from their valencies e.g. a human with 2 hands would require 2 dogs to complete the bonding rule, resulting in a "molecule" or HuD_2.

Although this analogy is cute, it was not particularly productive. More productive were our kits of atomic models (similar to molymod models) with the bonding powers built into each type of atom. Students quickly "discovered" the bonding power (valency) of each type of atom and were able to build molecules accordingly. They were able to articulate these bonding powers, and convert structural formula into molecular model versions, and vice versa. Double bonds, triple bonds and cyclic molecules (like ozone and benzene) were an easy step away. We discussed families of molecules, like alkanes and alkanols. A few amino acids were built, as well as a couple of DNA nucleotides (guanine and thymine). Students were very proud of their molecular model constructions, and eagerly sought teacher feedback to see if they had completed them correctly. It was almost hard to keep up with them. It seemed a good stepping stone to move to polypeptides and other polymers. This could have been done at this point in time, but we wanted to move to the concept of chemical reactions first.

Chemical Reactions Credit: ABC 7:30 Report

Chemical Reactions - BOOM!

The next port of call was the topic of chemical reactions. We took a balloon of hydrogen and reminded students that it contained H_2 molecules, and outside in the air were O_2 molecules. (It was satisfying to hear a Year 3 student verbally and publically explain the difference between hydrogen atoms and hydrogen molecules. At this stage, students were instinctively referring to elemental hydrogen as H_2, not H.) We brought a flame to the balloon and exploded it, with a great sense of theatre... and noise. We gave them some molecular models of hydrogen and oxygen molecules, and the spectacular amount of energy released gave a good excuse to suggest that the hydrogen and oxygen bonds had been broken. With their new-found ability to combine atoms using models, they quickly reconstructed water molecules as the products of the reaction.

Students wrote the chemical equation in two stages. First they wrote down the formulae of the physical models they handled to represent the chemical change. They wrote down two H_2 formulae separately to record the two hydrogen models, one O_2 formula to record the single O_2 model, and two H_2O formulae separately for the two that they needed to satisfy the bonding rules and conservation of mass in their rehearsed version. See below which shows this step:

BEFORE AFTER

$H_2 + H_2 + O_2$ --> $H_2O + H_2O$

reactants products

Then we introduced coefficient in front of the formula to condense multiple formulae of the same molecule. We then dubbed them "rocket scientists" as this simple chemical reaction is the one that propels rockets through space. See below which shows this step:

BEFORE AFTER

$2H_2 + O_2$ --> $2H_2O$

reactants products

A more complicated example of the combustion of methane to form CO_2 and H_2O was also completed.

The Year 4/3 composite class was "up for it" to balance chemical equations. But we felt now was a good time to take a break and optionally delay this section till a later year.

Teaching materials

Year 3 Kids Can Understand Quantum Mechanics

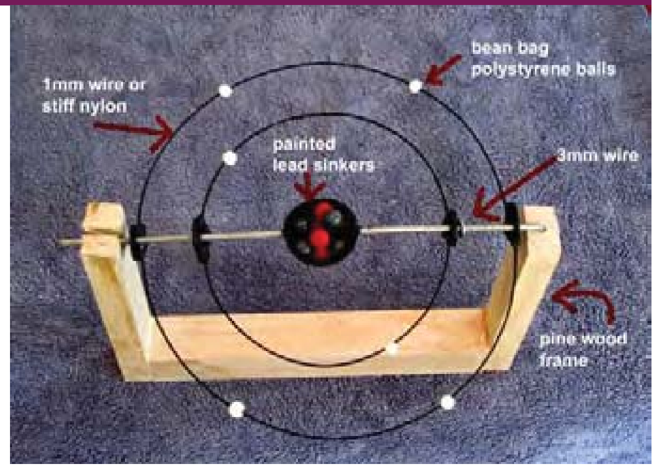
Ian Stuart

My career has been spent teaching at year 11 and 12 level. The thing that struck me upon walking into a primary school class was that the kids were more enthusiastic; and they also had shorter attention spans. Teaching complex concepts therefore needed to take both these aspects into account, so focused rotation between activities, analogies, models, animations, demonstrations was key to keeping the kids awake and progressing along the designed conceptual path. As a result I spent several years developing cute contraptions in my garage before testing them in situ. Many prototypes were abandoned, but enough have survived the classroom's natural selection process to create a useful collection of teaching materials, sufficient to enrich this curriculum unit for young minds. Most conceptual steps are thus accompanied by one or more hands-on activities and/or demonstrations.

These teaching materials can be replicated by other teachers on a shoe-string budget, with some time and effort required for their construction. Once assembled, they would be sufficient for a whole school and robust enough to use for many years. I can provide advice and assembly plans to expedite the process, bypassing hours of trial and error.

Here is a list of successful teaching materials developed at this point in time:

- Collection of elements for observation: H, He, C, Mg, Al, Si, P (red), S, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Nb, Ag, Sn, Au, Hg, Pb. Many elements can be easily found around the home or hardware store e.g. C, Al, Fe, Cu, Pb Co, Ni. Some can be purchased from chemical suppliers e.g. S, Zn, Hg. I scouted around Australian tertiary and commercial labs to request donations of difficult-to-get elements such as Cr, Si, Nb. You can purchase silver and gold bullion at spot prices from Ainsley Bullion in Brisbane CBD: https://www.ainsliebullion.com.au. Although costly, they are also an investment hedge against future central bank money printing. [Editor's note: When I taught in primary school I used to identify the parent in the school who worked in or had something to do with chemistry, and order through them. Of course, risk assessments needed to be completed, and appropriate storage found.]
- Class set of 18 atomic structure wire-circle models with protons and electrons.
- Set of metre rulers divided into 1,000 mm for Size of the Atom activity, and a set of plastic rulers and woolen rags for electrostatic experiments. I got mine at a local newsagency.
- Editable, printable Periodic Table as a Photoshop PSD or JPG file that holds a Creative Commons copyright licence (Attribution-Non-Commercial -Non-Derivative).
- Animation connecting atomic structure to the Periodic Table (excluding neutrons at this stage). See http://www.youtube.com/watch?v=NXQZjKdlvgc.
- Beginning of a set of videos to back up the classroom delivery. The first draft of the first 10-minute video The World Is Made Of Atoms is at http://www.youtube.com/watch?v=KTSbMczur88. It will soon be re-edited for better sound. Other videos in production include "The Size Of An Atom", "Atomic Structure" , "The Periodic Table" and "Chemical Bonds", "Chemical Reactions" and "Chemical Equations".



Atomic structure wire circle models with protons and electrons

- Plasma Ball for emission of photons due to quantum leaps demonstration.
- Two models of a dinosaur (external & skeleton) to demonstrate the concept of a model.
- Set of magnetic atom models for sticking on white board to demonstrate chemical reactions.
- Magnesium ribbon and holder to demonstrate combustion of magnesium. Easy to source at a laboratory supplier.
- 5 mm perspex safety shield & stand, gloves, ear muffs to demonstrate explosion of hydrogen balloon (see previous photo). I purchased the perspex at a hardware store and built a wooden frame to hold it upright.
- Class set of test tubes, test tube racks, test tube holders, 0.1 M HCl & Mg pieces for experiment involving a chemical reaction. Easy to source at a laboratory supplier.
- Class set (18 units) of magnetically connectable atom models to form molecular models. The advantage of this design over the traditional Molymod design is that the magnetically connected bonds better mimic the attraction-at-a-distance characteristics of electrically formed covalent bonds. The stickiness of the bonds also allows students to get a "feel" for the effort required to pull bonds apart (requiring energy) and the spontaneous manner of bond formation (releasing energy). This prompts the topic of energy transformations during chemical reactions.

Assessment

After teaching year 12 Chemistry and Physics for over 20 years at a prestigious private school (where assessment was a fetish), I have internalised the instinct of sensing when students "get it" (and whether they could pass a test on it). We also deployed a range of mostly formative testing instruments, including the following:

- selection tasks (true/false and multiple choice).
- short answer tasks, mostly as worksheets that we overviewed on the fly as students were doing them, and sometimes collected for appraisal.
- written interpretations of the Periodic Table.
- performance tasks, including the observation of elements by recording colour, lustre, magnetism, state and (sometimes) density; charging a plastic ruler to creating electrostatic effects; manipulation of the wire-circle Atomic Structure models to "build" the first 10 elements of the Periodic Table with model protons and electrons; building molecular models from atomic components based on structural formulae, and vice versa; performing a chemical reaction experiment by adding magnesium ribbon to a test tube containing 0.1M HCl, then testing the evolved gas as hydrogen.
- Q & A in whole of class as well as individual situations. Many of these were videoed and a sample of the conversations were:

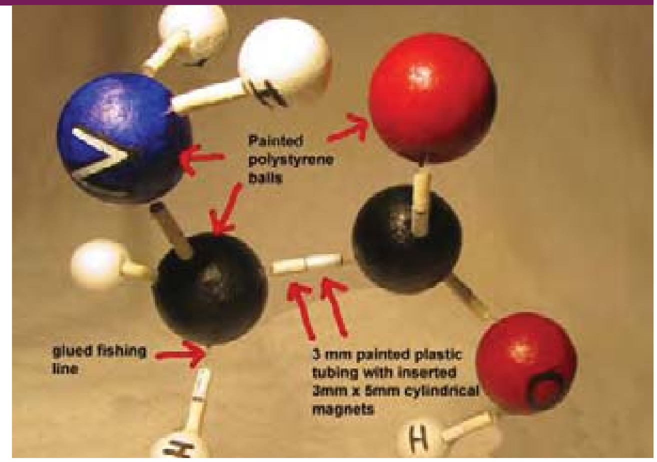
Q: What is the chemical formula of this molecule? (Student has created a molecular model of butanoic acid.)
A: C4H8O2
Q: How many and of what type of atoms are there in this molecule?
A: 4 carbon atoms, 8 hydrogen atoms and 2 oxygen atoms.
Q: How many protons and electrons does a carbon atom have, and where are they?
A: 6 protons in the nucleus, 2 electrons in the first shell and 4 electrons in the second shell.
Q: How many bonds will oxygen form by sharing, and why?
A: Two, because it has 6 electrons in its outer shell, and 2 spaces for sharing electrons.

Opportunities

It is thrilling to discover that early primary school kids can cope with, as well as hunger for, a dramatically more advanced science curriculum than we currently offer.

This is out of whack with the Australian Science Curriculum which avoids atomic theory - or anything microscopic - until years 9 and 10, and then only fleetingly. Students have to wait till year 11 Chemistry and/or Physics, and, as most students do not choose these subjects they miss out on any detailed coverage of atomic theory altogether. Those who do choose to study Biology without Chemistry and Physics are then missing a key part of their understanding upon which much of their Biology relies.

This course brings forward atomic theory by about 6 or 7 years compared to the Australian Curriculum, and



Magnetically connectable atom models to form molecular models

then it treats it in more depth and breadth.

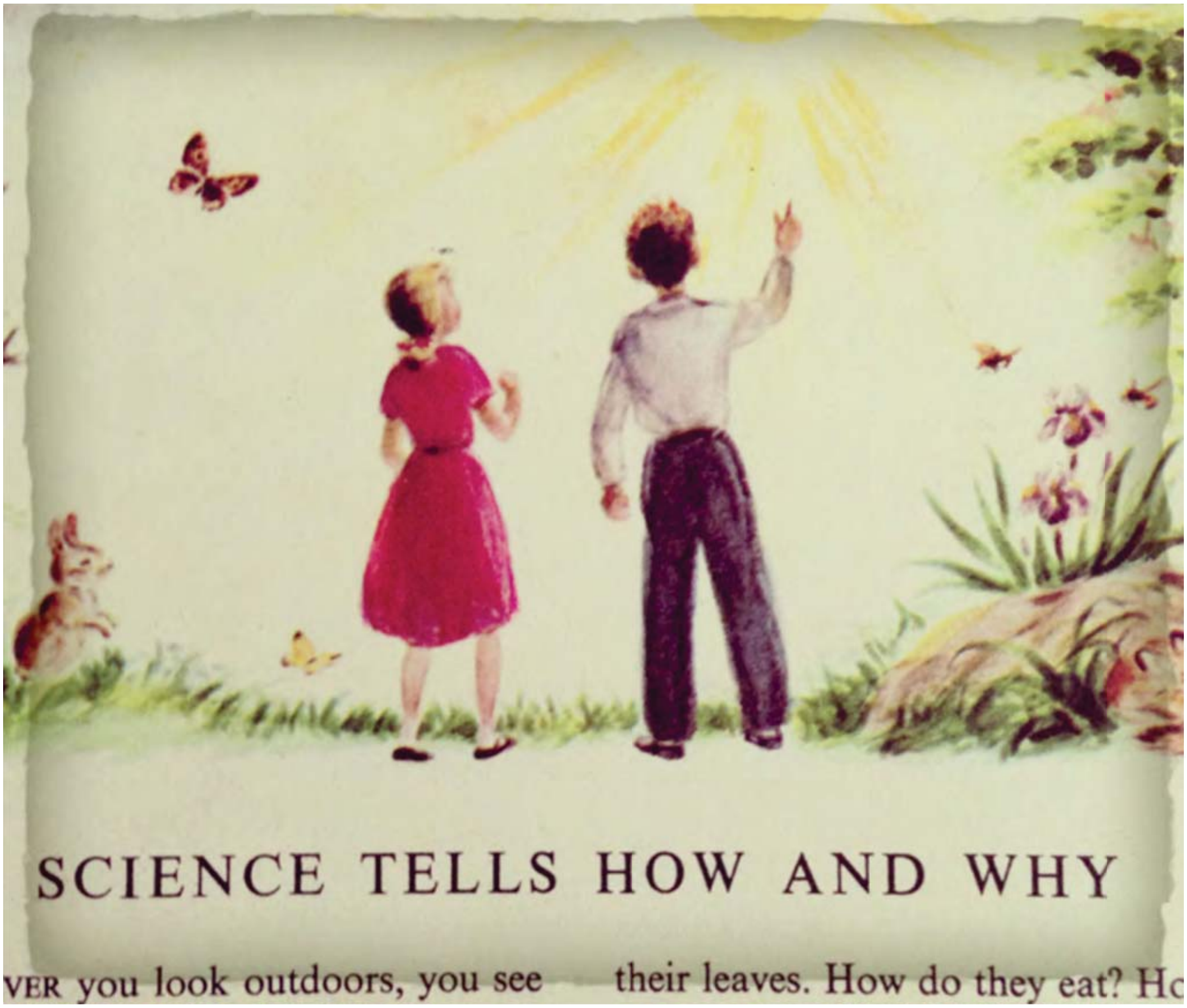
From another perspective, the course can be considered to be complementary to the Australian Science Curriculum. For example, when changes of state and the relationship to heat is covered in years 3 and 5, students of this course could make the connection between the macroscopic observations of phase changes (e.g. expansion and contraction) and the underlying microscopic behaviour of molecules that explain them. This connection could be made for most topics covered by the Australian Science Curriculum. Kids pick up these concepts quickly so there would be little time impact on the rest of the curriculum if it were to be treated as a "bolt-on" course.

Also the cost of resources is low. I have developed a wide range of models, activities, demonstrations that can be made on a shoe string. Education does not need to be expensive, but it does need an ambitious curriculum.

We can lift science education an order of magnitude beyond the current curriculum, improving the wealth of intellectual capital in our nation's young people and prepare our country up for a future of innovation and productivity.

The broader task is to introduce atomic theory in all Australian primary schools. Our main strategy is to introduce it into individual schools and hope it spreads and reaches a critical mass. A number of schools have already indicated they want to do this in 2013.

Editor's note: Ian and Adrian have accomplished a wonderful thing by teaching these concepts to their students, but they're not the first to do so. Back in the 1970's, Joseph Novak, an American academic, performed controlled longitudinal research that showed that children who learn advanced molecular concepts not only do better in science throughout high school, but finish school with significantly less misconceptions in science. For more details about teaching molecular concepts in the early and primary years, see the article by Dr. Tony Wright in the previous volume of the Queensland Science Teacher, 38(4). STAQ is certain there are many amazing primary and secondary teachers delivering exceptional programs to students, and would like to showcase this work.



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