Contents

Contributions on any matter of interest to second-level chemistry teachers are welcome. Normally the results of research (chemical or educational) are **not** published, except in a general form or as a review. Articles should be submitted electronically (email or disc) to **peter.childs@ul.ie** together with a printed copy.
For subscription details etc. see inside back cover.
Cover design: Tony Hartnett, Shoreline Graphics, Ballyvaughan, Co. Clare
Cover photo: The Trent and Mersey canal at the Harecastle tunnel near Stoke-on-Trent, coloured by iron in the water. See article p.50 (Photo: P.E. Childs)

Editorial

New draft LC Chemistry syllabus

The draft syllabus for the revised LC Chemistry (and Physics) syllabus has been put on line by the NCCA for consultation. Responses are due back in the Autumn 2011 and it has to be said this is not the best time of year to get effective feedback. Schools are winding down for the end of the school year and exams, and nothing will happen until September. Since the NCCA is supposed to allow 18 months before a new syllabus is introduced into schools, to allow for publishers to produce new books, and hopefully for PDST to provide inservice courses, the earliest the new syllabus can start is 2013, examined in 2015. The syllabus represents a major revision and is intended to include assessment of practical work for the first time. This is a major change and an expensive change in time and personnel. For proper implementation a new syllabus needs enough time before being introduced to retrain teachers, develop new examination papers and provide necessary resources. In the past none of these were done adequately or in time. There is nothing worse than a good idea being still-born due to poor preparation, so it never reaches its full potential. Considering the straightened economic times I am surprised that the new syllabi are being introduced as if they cannot be done properly, and financed adequately, they will turn out to be another wasted opportunity. There is aklso a strong case for a phased introduction, especially with the introduction of practical assessment, which will put new pressures on schools. To introduce this in all the science syllabi at once might be a straw too much and a bridge too far. There is no point, in my view, in undertaking curriculum change, however necessary or worthy, if it cannot be done properly. A new syllabus needs sufficient in-service training, adequate resources, early release of draft exam papers, and time to adjust to a new assessment scheme for practical work – all these need to be done in time and need time to bed down. I hope that we will learn from mistakes in the past and if and when the new LC Chemistry and Physics syllabi are introduced, that this will not be done in a rushed manner to meet some political deadline.

More talk of change

There is also talk from the new Minister of Education, Ruairi Quinn, of a wholesale revision of the Junior Certificate. One lesson we should learn from the UK is the damaging effect of too much change too quickly, and the increase in paperwork that continuous assessment brings. We already have an under-resourced education system; we have the mounting pressure of increased pupil numbers at primary and soon at second level; and reduced staffing levels due to the cut-backs. To introduce major change into an already strained system should not be done lightly and must be done carefully and incrementally, if we are not to end up in worse state than when we began.

Teachers are the key ingredient for a high quality, effective education system. Anything that demoralises teachers, or makes their job more difficult, is counter-productive. The loss of senior staff who have taken early retirement and their non-replacement, the large numbers of young teachers on temporary contracts, the cap on special needs teachers at time of ever-increasing need, all these factors make teaching more difficult and less attractive to new teachers. We now have a surplus of unemployed young teachers at both primary and second level, and very little chance for the majority of them to get work in Ireland. What a waste of potential and skills!

Finland is often held up as the model of a successful school system and their country also went through an economic crisis in the 90s. However, they made a crucial decision to invest in education and to improve the quality of the teaching profession and this has paid off. Ireland cannot afford to reduce investment in education and it should be a top priority for the new government. Even when there are few jobs available, it still makes long-term sense to send people to third level and to give new graduates opportunities for more specialised further education. Paying people to study makes more sense than paying them to be on the dole and in one way the current economic situation provides an opportunity to up-skill the workforce.

Peter E. Childs
Hon. Editor

Education News and Views

Science is the Most Popular Subject at School

On March 16, 2011, the Department for Business, Innovation and Skills (BIS) published Attitudes to science: survey of 14-16 year olds. The research, conducted via an online questionnaire, included 500 learners aged 14-16 currently undertaking their GCSEs. It is an overview of what they think about science, scientists and science policy across the UK.

This new survey of 14-16 year olds finds that science is the most popular subject at school. In response to the question, 'Which is your favourite subject at school or college?' 16% prefer science (followed by English 12%, Art 9% and Maths 8%). The main appeal is that pupils find science interesting, worthwhile and important. Pupils like the way it explains things and that it is relevant, logical and factual. Other important factors include enthusiastic teachers and stimulating practical work.

The survey also looks at the effect of extra-curricular science clubs and, not surprisingly finds that those engaged in science through clubs and school visits are significantly more likely to study science in the future and consider STEM-related careers.

Since 2000, the Department for Business, Innovation and Skills (BIS) and its predecessor Departments have been responsible for funding a series of surveys on Public Attitudes to Science.
http://www.bis.gov.uk/assets/biscore/science/docs/a/11-p112-attitudes-to-science-14-to-16

New education adviser

John Walshe of the *Irish Independent* becomes special education adviser to Ruari Quinn, Minister of Education and Skills in the new coalition government.

The big ideas in science

The ASE in the UK published a document at the end of 2010, based on the findings of a study group, on the *Principles and Big Ideas in Science Education*, edited by Wynne Harlen. I was excited by this as it offered a chance to see what we should be teaching in introductory science courses. Their prescription is given below. First of all they give 10 Principles of Science Education and then 10 Ideas *of* Science and 4 Ideas *about* Science. These are all discussed in detail in the report and these lists come from the summary at the beginning.

Ten principles of science education

1. Throughout the years of compulsory schooling, schools should, through their science education programmes, aim systematically to develop and sustain learners' curiosity about the world, enjoyment of scientific activity and understanding of how natural phenomena can be explained.
2. The main purpose of science education should be to enable every individual to take an informed part in decisions, and to take appropriate actions, that affect their own wellbeing and the wellbeing of society and the environment.
3. Science education has multiple goals. It should aim to develop:
   - understanding of a set of 'big ideas' in science which include ideas *of* science and ideas *about* science and its role in society
   - scientific capabilities concerned with gathering and using evidence
   - scientific attitudes.
4. There should be a clear progression towards the goals of science education, indicating the ideas that need to be achieved at various points, based on careful analysis of concepts and on current research and understanding of how learning takes place.
5. Progression towards big ideas should result from study of topics of interest to students and relevance in their lives.
6. Learning experiences should reflect a view of scientific knowledge and scientific inquiry that is explicit and in line with current scientific and educational thinking.
7. All science curriculum activities should deepen understanding of scientific ideas as well as having other possible aims, such as fostering attitudes and capabilities.
8. Programmes of learning for students, and the initial training and professional development of teachers, should be consistent with the teaching and learning methods required to achieve the goals set out in Principle 3.

9. Assessment has a key role in science education. The formative assessment of students' learning and the summative assessment of their progress must apply to all goals.
10. In working towards these goals, schools' science programmes should promote cooperation among teachers and engagement of the community including the involvement of scientists.

Ideas *of* science
1. All material in the Universe is made of very small particles.
2. Objects can affect other objects at a distance.
3. Changing the movement of an object requires a net force to be acting on it.
4. The total amount of energy in the Universe is always the same but energy can be transformed when things change or are made to happen.
5. The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate.
6. The solar system is a very small part of one of millions of galaxies in the Universe.
7. Organisms are organised on a cellular basis.
8. Organisms require a supply of energy and materials for which they are often dependent on or in competition with other organisms.
9. Genetic information is passed down from one generation of organisms to another.
10. The diversity of organisms, living and extinct, is the result of evolution.

Ideas *about* science
11. Science assumes that for every effect there is one or more causes.
12. Scientific explanations, theories and models are those that best fit the facts known at a particular time.
13. The knowledge produced by science is used in some technologies to create products to serve human ends.
14. Applications of science often have ethical, social, economic and political implications.

Comment:
My initial reaction was: where is the chemistry? The only oblique reference to chemistry and chemical ideas is #1: ***All material in the Universe is made of very small particles.*** Is this an adequate description of either chemistry or the big ideas that underpin the physical world? Point #1 is amplified later in the document and is more explicitly chemistry:

All material in the Universe is made of very small particles
Atoms are the building blocks of all materials, living and non-living. The behaviour of the atoms explains the properties of different materials. Chemical reactions involve rearrangement of atoms in substances to form new substances. Each atom has a nucleus containing neutrons and protons, surrounded by electrons. The opposite electric charges of protons and electrons attract each other, keeping atoms together and accounting for the formation of some compounds.

The behaviour of materials is not determined by the behaviour of the atoms – sodium chloride has no resemblance to sodium or chlorine. All chemical bonding is ultimately the attraction of electrons and nuclei, whether ionic or covalent or metallic. The phrase 'for some compounds' suggests only ionic compound are in mind.

I felt dissatisfied and short-changed by this list and felt that some important chemical ideas were omitted. I noticed from the list of contributors that there were no chemists, only 2 biochemists, and the majority were physicists or engineers. It is surely not enough to say 'atoms are the building blocks' without mentioning the elements or the Periodic Table (the most important idea in chemistry); there is an indirect mention of bonding but no mention of conservation of mass in chemical and biological processes; and there is a mention of energy but not of entropy (or disorder), the arrow of time that determines the direction of all processes.
I would hate to see this list become the authoritative guide to introductory science courses, and I would be interested to know what our readers think of this list and my comments. However, as a chemist I may be biased!
You can download the report from the ASE website at:
http://www.ase.org.uk/documents/principles-and-big-ideas-of-science-education/

PEC

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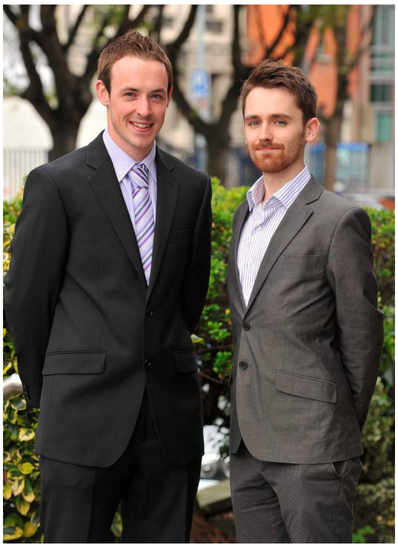
Making an Impact winners

On 13th April two PhD students, Dermot Donnelly (25), from the University of Limerick, and Daniel O'Donovan (26), of Trinity College, Dublin, won the Making an Impact competition, run by the Higher Education Authority in partnership with the *Irish Independent.*



Dermot Donnelly and Daniel O'Donovan, the two prize-winners.

Dermot Donnelly's idea of a virtual laboratory, where students can perform chemistry experiments online, is already being used in some schools. Daniel O'Donovan is working on a new generation of anti-depressants, which will be more effective and have fewer side-effects.
Both winners will receive a scholarship of €2,500. You can read more about Dermot Donnell's Virtual Laboratory below on p. 9.

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TY Science

It is hoped to have two new TY Science modules available for purchase in September: *Waste not, want not!* (The science of Waste), written by Hannah McDonnell and *Power to the people*! (The science of energy), written by Nicholas Ryan. These were developed and trialled in the 2010-2011 school year. If you would like to order these or any of the earlier modules (listed below) email: marielizwalsh@eircom.net for an order form. Each module costs €10 for a Student's Guide and a Teacher's Guide, plus a contribution to p&p.
Existing titles are:

- *Forensic Science*
- *Cosmetic Science*
- *Science of Sport*
- *Environmental Science*
- *Science of Survival*
- *Food Science*
- *Science and Medicine*
- *Issues in Science*

Two new models are being developed this summer and will be available for trial in September*: Smart materials and nanoscience* (Martin Sheehan) and *The science of toys* (Joannah Kennedy). If you would like to take part in the trial please email peter.childs@ul.ie for more information.

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30th ChemEd-Ireland

Sat. 22nd October 2011

Don't forget to mark Sat. 22nd October on your calendar – the 30th. ChemEd-Ireland conference will be held in Cork, in UCC, organised by Dr Declan Kennedy and his team. This is an important annual event and I am sure you won't be disappointed if you come. You can email Declan for details at d.kennedy@ucc.ie and a registration form.

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NCE-MSTL website

Don't forget to register on the website of the National Centre for Excellence in Mathematics and Science Teaching and Learning, www.nce-mstl.ie.
Registration is free-of-charge and over 2,000 teachers have already registered. You can access free resources in maths and science, including the Research and Resource Guides, and materials for Project Maths.

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Ruari Quinn to seek radical reform of Junior Cert

Irish Times 21/04/11

Minister for Education & Skills Ruairí Quinn is to press ahead with radical reform of the Junior Cert, with a remodelled exam being rolled out "as soon as possible". The Minister believes the exam is "no longer suitable as the main form of student assessment in lower-secondary education'' and must be changed.
The revamped Junior Cert will see 55,000 students taking far fewer subjects – and an end to the current system where a dozen subjects are routinely examined. Education sources say the new Minister also wants the exam to put a new stress on problem-solving, rather than the traditional rote learning.
He is also likely to back more continuous assessment by teachers of their own pupils and a new stress on building oral skills in languages. The main second-level teacher union has backed Junior Cert reform. Pat King, general secretary of the Association of Secondary Teachers, Ireland

said; *"We are very concerned about the decline in standards. When it comes to educational reform we are up for it, provided the necessary support structures and funding is in place."* But Mr King also cautioned that more continuous assessment could damage public confidence in the integrity of the revamped exam. Reform of the Junior Cert is a key element in a package of measures proposed by the Minister, all designed to address declining standards in Irish education.
In April 2011 a European Commission report raised further questions about the quality of the Irish education system. It said the number of low achievers in reading, maths and science had increased from 11 per cent in 2000 to 17 per cent in 2009. Last year the OECD ranked Ireland as average or below average in literacy, science and maths.

The National Council for Curriculum and Assessment will shortly table a final series of proposals on Junior Cert reform. Many of these will be incorporated into Mr. Quinn's own proposals which are expected to be published around September.

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Waterford Institute of Technology hosted Eurachem 2011 competition

Eurachem Ireland & The Association of Heads of School of Science present the European Analytical Measurement Competition (EAMC), which was hosted by the Science Department in Waterford Institute of technology on April 13th 2011.
The annual competition is designed to raise awareness among student analysts of uncertainty in measurement and the requirement for excellence in analytical skills. It is open to teams of two full-time third-level registered students studying laboratory sciences in Universities or Institutes of Technology anywhere in Ireland and who have not yet entered the third year of their course.
Competitors are chosen by their own Institution, for their practical laboratory skills.
The overall winners this year were a team from Waterford Institute of Technology, with runners up from IT Sligo and GMIT.

Overall Winners: Waterford IT
Team members: Christopher Burke and Damien Reid. Accompanying lecturers: Evelyn Landers & Bernadette Whelan

Runner-up: Sligo IT
Team Members: Tamara Steiner and Melissa Brady. Accompanying Lecturer: Ted Mc Gowan

Runner-up: Galway-Mayo IT
Team members: Geresu Balcha and Shuyu Chu
Accompanying Lecturer: Kathleen Locke

On the day a bouquet of flowers was presented by Dr Ray Leonard (one of the EAMC judges) to Dr Margaret Franklin, recently retired from lecturing in chemistry at Athlone IT, who is a member of the EAMC committee.

Ray Leonard making the presentation to Margaret Franklin

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Chemistry and Art competition hosted by NUIG for IYC 2011

NUI Galway is hosting a Chemistry-Art exhibition called "Capturing Chemistry" for International Year of Chemistry 2011. It's open to submissions from anyone, young or old, student or working...
There's some info on their Facebook page:
http://www.facebook.com/group.php?gid=154336711248275
The application form is here:
http://www.nuigalway.ie/chemistry/documents/capturingchemistry.doc

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LIT student develops website on Chemical Instrumentation for LC Chemistry students

Dean Meagher, a final year student on the B.Sc. in Chemical Instrumentation and Analysis in Limerick Institute of Technology, developed a website on chemical instrumentation for leaving certificate students as part of his final year project. The webpages have been very favourably received by teachers who evaluated them. However, this is still a work in progress which it is hoped to expand on next year.
If you have time to take a look at the website at www.chemicalinstrumentation.weebly.com and send any comments or evaluations they would be appreciated. Send your comments either to Dean via the evaluation form on the website or by email to Marie.Walsh@lit.ie

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SciFest 2011 starts in LIT

SciFests around the country began this year on April 5th with the Limerick Institute of Technology SciFest. This year there were almost 100 entries on the day and an exciting array of topics were investigated by the young researchers. The Scifests around the country were the brainchild of Sheila Porter, who is the Project Manager, and they are a testament to her encouragement and enthusiasm for science education using investigative methods.

An extra prize is being presented at each host venue this year to mark the International Year of Chemistry. Attached photo shows the IYC prizewinners in LIT being presented with their award by Ms Siobhan Murphy, Education Executive Pharmachemical Ireland.

Chemistry winners at LIT were: Oonagh Pierce, Brian O'Rourke and Isabelle Olsthoorn from Colaiste Chiaran, Croom, with their project 'An investigation of percentage of metal salts that can be absorbed from lichens'. Their teacher/mentor was Mr. Christopher Kiely.

(For more on SciFest see the articles on p. and p.)

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Thinking small has a big future

Sunday Times 13/02/11

Students will now have the opportunity to study the exciting world of nanoscience as an undergraduate degree at Trinity College Dublin. The course titled 'Nanoscience – Physics and Chemistry of Advanced Materials', jointly run by the Schools of Chemistry and Physics, will provide students with a deep understanding of the science of advanced materials such as superconductors, polymers and lasers found in new technologies that underpin the nano revolution. The degree course was launched in September by Trinity and the first intake of students will be in 2011.

"This degree course offers the opportunity to future students to get a well rounded and excellent grounding in some of the most relevant and advanced science in the world today. It is an area that will revolutionize our world and sustain the knowledge economy in Ireland," explained the Head of School of Physics, Professor John Donegan.

Nanoscience belongs to both physics and chemistry; therefore students will gain a solid grounding in these subjects as well as mathematics in the first two years, which will include laboratory work, lectures and problem-solving tutorials.

Students will then specialize in nanoscience in the third and fourth years, spending six hours per week in a nanoscience laboratory, where they will be introduced to a wide range of techniques for the formulation and characterization of nanomaterials. Trinity's flagship nanoscience institute, CRANN, is recognized internationally as a leading institute for nanoscience research where students will have access to its state of the art facilities.

In a challenging and exciting final year for students, they will carry out a major research project, working in an academic or industrial research laboratory often abroad, and arranged by Trinity, where they will become familiar with the applications of advanced materials and nanodevices in real life situations.

Nanotechnology is estimated to have a global market value of $3 trillion by 2015 across a diverse range of sectors. Nanoscience contributes to product innovation in virtually every field of manufactured goods and is vital to Ireland's economic future. Three of the largest industries in Ireland will be directly impacted by nanoscience research − medical devices, pharmaceutical drugs and information communication technology (ICT). It is estimated that 10%, about €15 billion, of Ireland's annual exports are now associated with nanotechnology and that there are in excess of 150,000 employees working in companies in which nanotechnology plays an important enabling role. Industries such as Intel and Hewlett Packard are key developers and users of nanotechnology in Ireland.
"Graduates of this new nanoscience degree will be strongly sought-after in the knowledge economy where their interdisciplinary training in physics and chemistry will give them a clear edge in solving real life problems in high-tech industry," concluded Head of the School of Chemistry, Professor David Grayson.

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STOP PRESS

The LC and JC examinations started on June 8th. and we hope to provide the annual analysis of the results in the next issue (#94).

55,550 candidates are registered to sit the LC in 2011, 3,245 are sitting the LC Applied and 57,732 the JC examination, spread across 4,750 exam centres. Concern is already been expressed (Irish Times 7/6/11) about the low numbers taking HL LC Maths (10,435) as this numb er always drops at the last minute as pupils drop down to the OL paper. Fewer pupils take HL in LC Maths than any other LC subject. A slightly higher % of pupils are opting for the HL paper in the pilot schools who did Project Maths than in schools doing the traditional course.

We are also starting to see the upturn in the numbers doing the JC and LC examinations as the increased birth rate starts to move up through the educational system

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A Virtual Laboratory to Support Scientific Enquiry in Irish Post-Primary Schools

Dermot Donnelly, John O'Reilly & Oliver McGarr
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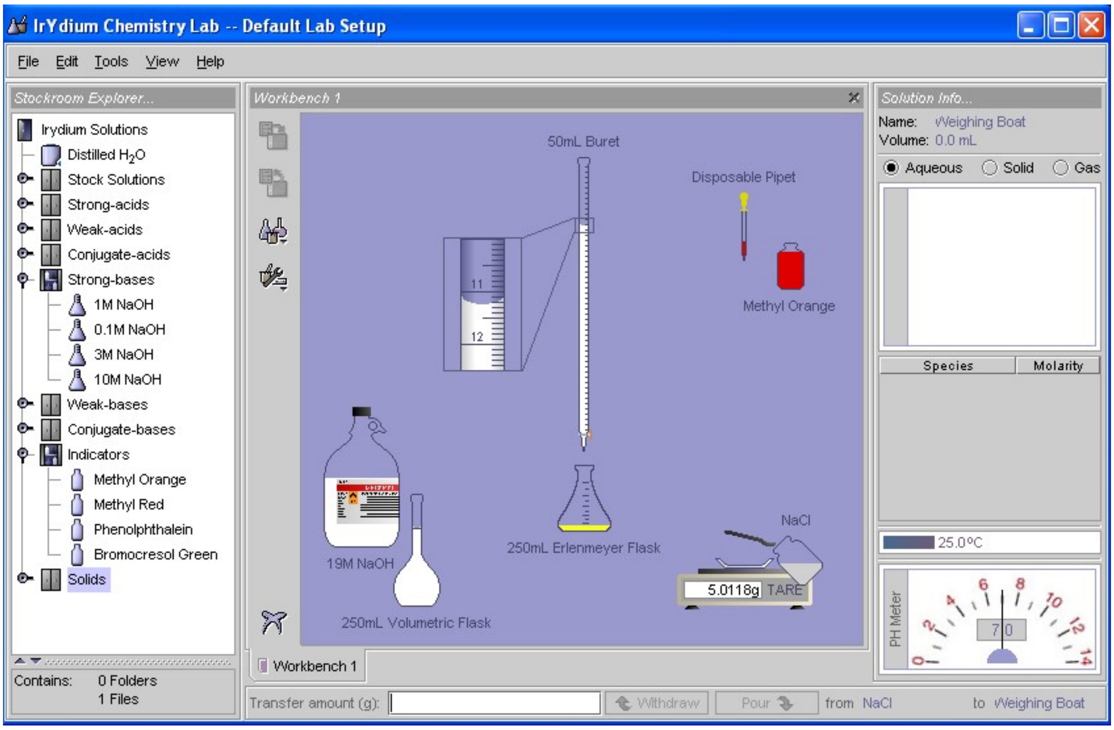
One had to cram all this stuff into one's mind for the examinations, whether one liked it or not. This coercion had such a deterring effect on me that, after I had passed the final examination, I found the consideration of any scientific problems distasteful to me for an entire year.
Albert Einstein

Not every student dreams of being part of a quiz show. However, with a large focus in secondary school science examinations on recalling facts, one may be forgiven for thinking otherwise. Despite it being the 'information age', where students can find out facts at the click of a button, we still persist in churning out students that have an uncanny resemblance to mini-libraries. Therefore, it comes as no surprise that many students do not look forward to learning about science. In 'fact', they dread how much they will have to learn-off for an examination.

Learning science should be like watching a live sporting event. You are sitting on the edge of your seat, observing the spectacle as it unfolds, noting every little detail, immensely engrossed at the possibilities of what might happen. Despite this 'live' excitement, watching the highlights of the same sporting event does not have the same appeal with the result being known. Yet, in many schools, many students experience a 'science of highlights' where they are told the result beforehand and have to follow instructions towards getting that result. This in turn leads many students to see everything in science as already solved and thus as an exercise in learning off facts. We should instead want students to engage in the excitement of doing real science: making predictions, making observations, finding evidence and much, much more.

You do not need to be Einstein to know that a science of highlights is not the way students should be learning science, yet why does the problem persist? Concerns often mentioned by teachers are those of student safety, preparation and tidy-up time within 40 minute class periods. These concerns are understandable considering it is impossible to watch at many times over 20 students with only 2 eyes. Not to mention having to get everything tidied and set up for the next class and so on. Some teachers feel more like a fire-fighter than an educator when doing class experiments, running around to each student's desk to ensure safety and careful procedure. It would be great to have smaller class sizes and thus allow more student freedom in how they carry out experiments. However, this would require lots of money, money that is not available in many tight school budgets.

So what are the solutions? This research project is looking at how free computer software (called virtual lab, see image below) could be used to offer a new way in which students can learn about science. The purpose of course is not to replace experiments but to enable students to have more ownership, responsibility and freedom in the experiments they carry out. The virtual laboratory achieves this through facilitating student decision-making in every aspect of the experiment, from what sized beaker to use, what volume of acid to add and so forth. The virtual lab can also address the previously mentioned teacher issues and would allow more time and space for students to investigate, just like what real scientists do. It would even cater to special education needs students who may not be able to carry out certain experiments but could do so within the virtual lab.



Results of the research so far have shown very positive attitudes by both students and teachers to the use of the virtual lab. Students like the quick and easy-to-use nature of the virtual lab. The virtual lab allows the students to ask many 'what if' questions and find out the answers quite readily, both at school and at home. The safety aspect of the virtual lab encourages these questions by the students. Many students have also agreed that they would be happy with the virtual lab as part of or as an option in their examinations. The use of the virtual lab in this way would aid in a movement away from rewarding mostly recalling facts to more student involvement in their experiments. Teachers appreciate the safety aspect of the virtual lab and note the impact of the virtual lab on their teaching. The virtual lab allows teachers to better concentrate on students' understanding of experiments compared to experiments in the actual lab where they concentrate more on preventing breakages and spillages.

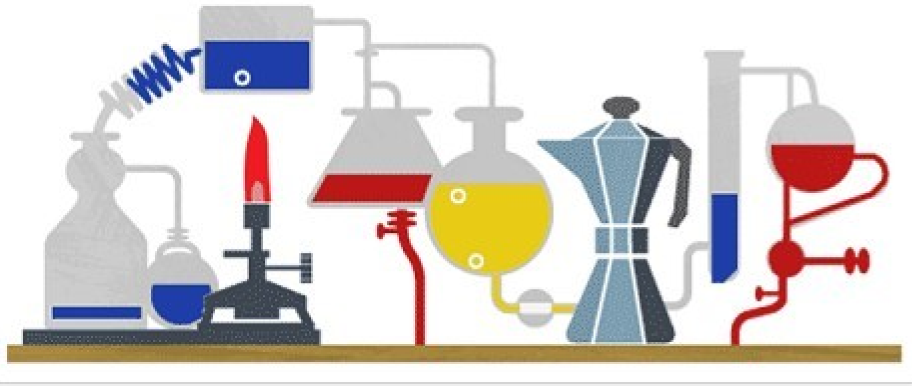
The virtual lab has undoubtedly made a significant impact on the students and teachers who have used it so far. With further research and further development, the virtual lab has the potential to make a much bigger and broader impact in how science is taught and assessed in Ireland. It would also serve as an example to the international community. Importantly, the virtual lab would lead to science that is more interesting, relevant and engaging to students. Humans by nature have inquisitive minds and our education system should strive to encourage this if it hopes to produce more creative and innovative students.

The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed.

Albert Einstein

This research project is based at the University of Limerick under the supervision of Dr John O'Reilly and Dr Oliver McGarr. Dermot Donnelly is a PhD student in the Education and Professional Studies Department at the University of Limerick. For further information please contact dermot.donnelly@ul.ie.
The virtual laboratory is available online: http://www.chemcollective.org/vlab/vlab.php.
Irish related problems are contained within the Homework Repository in the File menu.

2011 anniversaries: Robert Bunsen 1811-1899



Robert Wilhelm Bunsen
(1811-1899)

This animated image was used as a Google Doodle on March 31st. to celebrate Robert Bunsen's birthday on 31/3/1811 – so this is the 200th anniversary of his birth.
Some short biographies:
http://micro.magnet.fsu.edu/optics/timeline/people/bunsen.html
http://www.corrosion-doctors.org/Biographies/BunsenBio.htm

Bunsen is most famous for the Bunsen burner but his most important work, done with Gustav Kirchoff, was to show that it was possible to identify the elements using their line spectra, as described in this 1859 letter:
"At present Kirchhoff and I are engaged in a common work which doesn't let us sleep...Kirchhoff has made a wonderful, entirely unexpected discovery in finding the cause of the dark lines in the solar spectrum....thus a means has been found to determine the composition of the sun and fixed stars with the same accuracy as we determine sulfuric acid, chlorine, etc., with our chemical reagents. Substances on the earth can be determined by this method just as easily as on the sun, so that, for example, I have been able to detect lithium in twenty grams of sea water."

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The nuclear atom, April 1911

The article below appeared as an editorial in the Irish Times on 2nd. April 2011, and is an excellent example of science communication to the public and a reminder of an important anniversary. The heading 'The Fly in the Cathedral' is the title of a book by Brian Cathcart. The subject of the editorial is very relevant both to the Junior Certificate Science course and to Leaving Certificate Chemistry and the Physics courses.

The fly in the cathedral

***Irish Times* 2/4/11**

'IF YOU can't explain your physics to a barmaid," Ernest Rutherford suggested, "it is probably not very good physics". And, in truth, Rutherford's physics passed his own somewhat sexist test with flying colours, its insights deceptively simple and yet, like so much great science, gloriously elegant. And well worth celebrating.
One hundred years ago this month, at the Manchester Literary and Philosophical Society Rutherford, a 39-year-old professor, head of physics at the city's university and already a Nobel winner for his part in the discovery of the alpha particle, opened a new chapter in the history of science with a remarkable presentation on the shape of the atom, a model now so central to popular understanding it is hard to appreciate its novelty then.
The New Zealander's new model, a miniature planetary system of tiny, negatively charged electrons revolving around a heavy, positively charged nucleus, laid the basis for the development of nuclear physics in the way that the discovery of the elegant helix shape of DNA would spawn the modern science of genetics.
At the time Rutherford was struggling to reconcile his mentor JJ Thomson's description of the atom, the "plum pudding" model, with experiments by two colleagues, Hans Geiger and Ernest Marsden. Thomson had suggested the atom consisted of a lump of "positive electricity" in

which negatively charged electrons were embedded like plums in a pudding. But the experiments, involving firing particles at a fine gold foil, were difficult to reconcile with this view – most of the particles simply passed through the foil, some were deflected, and a small number, about one in 800, bounced back.

"It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you," Rutherford would tell his barmaid. But the results suggested, he argued, that the atom consists of a tiny central core containing virtually all the atomic mass, "like a fly in a cathedral". Most of the bombarding particles simply passed through the empty space but if a particle collided head on with the nucleus it would recoil straight back like a ball bouncing off a wall.

Later, Niels Bohr would explain how electrons kept up their orbits, James Chadwick would discover the neutron, and in 1932, following Rutherford's suggestion that the atom could be artificially split James Cockcroft and Dubliner Ernest Walton did so in the first particle accelerator. They would be among 11 students and colleagues of Rutherford's eventually to receive Nobel prizes.

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Bernard Courtois and the discovery of iodine 1811

Bernard Courtois (1777-1838)

Iodine is widely spread in nature and iodine-containing sponges had been used medicinally to cure goitre without knowing what they contained and how they worked. The discovery of iodine is one of those great tales of serendipity in science. Bernard Courtois was a French chemist engaged in producing saltpetre for gunpowder. Due to a shortage of wood ash Courtois was extracting potassium salts from burnt seaweed, known as varech in France and kelp in the UK and Ireland. One day he was cleaning out his copper pans with sulphuric acid when he notice purple fumes coming off, condensing to shiny crystals on cool surfaces. Seaweeds concentrate iodine from sea water and when burnt to an ash and extracted with water, iodine salts are extracted. Sulphuric acid liberated iodine from the iodine-containing residue. Courtois suspected he had found a new element but as a busy manufacturer he hadn't time to follow up his discovery. He passed samples on to, two French chemists, Nicolas Clément and Charles-Bernard Désormes, who established its chemistry and elemental qualities. The first publication was in 1813 and there was considerable competition and some animosity between the French chemists (including also Louis-Joseph Gay-Lussac and André M. Ampère) and Humphry Davy (see below).

"This substance was discovered accidentally, 2 years ago by Courtois, a Paris manufacturer. In the course of the procedure by which he obtained soda from seaweed ash, he found that the metal vessels he used were corroded and he looked for the cause, when he discovered the new substance. It appeared when a little sulfuric acid was added to the ash after extracting carbonate of soda. When the acid is concentrated enough to produce a strong heat the new substance appears as a beautiful violet vapour and condenses in crystals which are the colour and lustre of graphite."

Humphry Davy

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The chemical algebra of quantities

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In a previous paper[1] I sabered down the factor-label method. I now realize that I should have discussed its alternative, the algebra of quantities, in more detail. In this article I shall describe how this method enables us to perform chemical calculations in a logical manner.

1. Scientific calculations

In science, calculations are done with *quantities*, and in these calculations the rules of algebra are used. A quantity is a property that can be measured. An example is the breadth of the page on which this text is printed. The result of a measurement is to be expressed in appropriate units. As you can easily check, the breadth of this page is 20.6 cm. This example reveals the basic structure of a quantity: it is a number *multiplied by* a unit, or

(1) *Quantity* = Number x Unit

The symbols of quantities are to be printed in sloping type, their numerical values and units (and other useful information, such as the phases and formulae of substances) are to be printed upright. If we would want to multiply two quantities with each other, then the multiplication must be performed not only with the two numbers, but also with the two units. As the length (= l) of this page is 29.1 cm, and its breadth (= b) is 20.6 cm, the area (= A) of the page is

(2) $A = l \times b$ = (29.1 cm) x (20.6 cm) = (29.1 x 20.6) x (cm x cm) = 599 cm^2

A quantity is unambiguous only, if both its numerical value and its unit are given.

2. Samples of substances

Chemical calculations often pertain to properties of samples of substances. A *sample* of a substance is a finite, hence measurable, amount of that substance. Examples of samples of substances are a lump of sugar, a sip of water, and a whiff of air.

3. Extensive and intensive quantities

In science, one distinguishes between two types of quantities, namely *extensive* and *intensive* ones. The value of an extensive quantity of a sample is proportional to the *size* of that sample. Examples of extensive quantities of a sample are its mass, and its volume. The internationally agreed upon (ISO-norm) symbols of these quantities are m, and V, respectively.

The value of an intensive quantity of a sample does not depend on the size of that sample. An example of an intensive quantity of a sample is its temperature, T. The temperature of a well-stirred sample of boiling pure water is 373 K throughout. Other examples of intensive quantities shall be discussed presently.

4. The size of a sample of a pure substance

Here, I restrict myself to pure substances that consist of particles of *one* kind. These particles may be atoms, or molecules. The kind of substance, or the kind of its constituting particles, shall be denoted by the symbol X. The number of particles contained in a sample of X is denoted by N(X). The *size* of a sample is determined by giving any of its extensive quantities.

Consider, for example, a piece of pure aluminum. Its mass can be determined by putting it onto a balance. The result of weighing may be written as m(Al) = a g. The volume of the piece can be found by measuring the volume of water that it displaces. In this way, we can find V(Al) = b cm^3. If we were able to count the number of atoms contained in the piece, we could, after a while, end up with the dimensionless result N(Al) = c.
These three ways of fixing the size of our piece of aluminum are of a *physical* nature. In chemistry, one is more interested in the relationship of any of these quantities of samples of *different* substances. For example, a chemist would want to be able to answer a question like: if 10.0 grams of aluminum were completely transformed into aluminum oxide, which mass of the oxide would then be obtained? In order to do so, a brand-new unit has been added to the SI in 1967, and amendments of its definition have been made until 1980. This new unit was given the name *mole* (symbol: mol),

and the extensive base quantity associated with it was named *amount of substance* (symbol: n).

5. Amount of substance and mole

I must start by citing the SI definition[2] of the mole. It consists of three parts.

1. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kg of carbon 12.
2. In this definition, it is understood that unbound atoms of carbon 12, at rest and in their ground state, are referred to.
3. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

Elsewhere[3] I have argued that, *for use in chemistry*, the terms "system" and "elementary entities" of the SI definition of the mole can be replaced by "sample (of a substance)" and "particles", respectively. Now, this definition can be simplified to become

The mole is the amount of substance of a sample (of a substance) which contains as many particles (of that substance) as there are atoms in 0.012 kg of carbon 12.

The number of carbon atoms in 0.012 kg of carbon 12 is fixed. This number is denoted by the symbol[4] N_0, it is named Avogadro's number, and its rounded value is

(3) $N_0 = 6.022 \times 10^{23}$

Using Avogadro's number, the simplified definition of the mole can be made even simpler:
The mole is the amount of substance of a sample (of a substance) which contains N_0 particles (of that substance).

6. Intensive quantities

Consider a sample of a pure substance X. Its mass is $m(\mathrm{X})$, its volume $V(\mathrm{X})$, its amount of substance $n(\mathrm{X})$, and it consists of $N(\mathrm{X})$ particles.
If we form a quotient of any two of these extensive quantities, we get an intensive quantity, which usually still depends on X.

A well-known example of such an intensive quantity is the volumic mass (usually called "density"), which is defined as

(4) $\rho(\mathrm{X}) = m(\mathrm{X})/V(\mathrm{X})$

If we express $m(\mathrm{X})$ in kg , and $V(\mathrm{X})$ in m^3, then $\rho(\mathrm{X})$ gets the unit kg m^{-3}. Contemplating this unit, it is clear that $\rho(\mathrm{X})$ is neither a mass, nor a volume. Instead, it is a completely *new* quantity, with the ability to close the conceptual gap which exists between the different extensive quantities mass and volume. Its meaning is that of a *bridge-quantity*[3], which enables us to calculate the mass of a sample, if its volume is given, and *vice versa*. If temperature and pressure are both fixed (usually at their standard values), $\rho(\mathrm{X})$ is a *constant* of substance X. Most textbooks contain a table in which such volumic masses (densities) are listed for different X.

7. Molar quantities

If the extensive quantities of a sample of substance X (see section 6) are divided by its amount of substance, so-called *molar* quantities are obtained. Using ISO normsymbols, these are the molar mass

(5) $M(\mathrm{X}) = m(\mathrm{X})/n(\mathrm{X})$
the molar volume

(6) $V_\mathrm{m}(\mathrm{X}) = V(\mathrm{X})/n(\mathrm{X})$
and the molar number of particles of type X

(7) $N_\mathrm{A} = N(\mathrm{X})/n(\mathrm{X})$

These three molar quantities function as bridge-quantities, in a similar way as does $\rho(\mathrm{X})$ of section 6. For example, $n(\mathrm{X})$ may be calculated from eq (7), if this equation is rewritten as

(8) $n(\mathrm{X}) = N(\mathrm{X})/N_\mathrm{A}$

I now consider a sample of substance X which has an amount of substance of exactly 1 mol, thus $n(\mathrm{X}) = 1$ mol. According to my last version of the definition of the mole, this sample consists of N_0 particles of type X, hence $N(\mathrm{X}) = N_0$. Substitution of these values of $n(\mathrm{X})$ and $N(\mathrm{X})$ into eq (8) gives

(9) $1\ \mathrm{mol} = N_0/N_\mathrm{A}$

This result is valid for *any* substance X, so the "1 mol" in the left-hand side of eq (9) applies to *any* substance X, and is, therefore, *independent* of X. In the right-hand side of eq (9), N_0 represents the constant of eq (3), which neither depends on X. Consequently, N_A of eq (9) must be *independent* of X, although this does not follow from eq (7). Rewriting eq (9), we find

(10) $N_A = N_0 \text{ mol}^{-1}$

The numerical value of the molar number of particles, N_A , equals Avogadro's *number*. For this reason N_A has been named Avogadro's *constant.* Now that the meaning of N_A has become clear, eq (8) may be regarded as the *definition* of the quantity "amount of substance".

8. Calculation of molar masses

Molar masses play a most important role in chemical calculations. Therefore, students should be able to calculate M(X) for any X.
The mass of a single particle of type X shall be denoted by the symbol m(1 X). If a sample of substance X consists of N(X) particles, then the mass of that sample should be equal to

(11) $m(\text{X}) = N(\text{X})\, m(1\text{ X})$

Unfortunately, this equation is correct only, if the particles of the sample do not interact with each other. This may be assumed to be the case in the gaseous state, and so eq (11) can be used for a sample of helium, say.

If a gaseous sample is condensing to form a liquid or solid, its particles have started to interact with each other. During the condensation process the sample gives off energy. This loss of energy is proportional to a *mass defect*. Consequently, the mass of all particles in the condensed phase is slightly smaller than that of those in the gaseous phase. Fortunately, the decrease of particle mass due to changes of phase (or chemical processes) is so small that it can be neglected, Hence, eq (11) may be used for samples of any phase.

Substitution of eqs (8) and (11) into eq (5) leads to

(12) $M(\text{X}) = N_A\, m(1\text{ X})$

I now consider the case in which X stands for a type of *atom*. Most textbooks contain a table of atomic masses. These are expressed in unified atomic mass units with the symbol u. By definition[5] we have

(13) $1\text{ u} = m(1\ ^{12}\text{C})/12$

The definition of the mole leads to

(14) $N_0\, m(1\ ^{12}\text{C}) = 12\text{ g}$

Eqs (13) and (14) can be combined to giveN_0

(15) $\text{u} = 1\text{ g}$

Denoting the dimensionless *relative* atomic mass by the symbol m_r(1 X), we have

(16) $m_r(1\text{ X})\text{ u} = m(1\text{ X})$

Using eq (15), we can replace the unit u by the unit g, and obtain

(17) $m(1\text{ X}) = (1/N_0)\, m_r(1\text{ X})\text{ g}$

Substitution of eq (17) into eq (12) gives

(18) $M(\text{X}) = (N_A/N_0)\, m_r(1\text{ X})\text{ g}$

and, with help of eq (10), we finally arrive at

(19) $M(\text{X}) = m_r(1\text{ X})\text{ g mol}^{-1}$

Eq (19) enables us to find the molar mass (expressed in g mol^{-1}) for any kind of *atom*. The molar mass of a substance consisting of *molecules* is found by adding the molar masses of all atoms contained in that molecule. For example, the molar mass of sulfuric acid is found as

(20) $M(H_2SO_4) = 2\, M(\text{H}) + M(\text{S}) + 4\, M(\text{O})$

The molar mass of a *salt* refers to its smallest neutral group of ions. In the case of sodium chloride, this group is the $(Na^+)(Cl^-)$ ion pair. The molar mass of sodium chloride then is

(21) $M(\text{NaCl}) = M(\text{Na}^+) + M(\text{Cl}^-) = M(\text{Na}) - M(\text{e}^-) + M(\text{Cl}) + M(\text{e}^-) = M(\text{Na}) + M(\text{Cl})$

This example shows that we may calculate the molar mass of a salt, as if it were built from atoms, instead of ions.

9. The molar volume

The molar volume of substance X is defined by eq (6) as the quotient of two *extensive* quantities:

(6) $V_m(X) = V(X)/n(X)$

eqs (4) and (5) can be rewritten as

(22) $V(X) = m(X)/\rho(X)$
and

(23) $n(X) = m(X)/M(X)$

respectively. Substitution of eqs (22) and (23) into eq (6) gives

(24) $V_m(X) = M(X)/\rho(X)$

Now the molar volume is equal to the quotient of two *intensive* quantities, and this relationship is valid for any pure substance, irrespective of its phase. If X happens to be a *gas*, then an approximate value of the molar volume may be obtained from the ideal gas law, $pV = nRT$. It is

(25) $V_m(T, p) = V/n = RT/p$

This result is seen to be independent of X.

10. The heart of chemical algebra of quantities

The most important chemical calculations are those which relate to chemical reactions. The net result of a chemical reaction is depicted by its equation. The equation of the reaction in which the reactants A and B are transformed into the products P and Q can be written as

(26) a A + b B → p P + q Q

Here, A, B, P and Q represent formulae of substances, and a, b, p and q denote appropriate coefficients. It is customary to choose these to be the smallest integers that balance eq (26). They show that a particles of substance A can react completely with b particles of substance B. If we would multiply all coefficients by the same integer, then eq (26) remains balanced. Hence, samples of the substances A and B can react completely with each other, if the numbers of their particles satisfy the proportion $N(A) : N(B) = a : b$, or

(27) $N(A)/a = N(B)/b$

In a similar way we find

(28) $N(P)/p = N(Q)/q$

Eq (26) shows that, if a particles of A react away, p particles of P are formed. Hence, the consumption of A and the formation of P are linked to each other in such a way, that

(29) $N(A)/a = N(P)/p$

Combining eqs (27) – (29) with each other, we find

(30) $N(A)/a = N(B)/b = N(P)/p = N(Q)/q$

Finally, dividing all terms of eq (30) by N_A, and using eq (8), we arrive at

(31) $n(A)/a = n(B)/b = n(P)/p = n(Q)/q$

As this equation probably is the most important one in the field of chemical calculations, I have characterized it as[6] "the heart of chemical quantity calculus". But since in chemical calculations the rules of algebra, rather than those of calculus, are used, I would now call it "the heart of chemical algebra of quantities". Earlier, Tykodi[7] called eq (31) the "de Donder relation", and its terms "de Donder ratios", in honour of the Belgian mathematician and physicist Théophile Ernest de Donder, who apparently derived it first.

11. Sample calculation

A calculation pertaining to a chemical reaction consists of four steps[8].

1. Write down the balanced equation of the reaction at hand.

2. Calculate the amount of substance of that substance about which information is given.

3. Select the appropriate de Donder ratios, and calculate the amount of substance of the substance to which the problem refers.

4. Find the answer to the question posed in the problem.

I now return to the question mentioned in section 4: if 10.0 grams of aluminum are completely transformed into aluminum oxide, which mass of the oxide is then obtained? In finding the answer to this question, I assume that the pertinent molar masses are given, or can be taken from a table. If not, these have to be calculated first.
The four-step procedure for this problem is:
1. $4\ Al(s) + 3\ O_2(g) \rightarrow 2\ Al_2O_3(s)$

2. $n(Al) = m(Al)/M(Al) = 10.0\ g/(26.98\ g\ mol^{-1}) = 0.3706\ mol$

3. $n(Al_2O_3)/2 = n(Al)/4$, or $n(Al_2O_3) = n(Al)/2 = 0.1853\ mol$

4. $m(Al_2O_3) = n(Al_2O_3)\ M(Al_2O_3) = 0.1853\ mol \times 101.96\ g\ mol^{-1} = 18.9\ g$
If 10.0 grams of aluminum are completely transformed into aluminum oxide, then 18.9 grams of the oxide will be obtained.

12. Concluding remarks

We take for granted that students can memorize the symbols of some thirty chemical elements. If they are to perform chemical calculations in the way described in this article, they need to remember the symbols of far less quantities. Because in actual chemical calculations the symbols N, N_A and N_0 play no important role, the symbols to be remembered are m, M, n, ρ, V and V_m. Finally, the calculations themselves only involve relationships of the type A = B C, and the two related ones B = A/C and C = A/B. These three can be retrieved from a calculation triangle[9]. This triangle is equilateral with sides of 3 cm, say. At half its height a line parallel to its base is drawn. This line serves as the symbol for division. In the small upper triangle the letter A is written, and in the lower trapezoid we write B C.
If we now hide one of these three letters by putting a finger over it, the hidden symbol equals that what still can be seen. If we hide the symbol C, for example, we find C = A/B.
The algebra of quantities is not more difficult than the factor-label method. There is an important difference though: whereas the algebra of quantities is based on logic, the factor-label method is based on nonsense[1,3].

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Proceedings, 29th ChemEd-Ireland

DIT, Kevin Street

9th October 2010

In this issue we carry the Proceedings of the 29th. ChemEd-Ireland held in DIT, Kevin Street on October 9th. 2010, and organised by Michael Seery and Claire McDonnell. A report on this appeared in the last issue of *Chemistry in Action!* (#92, Winter 2010, p.46) The conference was a mixture of plenary lectures and workshops and the feedback was encouraging, although it was only possible to people to go to one workshop. The timetable for the day is given below. It has only been possible to include some of the presentations given at the conference in the Proceedings, which were received in time (those shown in bold in programme below).

This year's ChemEd-Ireland will be held in Cork at UCC on Saturday October 22nd and organised by Declan Kennedy and his team. This conference will mark 30 years of the ChemEd-Ireland conferences, started in Limerick in 1982 by Peter Childs.

Time	Speaker / Workshop Facilitator	Activity
9.00-9.40		Registration and Tea / Coffee and Exhibits / Posters
9.40-9.45	Declan Mc Cormack, Head of School of Chemical & Pharmaceutical Sciences	Welcome
9.45-10.30	Jane Essex, University of Keele	**Teaching Students of Differing Ability**
10.30-11.15	Tim Desmond, Chief Examiner, State Examinations Commission	Observations of the Chief Examiner
11.15-11.45		Tea / Coffee and Exhibits / Posters
11.45-12.45	Martina Crehan and Marian Fitzmaurice	**WS1**: Reflecting on Teaching Practice
	Fionnghuala Kelly and Muireann O'Keeffe	**WS2**: Incorporating Web 2.0 in Teaching
	Michelle Dunne and Sheila Porter (SciFest Project Manager, Intel)	**WS3**: **Preparing students for entry into SciFest and Young Scientist competitions**
	Peter Childs and Maria Sheehan	**WS4**: **Resources for Teaching the Particulate Nature of Matter**
	Patrice Behan, Peter Brien, Caoimhe Ní Neill, Christine O'Connor, Aoife Power & Michael Seery	**WS5**: Context-based Learning Materials (Forensic & Environmental Chemistry and Nanotechnology)
12.45-2.00		Lunch
2.00-3.00	Aisling Judge and Sheila Porter (SciFest Project Manager, Intel)	Supporting Entrants for the Young Scientist Exhibition and / or SciFest
3.00-3.30	Maria Sheehan & Peter Childs, University of Limerick	Teaching the Particulate Nature of Matter
3.30-3.45		Tea / Coffee
3.45-4.00	Michael Seery, Dublin Institute of Technology	Class Websites and Podcasts Using Google Sites
4.00-4.15	Peter Jackson , PDST Local Facilitator	PDST (Professional Development Service for Teachers)
4.15-4.20	Odilla Finlayson, Dublin City University	**The ESTABLISH project – Promoting Inquiry-Based Science Education**
4.20-4.30	Brian Murray, Institute of Technology, Tallaght & Institute of Chemistry of Ireland	International Year of Chemistry 2011 followed by award of Schools Chemistry Newsletter prize

Teaching Chemistry to Students of Differing Abilities

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Teachers of Chemistry commonly have difficulties in teaching the material to students of widely varying abilities. The problems manifest themselves more widely in lower secondary aged pupils who are required to undergo study of some aspects of Chemistry . However, the problem changes but does not entirely disappear once students have had an opportunity to select against continuing with Chemistry, since career aspirations may encourage them to persist with the subject despite a lack of notable success up to the point of selection of subjects. Indeed, the challenge is commonly exacerbated when teaching students of post-compulsory age who opt to study Chemistry in small numbers, so there is very little chance of sub-dividing students into groups of similar abilities. The teacher wis required to provide a differentiated experience of teaching and learning, which I shall define as,
the provision of support , tasks and stimulus appropriate to the capacities of individual learners within a group, aimed at optimal development for each learner.

Whilst differentiation is always a challenging aspect of the teacher's job, Chemistry presents particular obstacles. It is to the difficulties inherent in the subject that I wish to turn first. The high demands of the Chemistry content, relative to the capacity of many learners, was first documented 30 years ago. When the cognitive demands of the then Chemistry school leaving qualification was assessed against Piagetian schema, they were found to demand a higher level of functioning than most students in the target age range (Shayer and Adey, 1981). One aspect of the high level of cognitive demand is the need to work between three levels of representation in order to apply the core models of the discipline (Johnstone, 1991). A second difficulty presented by Chemistry is the nature of the technical vocabulary. Although literacy barriers are common to the study of science generally, students of Chemistry are poorly served at all but the most basic level of study if they are not able to use correct chemical nomenclature. Thus they are required to assimilate nomenclature and concepts about composition simultaneously. The final aspect of the subject, which causes difficulties to many students at all levels of study, is the mathematical skills that are required.

The inherent demand of the subject means that it presents a challenge to the most able learners, but rapidly becomes incomprehensible to the less able. An obvious response to the difficulties inherent in the subject matter is to focus the learning activities on low level thinking skills, requiring recall but with minimal deep understanding or application (Newmann and Wehlage, 1993). Although this may appear to provide differentiation, paradoxically it may equally prove disengaging experience for the learner (Daloz, 1986).

So how may we provide an engaging experience of Chemistry for all learners? Naylor and Keogh (1998) identify three forms of differentiation for different learners; differentiation by support, by task and by outcome. (See Table 1) If a combination of these measures is deployed in order to address the 'extremes' of the learning population, identified by the collation of previous evidence, the middle ability learners' needs should be encompassed. In addition, several of the strategies permit individualisation for each student. The following table summarises some of the most commonly used means of meeting the learning needs of the very able and least able in the Chemistry class. All these strategies require robust evidence of learners' capabilities and difficulties to ensure that they are effectively targeted. (It is also worth noting that many students exhibit both competence in some areas and difficulties of others; students with Asperger's Syndrome are a prime example of this.)

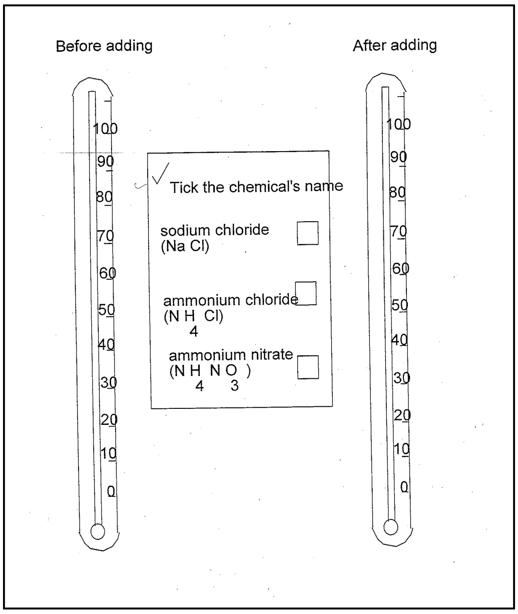
Table 1 Three forms of differentiation for different learners (Naylor and Keogh, 1998)

Differentiation	For the most able	For the least able
By support	Mentoring or reviewing by older student mentors, or adult experts, or peers of same ability.	Use of support staff; older students or adult volunteers; peers of similar and higher ability as supporters.
	Limited support and more complicated tasks requiring a high level of self-organisation e.g. in undertaking research or designing investigations.	Support with organisation of tasks e.g. provide writing frameworks; use only one or two of Johnstone's levels of representation at a time.
	Reduced time for tasks to increase pace.	More time permitted for a reduced number of tasks; time clearly allocated to components of work
	Repetition through application or evaluation of information in complex contexts.	Ample repetition and rehearsal of selected key concepts. For example, literacy support by use of morphographic approach (see Table 2)
By task	Appropriate assessment entry level (e.g. Higher level leaving Certificate)	Appropriate assessment entry level (e.g.Junior certificate only; Ordinary level leaving Certificate)
	Set clear targets and review (self-review) progress regularly	
	Set clear differentiated objectives (e.g. 'Must, should and could' objectives set at the start of the lesson.) Review (self-review) progress regularly and set new targets accordingly. Where possible, permit a choice of task whilst still working towards agreed outcomes.	
	Create opportunities to deploy higher order thinking skills, for example Problem Based Learning (open-ended, relevant problems with several possible solutions).	
	Being given material of greater complexity, including with multiple perspectives and material requiring more student analysis. Present with more technical vocabulary Extend mathematical tasks, including approximation, prediction, identification of complicated patterns	Fewer tasks, but meaningful ones. Reduce quantity of technical vocabulary Reduce amount and demands of reading and writing Use alternative means of recording material e.g. Table 3 Reduce mathematical demand by physical modelling and use of semi-quantitative and qualitative measurements.
By outcome	Higher assessment outcomes including work which demonstrates greater depth and breadth of understanding.	Lower assessment performance.

Table 2 The morphographic approach can facilitate understanding, as well as accurate spelling, of technical terms.

Word part	Meaning	Example	Word part	Meaning	Example
****in	protein	casein	hydro*	water	hydrogen
*able	can be	decomposable	hyper*	above	hypergylcaemia
*al	the(arabic)	alkali, alcohol	hypo*	below	hypoglycaemia
bi*	two (equal)	bisect	ign*	fire	igneous
bio*	living	biology	insula*	island	insulate
calor*	heat	calories	kilo*	thousand	kilometre
cat*	down/ thorough	catalyst	kine*	moving	kinetic
caust*	burn	caustic	litho*	stone	lithosphere
centi	hundredth	centimeter	*lysis	splitting	electrolysis
chlor*	green	chlorine	*mer	unit	monomer
chondr*	granule	mitachondria	meta*	changing	meta-analysis
chromo*	colour	chromosome	*meter	measure	thermometer
con*/com*	with	decompose	micro*	one millionth(small)	microscope
de*	Apart,away	decompose	milli*	one thousandth	millimetre
deci	tenth	decilitre	mito*	thread	mitochondrion
di*	two (equal)	dichotamy	mono*	one	monomer
dis*	apart,away	dissociate	*morph	shape	polymorph
duc*	lead, pull	ductile	ortho*	the same	orthodox
e*, ex*	(away) from	exothermic	para*	beside, beyond	parallel
eco*	home. Environment	ecology	photo*	light	photosynthesis
electron	amber		poly*	many	polymer
en*, endo*	(with) in	endothermic	pro*	for, before	pro-protein
epi*	above, in addition	epicentre	re*	again	reflection
flex*, flect*	bend	reflection	scope	seeing	microscope
fract(ion)	break, divide	refract	*stasis	standing still	homeostasis
*gen	make	hydrogen	sub*	below	submarine
geo*	earth	geology	super*	above	superheated
glyc*	sugar	hypoglycaemia	syn*	with, together	synthetic
*graph	writing	photograph	tetra*	four	tetrahedral
hetero*	different	heterogeneous	therm*	heat	thermometer
hom(e)o*	the same	Homogeneous	*thesis	placing	hypothesis
			trans*	across	trans fats

Table 3 One possible way of reducing the literacy demands of recording results



In conclusion, the teaching of Chemistry undoubtedly presents particular challenges, which are most acutely felt by less able students. In order to remain meaningful whilst being accessible, material needs to be thoroughly analysed for its demands and the cognitive demands of learning activities. The rate at which the learners meet these demands can then be managed to give optimal development. The teacher's awareness of the constituent demands of the subject content will enable them to support the not only the weaker students but enrich the learning experience of all students.

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SciFest – Inspiring and Promoting Excellence in STEM Education

Sheila Porter
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'Basic education is not sufficient to create wealth, to address concerns of food, water and energy security, to provide better health services and better infrastructure. For that, science is required'
Adnan Badran and Moneef Aou'bi
UNESCO Science Report 2010

SciFest is a series of one-day science fairs funded by Intel Ireland and Discover Science and Engineering as project partners and hosted nationwide by the Institutes of Technology. The aim is to encourage a love of science through active, collaborative, inquiry-based learning and to provide a forum for students at local/regional level to present and display their scientific investigations. The learning experience coupled with the opportunity of sharing their results with their peers and the judges at SciFest takes students to another level beyond just memorising facts. Students are then more likely to leave school equipped with the necessary skills for solving real world problems. They will also have learned to work collaboratively and to communicate and present their ideas.

Figure 1: SciFest 2010@LIT
Students discuss their project with the judges

SciFest supports the approach to teaching and learning science promoted by the Junior Certificate science syllabus. The syllabus emphasises an inquiry-based teaching methodology and recognises student practical work through the allocation of 25% of the final marks in the examination to project work and a further 10% to practical work completed over the three years of the junior cycle.

The first SciFest science fair was held in ITT in April 2006. The day included a session with the judges in the morning, lunch for the competitors and teachers, a selection of science talks, science demonstrations in the laboratories and a prize-giving ceremony. The students were given information on the STEM courses that were available in the Institute and many of the in-house lecturers visited the exhibition during the day and chatted to the students and teachers. The fair was held a second time in 2007 in ITT and proved so popular that the SciFest project was launched nationwide in 2008. Intel Ireland undertook to provide the administrative, logistical and marketing support while the Discover Science and Engineering programme provided funding for the secondment of a teacher to act as national coordinator on a full-time basis.

Institutes of Technology (ITs) all over Ireland were approached and in late April/early May 2008 nine ITs hosted SciFest science fairs. The number of participating ITs increased to fourteen in 2009. In May of that year the first SciFest science fair was held in Northern Ireland in Derry bringing the total number of venues to fifteen. No additional science fairs were set up in 2010; instead it was decided to concentrate on consolidation and on increasing participation at existing venues. This was achieved with a record number of 2649 students exhibiting 1097 projects. In all, in the three years since the launch of SciFest nationwide a total of 6241 students have exhibited 2613 projects. This reflects an increase in participation of 23% in 2009 over the previous year and a further increase of 34% in 2010 (Table 1).

Year	Students	% increase	Projects	% increase	Schools	% increase
2008	1612		680		100	
2009	1980	+23%	836	+23%	160	+60%
2010	2649	+34%	1097	+31%	196	+23%

Table 1: Number of students, projects, and schools and the % increase 2008 – 2010

SciFest has grown rapidly to become the largest second-level project-based STEM competition in Ireland. Students of all abilities and backgrounds are encouraged to participate in SciFest and to experience the magic of science and technology. The rapid increase in participation in SciFest is a clear indication of the interest and enthusiasm among students and teachers for the investigative approach to teaching and learning science.

With the numbers increasing so rapidly the SciFest programme has been expanded with the introduction of two new levels of participation for 2011. SciFest@School is where schools will organize their own in-house SciFest science fair. A pilot SciFest@School is underway and five schools are participating. It is intended to expand the programme nationwide in 2012. Resources and Best Known Methods will be provided on the SciFest website.

Figure 2: SciFest 2010 @GMIT
Intel Best Project Award and Discover Sensors Award
Roisin Kelly, Sadhbh Burke and Katie Connole, Mary Immaculate Secondary School,, Lisdoonvarna, Co. Clare

The second innovation of 2011 is the establishment of SciFest@Intel. For SciFest@Intel each of the Intel Best Project Award winners from each participating IT/venue (SciFest@College) will be invited to exhibit at the Intel facility in Leixlip in the autumn. Projects will be evaluated and one project will be selected to represent Ireland at the Intel International Science and Engineering Fair (ISEF) which is held annually in May in the US.

SciFest is a highly successful collaboration between the second and third level education sectors and between education, government and industry. It is an example of an easily scalable, cost effective model for the establishment of a network of regional science fairs. SciFest is now well established and a not-to-be-missed event on the second-level school calendar.

The SciFest website provides numerous resources to help teachers and students. These include

- ongoing support to help teachers implement the programme – see website 'Support for teachers'
- instructional materials that will help teachers implement inquiry-based strategies – see website 'Science by Inquiry' module
- sample project ideas, useful websites and reference books, etc.
- support materials and worksheets, e.g. 'Choosing an idea and getting started' and 'Report Book and Presentation'
- links to SciFest project partners, Discover Sensors project and Project Blogger
- entry guidelines for teachers and students and downloadable entry forms

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Sheila Porter is the National Project Manager for SciFest and is on secondment from teaching science in a second level school.

Science Exhibitions from a Teacher's Perspective

Michelle Dunne
St. Joseph's College, Presentation Convent, Lucan, Co. Dublin

Actions Taken by St. Joseph's College, Lucan to Attract Student Participation in Science Exhibitions

A number of years ago science was made compulsory for all junior certificate students in St. Joseph's College Presentation Convent Lucan Co. Dublin as the he school management realised the importance of science since it impinges daily upon our lives.

All second year students are now taken to the BT Young Scientist and Technology Exhibition each January where Ireland's young scientists showcase their accomplishments. St. Joseph's College has been fortunate that projects have been selected each year since 2003 when I commenced mentoring students for the exhibition. The science department co-ordinator Ms. Grainne Blake, then decided that the girls should have to complete a short worksheet to provide the trip with purpose. The students from St. Joseph's must survey the exhibits and complete a short worksheet while attending the RDS. Questions on the worksheet include the following "Name the four main categories" Where are the entries from St. Joseph's found? , "Give the title of a project which was of interest to you and a brief description of it outlining the experiments that were completed" It is a short worksheet that serves to focus their attention on a particular aspect of science but more importantly attempts to engage the girls with other people interested in science. The students are then free to interact and participate in activities organised by the various universities and companies. The trip is both an enjoyable and rewarding experience for the girls who gather lots of information and bags of freebies. Their excitement in meeting celebrities being clearly audible on the bus home to St. Joseph's! Upon return of the students to St. Joseph's, worksheets are returned to the science teachers who review the completed work and present the girls' with a positive comment and a class prize for their efforts. The exercise serves to stimulate the girl's imaginations and draw upon their curiosity with the hope that they will want to pursue a science project of interest to them be it in chemistry, biology, physics or mathematics in subsequent years.

Not allowing the second year students to rest on their laurels they are then asked to complete a project of interest to them before Easter. This project is part of their terminal exam in second year so each student is rewarded for their personal effort. On school awards day an overall best science project is presented to the individual that has completed a sound body of work which is nicely presented and well researched. Science is then constantly promoted throughout the second year of the junior certificate cycle by the activities of the science teachers.

If time permits projects completed by the girls would then be selected for entry in SciFest at the local institute of technology – Blanchardstown. The girls take pride in their work and communicate their project to members of academia. The simplest of ideas have been shown to be the recipe of success when both Aoife Clancy and Emilie Ryan Doyle undertook a study of which spoons - plastic or wooden- were

favoured by home economics teachers in the kitchens (see Figure 1).

1st Place, Junior Biological Sciences
Aoife Clancy and Emily Ryan Doyle, second year students participating at SciFest, 2010, Blanchardstown

Fourth year student Rachel Gillen (Figure 2) enjoyed her SciFest experience so much in second year that she participated again two years later and collected three prizes for her study on the occupational health of hairdressers.

The success of participants in SciFest and BT Young Scientist and Technology Exhibition is then showcased upon their return to school by displaying their work and project displays in the school library. Local papers carry photographs of the students and this raises the profile of the school and demonstrates its commitment to encouraging the student's pursuit of science and technology.

Figure 2 Rachael Gillen and Ciara Kilbane
1st Place Physical Science, 1st Place Discover Science and Engineering Award
Best Runner Up Overall SciFest Blanchardstown Institute of Technology Award (2010)

The students gain the following from participation at science exhibitions

- Encourages team work.
- Promotes aspects of science that impinges daily upon our lives.
- Demonstrates that science is real.
- Helps students realise that the world of science may be a possible avenue that they might pursue when leaving school
- Carry out research.
- Utilise data logging technology
- Interpret data
- Analyse findings
- Use skills such as ECDL to present a folder and display of their work.
- Communicate their project to members of academia.

What do teachers gain from participation at science exhibitions?

- Fosters a sense of pride in your subject area.
- Highlights the relevance and importance of science.
- Helps keep abreast of advances in the world of science.

- Promotes a better relationship between local universities and companies who are willing to assist with aspects of science

What is really needed by the teachers?

1. Beakers and beakers of energy!!!!
2. Time, a precious commodity but a lot can be planned at lunchtime.
3. 30 – 40 minutes of laboratory weekly access.
4. A schedule of work.

As Einstein said: *"To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science."*

Science exhibitions are not something that should be feared, as the advantages associated with participation far outweigh any reason that might be suggested for not attending. The key to success in my opinion is to start small with a simple idea that is well researched and well presented and most importantly that is of interest to the students.

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The ESTABLISH approach to inquiry-based science education

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ESTABLISH is an EU funded collaborative project coordinated by CASTeL, Dublin City University, involving 11 countries, focussed on inquiry based science education.

The aim of the ESTABLISH project (2010-2013) is to promote innovation in classroom practice through the provision of appropriate teaching and learning IBSE units and appropriate supports for both in-service and pre-service teachers to implement IBSE. Inquiry methods have been suggested as a way to encourage and motivate students in science by increasing student interest (Fensham, 1986; Linn, 2006). International reports (Rocard, 2007; Osborne and Dillon, 2008) have identified the need for an "engaging curricula to tackle the issue of out-of- date and irrelevant contexts and to enable teachers to develop their knowledge and pedagogical skills". Linking these ideas suggests that inquiry methods and curricula must be engaging and include up-to-date contexts to be successful in encouraging and motivating students.

The ESTABLISH project brings together the key communities in second level science education to work together to create authentic learning environments to drive change in classroom practice towards IBSE usage. These communities include: (1) Science teachers and educators, including science teacher networks; (2) the scientific community, both local enterprises and multinational industry as well as the scientific and industrial communities; (3) the students of science in second level schools; (4) the parents of these students; (5) the policy makers responsible for science education at second level, including curriculum developers and assessment agencies and (6) science education researchers. These communities have a role to play in second level science education but it is a complex relationship given the unequal strength of each. Fensham (1991) characterises science education as offering the realisation of the potential to meet the many societal demands of its learners for *individual* growth and satisfaction. Teachers, who have an important role in this relationship, want their students to do 'well', while industry needs employees with an ability to innovate, and policymakers want the economy to grow. The interactions of stakeholders incorporated in ESTABLISH are shown in Figure 1 and can be contrasted with the traditional modes of interaction as also shown.

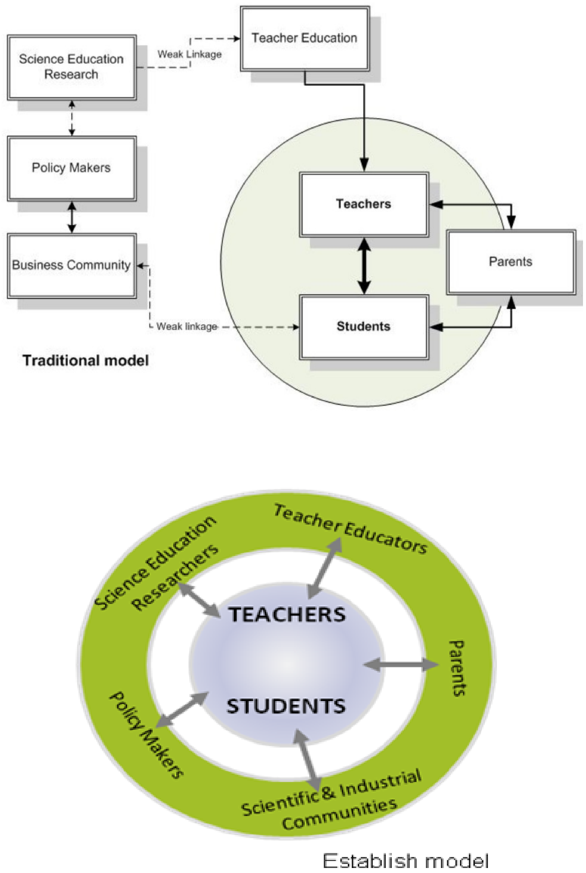

Figure 1: Modes of stakeholder interaction in science education; traditional (top) and ESTABLISH (bottom)

Because of this important role, teachers are central in driving change in classrooms across Europe and so they need to become confident and competent practitioners of inquiry based science education. Thus, there is a vital need for good examples of inquiry teaching materials coupled with teacher education both at pre-service and in-service level. ESTABLISH will address this need through the development of teacher education materials (IBSE units) focused on core scientific concepts that can be adapted for each national context/curricula, covering different disciplines and different contexts, as well as varying educational levels and educational systems thus providing a coherent approach to the delivery of IBSE in classrooms across Europe. Additionally ESTABLISH will, through its network of teacher educators, facilitate the supporting teacher education, in particular at in-service level, so that IBSE is implemented in a coherent and sustainable manner, ensuring that teachers and their students benefit maximally from this classroom practice.

If you are interested in finding out more on ESTABLISH, or if you wish to attend the summer workshop for teachers in DCU (21st-23rd June 2011), then please contact us at: info@establish-fp7.eu or directly at odilla.finlayson@dcu.ie, eilish.mcloughlin@dcu.ie.

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ITS Chemistry!

An intervention programme aimed at developing thinking skills in Chemistry

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Background

IT Chemistry is an intervention programme, which was developed in 2009-10, following a number of other investigations into the learning of Chemistry in the Irish school system. Initially research was carried out to determine the main problem areas/topics in Chemistry for second and university level Chemistry pupils and students. (Childs and Sheehan, 2009a) A follow-on study investigated the cognitive levels that pupils/students were operating at and the numbers and types of chemical misconceptions they possessed about fundamental topics in Chemistry e.g. the Particulate Nature of Matter etc. (Childs and Sheehan, 2011)

Chemistry is known to be one of the most difficult and conceptually challenging subjects on the school curriculum. Many factors contribute to the complex nature of this subject and much work has been carried out in attempting to make the content of this subject more accessible for those studying it. Chemistry by its nature is abstract and requires formal operational thought. It is a subject that contains many higher order chemical and mathematical concepts. Thus anyone not having reached this level of cognitive development will have difficulty with the study of Chemistry and one must wonder how many of our pupils have reached this stage of cognitive development. Chiappetta (1976) concluded after studying a number of investigations 'that most adolescents and young adults have not attained the formal operational stage of cognitive development'. In Ireland, it has been found that approximately 8.7% of Junior Certificate pupils (approximately 16 years of age) and 17.7% of Leaving Certificate Chemistry pupils (approximately 18 years of age) have reached the formal operational stage of cognitive development (Childs and Sheehan, 2009b.) The fact that the majority of Irish pupils studying Chemistry are operating at the concrete operational stage of cognitive development may explain some of the difficulties pupils are having with the subject, which for the majority of topics requires pupils to be able to operate at the formal operational stage of cognitive development.

Another area that may explain why pupils find particular topics in Chemistry difficult is that of chemical misconceptions. The misconceptions pupils' possess about fundamental topics in Chemistry have a major effect on the learning and understanding of new and more difficult information in Chemistry. Misconceptions held by the learner prevent further learning and understanding of many Chemistry topics. Ausubel (1978) stated that if he 'had to reduce all of educational psychology to just one principle, he would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach accordingly'. Information stored in the long term memory, if incorrect, results in major difficulties for the Chemistry pupil in learning new material Misconceptions exist as a result of the manner in which the person learns. Results of misconceptions tests carried out on Junior and Leaving Certificate Chemistry pupils indicate that they possess a large number of misconceptions relating to the Particulate Nature of Matter and the Mole. (Childs and Sheehan, 2011)

Why was ITS Chemistry developed?

Many intervention programmes have been developed which have aimed to enhance pupils' thinking skills. For example, The Cognitive Acceleration through Science Education (CASE) programme is widely recognised and accredited with causing large cognitive development gains for participants. The materials of the CASE programme, aptly named 'Thinking Science', introduced and developed formal operational thinking patterns over a period of two years with a large cohort of children in the UK. There are however a number of problems with running the 'Thinking Science' lessons in the Irish classroom. First off 'Thinking Science' activities are separate to the curriculum. Running the programme would take from the time allocated for the completion of an already over crowded Science/Chemistry syllabus. Secondly 'Thinking Science' lessons require a class of 70 minutes every two weeks A 70 minute slot every two weeks in a school laboratory will be difficult for all schools to achieve.

The 'ITS Chemistry' programme was developed to work within the tight constraints of the Irish Chemistry syllabus. 'ITS Chemistry' stands for 'Increasing Thinking Skills in Chemistry'. It was heavily influenced by strategies and methodologies that have proven to be successful in developing the thinking skills of the pupil, but infused these strategies and methodologies into the current Leaving Certificate Chemistry syllabus. 'ITS Chemistry' aims to develop thinking skills, address misconceptions and alleviate difficulties pupils are having with a number of topics on the Chemistry syllabus, while simultaneously achieving the syllabus aims and objectives.

Methodology

Prior to the development of the resource pack for this intervention programme a number of tasks had to be carried out:

1. A Cognitive Analysis Taxonomy (CAT) was carried out on the topics to be included in the intervention programme, in order to develop a logical progression of the content through the lessons. More abstract ideas, that would require formal operational skills, would be kept until the end of the intervention programme, whereas more concrete topics would be taught towards the start of the intervention.
2. A list of chemical misconceptions relating to the topics included in the intervention programme had to be constructed, in order to alert teachers to alternative ideas that would need to be addressed in their lessons.
3. An analysis of the current Leaving Certificate Chemistry syllabus had to be carried out in order to ensure the intervention programme was addressing the specific learning outcomes and mandatory activities included in the syllabus.

This intervention programme was developed for pupils who had just completed their Junior Certificate examination and who had chosen to study Chemistry for their Leaving Certificate. It was designed to be implemented in the first 12 weeks of the pupils' study of Chemistry. It was decided to address the areas of cognitive development and chemical misconceptions in particular because:

- Results of phase one of this investigation showed that pupils were having difficulty with abstract Chemistry topics, which would require the pupil to be operating at the formal operational stage of cognitive development in order to be understood successfully.
- Results from phase two of the investigation showed that the majority of Irish Junior and Leaving Certificate Science/Chemistry pupils in this study were in fact operating at the concrete operational stage of cognitive development. Pupils may thus have difficulty with Chemistry topics,such as those identified in phase one of this investigation, as they operate at a cognitive level below that required to study the Chemistry curriculum.
- Results of phase two also indicate that Junior and Leaving Certificate pupils possess a large number of chemical misconceptions about fundamental Chemistry topics and ideas that underpin understanding in other Chemistry areas.

The topics chosen to be covered as part of the intervention programme were the Particulate Nature of Matter and the Mole concept. These topics were selected for the following reasons:

- Previous investigations (Childs and Sheehan, 2009b) have shown that the Mole and calculations involving the Mole are perceived as being difficult.
- The Particulate Nature of Matter was also identified as an aspect of Chemistry in which pupils possessed a large number of misconceptions.
- These topics can be described as threshold topics. A threshold concept 'opens up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress'(Meyer and Land, 2003). It is important to construct a proper understanding of these fundamental topics if a pupil is to

understand more difficult Chemistry topics in the future.

- These topics are covered at the start of the Leaving Certificate Chemistry course and this is the obvious place to intervene.

Figure 1 outlines the content of the 12 week 'ITS Chemistry' programme.

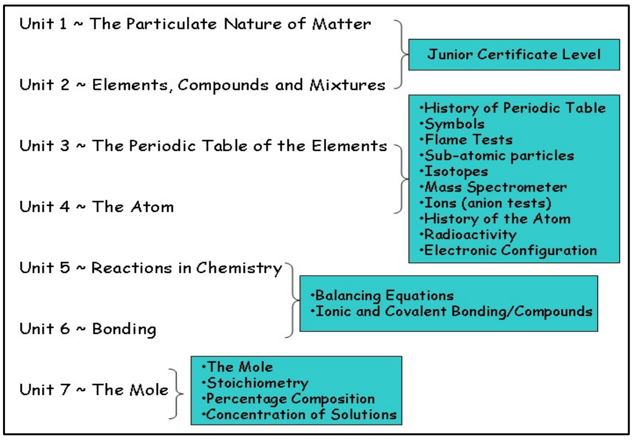

Figure 1: Structure and content of the 'ITS Chemistry' intervention programme

A number of different research projects inspired the development of the 'ITS Chemistry' intervention programme. Figure 2 outlines the different areas of Chemistry Education Research that inspired and shaped this intervention programme.

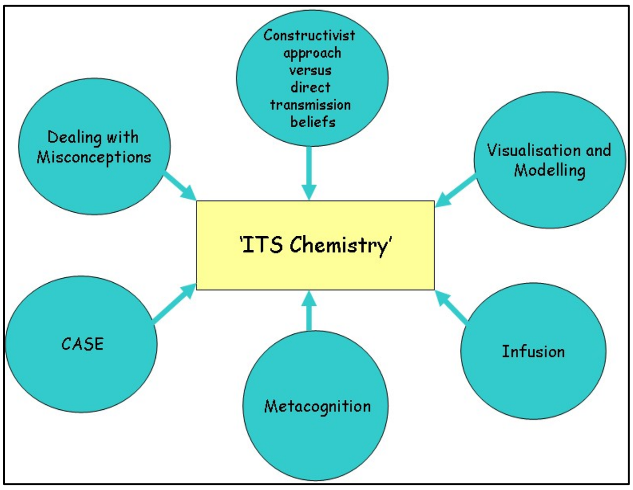

Figure 2: Areas of educational research that inspired the development of the 'ITS Chemistry' intervention programme

Successful strategies were collected from different studies in the areas of research listed in Figure 2 and were infused into the current Leaving Certificate Chemistry syllabus dealing with the Particulate Nature of Matter and the Mole concept. The advantage of infusing research on thinking and learning into the syllabus is that not only is there an enrichment in the delivery of content and the classroom learning experiences but also there is no loss of time in the completion of the syllabus, which will appeal to teachers who face constant pressures relating to course completion and exam preparation. The research areas that inspired the development of the 'ITS Chemistry' intervention programme will now be discussed in greater detail.

Dealing with misconceptions:

Initially it was important to determine the different chemical misconceptions that various studies have shown pupils to possess about the topics to be covered in the 'ITS Chemistry' intervention programme. It was important to make teachers aware of these documented misconceptions in order to address them. The programme looked to address the misconceptions pupils already had and make teachers aware of strategies to prevent misconceptions being developed in the classroom. Peer debate, classroom discussion and group tasks have been shown to address chemical misconceptions pupils already possess. Therefore elements of these strategies were included in intervention lessons. Participating teachers were also informed of a number of ways to prevent further misconceptions developing in their classroom. Garnett et al. (1995) believes that if careful attention is paid to a number of issues the teacher can improve students' understanding of Chemistry concepts and prevent the formation of misconceptions. The issues identified by Garnett et al. (1995) are as follows:

1. The use of everyday language in a scientific context ~ Educators need to use words that are unambiguous and which accurately describe the subject matter being considered.
2. The over simplification of concepts and the use of unqualified, generalised statements ~ Alternative conceptions arise when educators, in attempting to simplify concepts, provide descriptions which may be limited or even misleading.
3. The use of multiple definitions and models ~ there is a need to use alternative models with care

and to clearly enunciate the limitations of these models.
4. The rote application of concepts and algorithms ~ Material should be presented in ways that encourage student understanding of concepts, rather than in ways which promote rote learning and the unthinking application of algorithms.
5. Students' preconceptions from prior world experiences ~ the teacher needs to be aware of these in the classroom.
6. The over lapping of similar concepts ~ Students have a tendency to confuse related concepts.
7. The endowing of objects with human/animal characteristics ~ There is a need for more precise use of language and, possibly, greater emphasis on the mechanistic nature of particle behaviour.
8. Inadequate prerequisite knowledge ~ the lack of important prerequisite knowledge is another factor which can lead to alternative conceptions as new concepts are introduced.
9. Students' inability to visualise the particulate /submicroscopic nature of matter ~ This represents a major area of difficulty in developing a sound conceptual understanding of Chemistry
10. General teaching strategies and conceptual change ~ White and Gunstone (1989) have stressed the importance of using strategies which support sustained reflection such as the use of concept maps and 'what-if' questions.

Constructivism:

Areas of the constructivist beliefs that were included in the 'ITS Chemistry' intervention programme saw teachers facilitating pupils' own inquiry rather than demonstrating the correct way to solve a problem. Pupils were allowed to think of solutions to problems themselves before the teacher showed them. In the 'ITS Chemistry' intervention programme the thinking and reasoning processes of the pupil were equally as important as the specific curriculum content that the pupil was studying.

Modelling and Visualisation:

The 'ITS Chemistry' programme paid particular attention to the idea of using and building models. 'Models are a way into some key concepts and the process develops other skills such as group talk and evaluation. If pupils understand the concept of producing models, their progress in science will be enhanced' (Walsh, 2009). Models are also useful in presenting many concepts in a concrete tangible manner and allow pupils to visualise complex ideas. Diagrams were also used to facilitate visualisation of abstract ideas. The 'ITS Chemistry' pack included CD with PowerPoint presentations, to complement the lessons in the intervention programme. These PowerPoint presentations included animations, models and diagrams to enhance pupils understanding of the different topics in the ITS Chemistry programme. The use of multiple definitions and models for the same concept were avoided, as these are shown to increase the development of Chemical misconceptions.

Infusion:

At the very heart of this programme lies the infusion of thinking strategies into the everyday content of the Leaving Certificate Chemistry syllabus. The benefits of infusion are seen as:
- Matching thinking skills directly with topics in the curriculum;
- Invigorating content instruction leading to deeper understanding;
- Using classroom time optimally;
- Directly supporting teaching for thoughtfulness across the curriculum and;
- Facilitating transfer and reinforcement of learning'. (McGuinness, 2000)

The infusion technique aims to achieve the goals of topic understanding and the development of thinking simultaneously.

Metacognition:

Metacognition is defined as 'cognition about cognition", or "knowing about knowing. It can take many forms; 'it includes knowledge about when and where to use particular strategies for learning or for problem solving' (Santrock, 2008). Developing these skills will have positive gains for the participant in many aspects of their learning and not just Chemistry. Metacognition was encouraged in this intervention programme as part of the homework exercises and also in the allocation of time in the lesson and space in the workbook to return and correct answers to questions which saw pupils confront misconceptions. In the homework exercises pupils completed activities relating to those studied in class and were encouraged to explain how they came up with their answers.

Cognitive Acceleration through Science Education (CASE):

While the 'ITS Chemistry' intervention programme did not use the content or the resources of the CASE programme, it did take inspiration from the manner in which CASE lessons were structured. Figure 3 outlines how the lessons included in the CASE programme were structured.

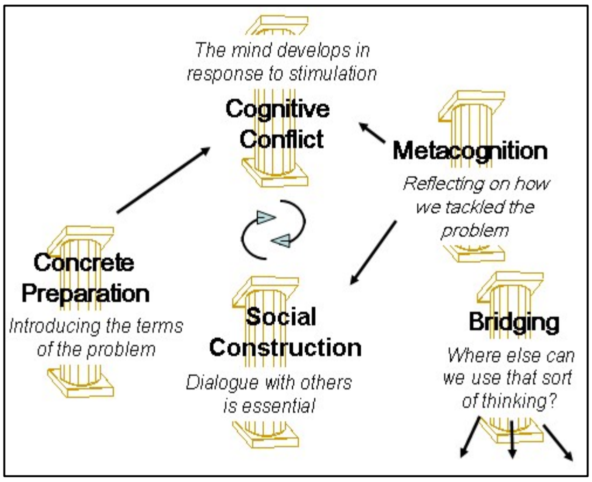

Figure 3: The interaction between the five pillars in a CASE lesson (Dickson, 2004)

The 'ITS Chemistry' intervention programme paid particular attention to the concrete introduction of topics, along with cognitive conflict and the social interaction aspects of the CASE lessons. This is because, not alone do these pillars promote the development of cognitive ability, but they are also shown as techniques used to address and reduce the Chemical misconceptions pupils may possess. The structure and key design features of a typical 'ITS Chemistry' lesson are shown in Figure 4.

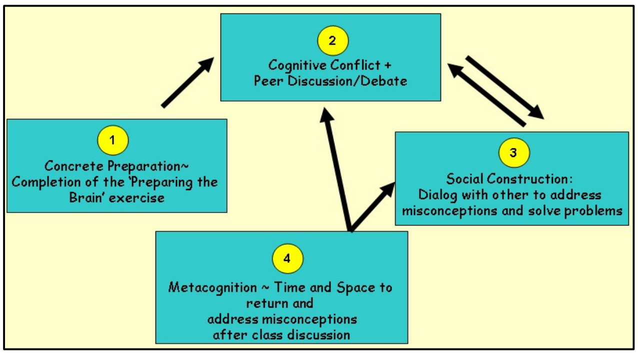

Figure 4: The structure and key design features of a typical 'ITS Chemistry' lesson

From Figure 4 it can be seen that each 'ITS Chemistry' lesson began with a revision of previous ideas and with an explanation of terms and equipment that the pupils would be using during the lesson. This section of the lesson in the pupils' handbook was titled 'preparing the brain' and was useful to focus pupils on what was to come next in the lesson. Figure 5 illustrates an example of a 'preparing the brain' activity.

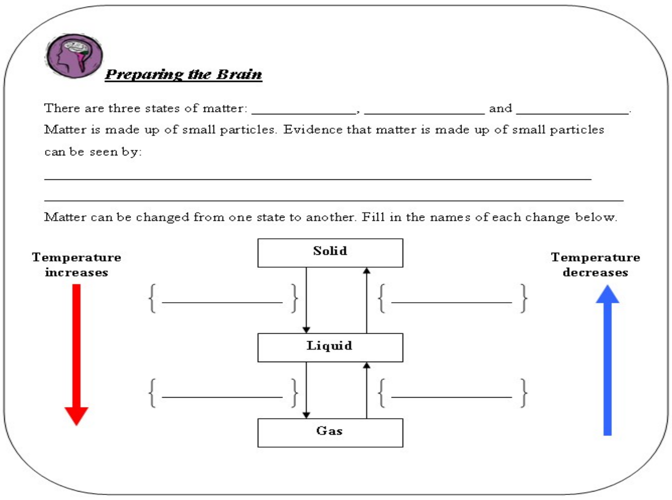

Figure 5: Example of a 'preparing the brain' activity which appeared at the beginning of each of the ITS Chemistry lessons

Lessons also included practical, hands-on activities and tasks focused around social interaction between pupils. They were used to provide pupils with an opportunity to discuss what was happening and why. Cognitive conflict was initiated as a result of social interaction and teacher intervention and was accommodated through group and teacher led discussion. Discussion of ideas and concepts also play an important role in the identification and altering of chemical misconceptions. It must be noted that while many thinking philosophies influenced the ITS Chemistry programme, this intervention programme is in fact an infusion approach aiming to develop thinking skills within and through the course content. Metacognition was encouraged in this intervention programme by allocating time in the lesson and space in the workbook to return and correct answers to questions which saw pupils confront misconceptions. In the homework exercises pupils completed activities relating to those studied in class and were encouraged to explain how they came up with their answers.

The teachers that agreed to take part in the implementation of this programme underwent training at the start of the school term 2009-10. Training involved a look at the history of this project, and a look at the structure of the intervention programme and how it fits in with the established Leaving Certificate Chemistry syllabus. The philosophy and the methodology of the project were explained to teachers. At the very beginning of this intervention programme the cognitive development of pupils in the experimental group was assessed using Science Reasoning Task Three. They then completed the 12 week programme and afterwards completed a post-test. The post-test took the form of another Science Reasoning Task and a misconceptions test and these scores were compared with the pre-test scores. Cognitive development and types and numbers of misconceptions were compared with a control group, which did not participate in the intervention programme, but covered the same material in the traditional way. The teachers' views were collected through a teacher's diary and a short questionnaire at the end of the project. The research questions to be answered by this investigation are as follows:

1. Can cognitive acceleration be achieved through infusing a successful cognitive acceleration technique into the normal Irish Chemistry syllabus?

2. Can general Chemistry misconceptions be addressed at the very beginning of the Leaving Certificate Chemistry course and as a result alleviate difficulties pupils have with different Chemistry topics, in particular the Particulate Nature of Matter and the Mole?

3. Can the cognitive ability of 16 – 17 year old pupils be positively affected by altering the methodologies involved in the teaching of Chemistry?

4. Does this research-based teaching strategy increase peoples understanding of the Particulate Nature of Matter and the Mole?

In total 5 schools (6 different class groups) trialled the 'ITS Chemistry' intervention programme. One of these schools involved the implementation of the programme by one of the researchers (MS). The profile of the experimental group involved in the implementation of the ITS Chemistry programme is seen below in Table 1.

	Profile of Experimental group for phase three of this investigation (n= 93)
Age Profile	15 Years Old = 24.7% 16 Tears Old = 71.0% 17 Years Old = 2.2% Missing = 2.2%
Gender Profile	Male = 42 (45.2%) Female = 51(54.8%)
Breakdown of pupils Mathematics level for the Junior Certificate Examination	Higher Level = 54 (58.1%) Ordinary Level = 37 (39.8%)
Breakdown of pupils Science level for the Junior Certificate Examination	Higher Level = 77 (82.8%) Ordinary Level = 14 (15.1%)

Table 1: Profile of the experimental group that participated in the ITS Chemistry implementation programme

Table 2 shows the profile of the control group used in this phase of the investigation.

	Profile of the control group for phase three of this investigation (n= 57)
Age Profile	15 Years Old = 17.5% 16 Tears Old = 50.9% 17 Years Old = 26.3% Missing = 5.3%
Gender Profile	Male = 38 (66.7%) Female = 19 (33.3%)
Breakdown of pupils Mathematics level for the Junior Certificate Examination	Higher Level = 41 (71.9%) Ordinary Level = 13 (22.8%)
Breakdown of pupils Science level for the Junior Certificate Examination	Higher Level = 54 (94.7%) Ordinary Level = 3 (5.3%)

Table 2: Profile of the control group that participated in phase three of this investigation

It is important to note that a higher percentage of the control group took the more difficult higher level examination in Science for the Junior Certificate than the experimental group. This may indicate that the control group are stronger in Science at the start than the experimental group.

Results and Conclusions

Results from this intervention programme indicate a positive effect of participation in the 'ITS Chemistry' programme on the cognitive development of the pupil and also their performance in a chemical misconceptions test. Figure 6 show the positive effect that participation in the programme had on the pupils' performance in a chemical misconceptions test.

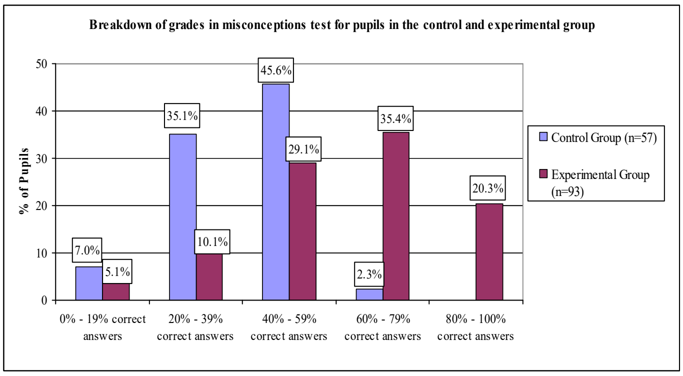

Figure 6: Breakdown of grades in the chemical misconceptions test for pupils in the control and experimental group

From Figure 6 it can be seen that those in the experimental group did much better in the chemical misconceptions test than those in the control group. This is very promising considering that pupils in the control group were probably stronger at Science than those in the experimental group, based on their Junior Certificate performance. Overall 42.1% of the control group scored less than 40% in the Chemical misconceptions test. This compares with 15.2% of pupils from the experimental group. 20.3% of the pupils in the experimental group achieve a grade higher than 80% in the test; no pupil from the control group scored above 80% in the chemical misconceptions test.

In terms of cognitive development Figure 7 shows the summary of the changes in cognitive levels after participation in the intervention programme.

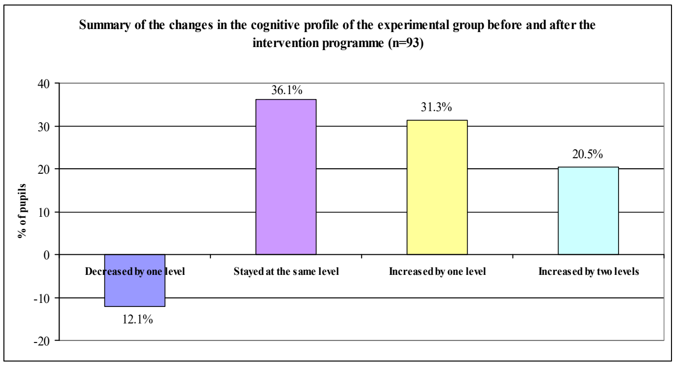

Figure 7: Summary of the changes in cognitive levels after participation in the intervention programme

From Table 7 the initial results indicate positive effects on the pupils' cognitive development after participation in the 'ITS Chemistry' intervention programme. More detailed tests would need to be carried out in order to determine the exact cognitive effect of the programme.

Discussion: Implications for teachers of Chemistry

The initial results of participation in this intervention programme indicate that it is indeed possible to improve the thinking skills of pupils, through an infusion of different teaching methodologies into the Irish Leaving Certificate Chemistry syllabus, and reduce the number of chemical misconceptions held. While a deeper evaluation of the 'ITS Chemistry' intervention programme is necessary, there is no doubt that it is successful, to some extent, in addressing chemical misconceptions possessed by pupils, that prevent true understanding of a variety of different Chemistry topics. It also has an effect on the cognitive ability of the pupil, but this needs further investigation. When compared to the control group and a LC group sampled in phase 2, the experimental group had a significantly higher percentage operating at the formal operational level.

Phase three of this investigation has proven that it is possible to develop lessons to include these methodologies without interfering with the delivery of the prescribed syllabus. In order to alleviate problems Irish pupils have with the study of Chemistry it is important to address a number of areas, bearing in mind a number of these areas are connected with each other. These include:

- Developing pupils' mathematical skills and understanding;
- Developing the cognitive level of the pupil in order to be able to understand and cope with the abstract aspects of Chemistry (of which there are many); and
- Addressing and acknowledging the chemical misconceptions that pupils may possess and offering a forum for discussion and debate among peers that will alter and eliminate these misconceptions which negatively effect progression and understanding in Chemistry.

The approach taken in this intervention programme can and should be applied to all topics in the Leaving Certificate Chemistry syllabus. Prolonged exposure to these techniques will undoubtedly go a long way to alleviating difficulties pupils have with the majority of topics on the Chemistry syllabus. The effects shown on both the cognitive ability and reduction of chemical misconceptions in this short intervention project suggest that using this approach for the whole course would have very significant effects. It should produce pupils who are much better prepared to study Chemistry and related subjects at third level.

Although none of the ideas and approaches used in this intervention are new, what is new is the packaging and application of a variety of ideas and approaches, based on Chemistry Education Research (CER), to a specific part of the Irish LC Chemistry syllabus. We believe this demonstrates the value and effectiveness of a curriculum and a teaching methodology which is based on evidence from CER.

This article is based on the talk and workshop given at ChemEd-Ireland in DIT. Since then the authors have given several workshops to groups of teachers, working with PDST and NCE-MSTL. These have been well received by teachers and it is hoped to disseminate the ideas and ITS Chemistry teaching materials to more teachers in future.

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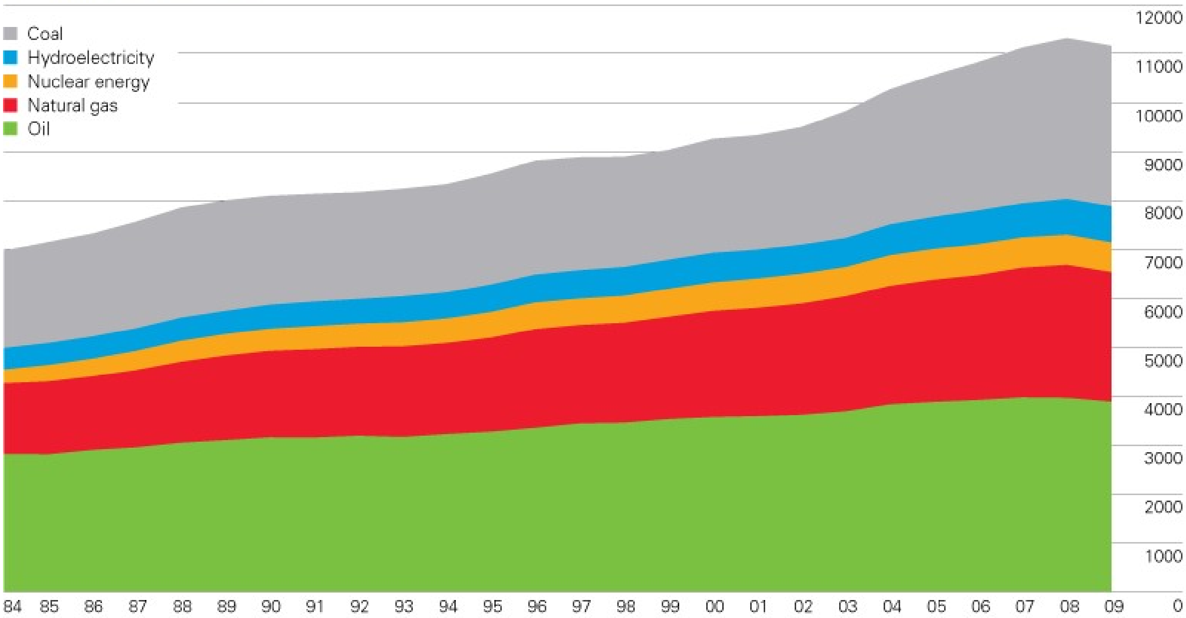
This work formed part of the PhD work by Maria Sheehan, done part-time while she taught at St. Caimin's Community College in Shannon and she was awarded her PhD in August 2010 by the University of Limerick. The work was done under the supervision of Peter E. Childs at the University of Limerick, as part of the activities of the Chemistry Education Research Group. For more details on the ITS Chemistry materials contact Maria Sheehan at maria.sheehan@ul.ie Maria Sheehan is also a regional chemistry facilitator for PDST.

ChemData: BP Statistical Review of Energy 2010

www.bp.com/statisticalreview

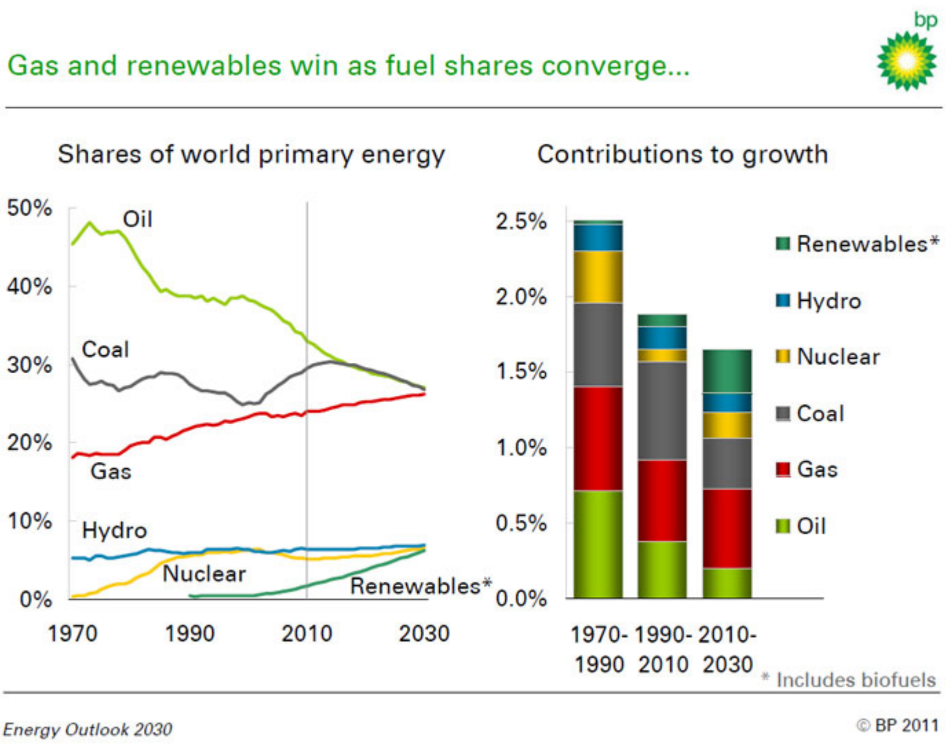
World consumption
Million tonnes oil equivalent



World primary energy consumption fell by 1.1% in 2009, the first decline since 1982. Consumption was weaker than average in all regions. While oil remains the leading fuel (accounting for 34.8% of global primary energy consumption), it continues to lose market share. Coal's share of global energy consumption was the highest since 1970.

BP Energy Outlook 2030

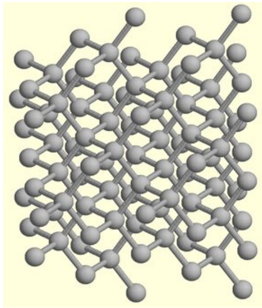
www.bp.com/Energyoutlook2030



Type of Bonding and Properties

There are four main types of chemical bond – three strong and one weak.

3 strong bonds:



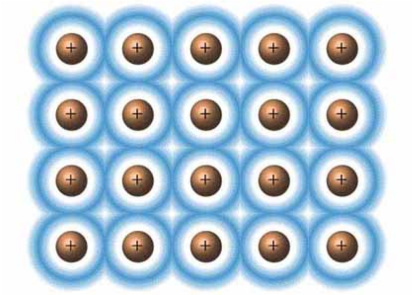
1. Covalent bonds – between two non-metal atoms (E.N. > 2.0)

Strength of bonding:

α number of electrons shared (- > = > ≡)

α 1/size of atoms

(decreases down the P. T.)



2. Metallic bonds – between two metals (E.N. < 1.5)

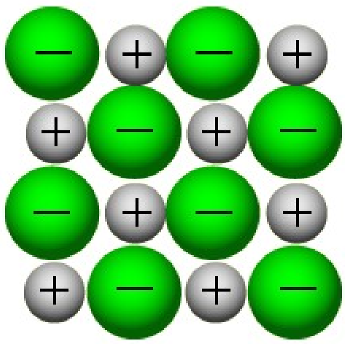
Strength of bonding:

α number of valence electrons

(increases across P.T.)

α 1/size of atoms

(decreases down P.T.)



3. Ionic bonding – between a metal and a non-metal (E.N. difference >1.7)

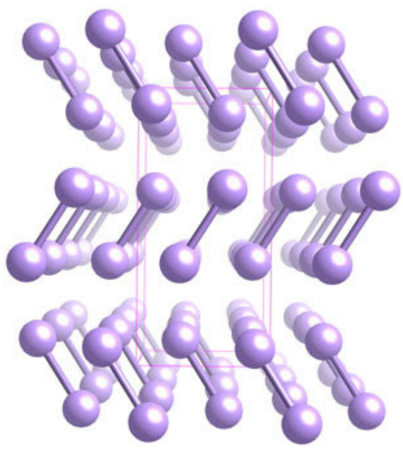
Strength of bonding:

α $(z_+z_-)/(r_+ + r_-)$ x constant

(decreases as ions get larger)

(z_+ and z_- charges on ions, r_+ and r_- radii of ions; constant depends on crystal structure)

1 weak bond (or group of bonds)



Molecular bonds (Van der Waals bonds) – between two molecules

Strength of bonding:

α size (or GMM of molecule)

α polarity

Strength of bonding affects m.pt. and b.pt. – stronger the bonding that holds the particles together, the higher the m.pt. and b.pt.

Choosing Chemistry: giving the right impression

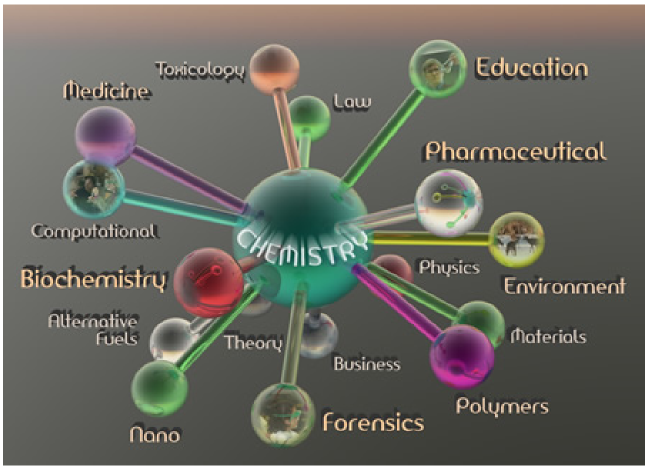
Why should you choose to study chemistry for the Leaving Certificate (LC)? Would the following description of Chemistry persuade you to study it?
"Students taking chemistry have to learn off the chemical components of a series of prescribed experiments. They will be required to present the elements of four such experiments in their examination."
Irish Times 1/3/11

This has to be one of the most inadequate, incomplete, misleading and pathetic descriptions of LC chemistry, which would convince no-one to study the subject.

The description of Physics is almost as useless in trying to present an accurate view of a subject:
"Physics has a strong maths element and requires the learning off of many formulae. Students must maintain a laboratory book, as there are 27 mandatory experiments, four of which are offered on the Leaving Cert paper, with three to be presented."
Irish Times 1/3/11

These are not fair or accurate descriptions of Chemistry (or Physics) and it is no wonder that pupils and parents have a poor understanding of what subjects to choose, or what careers they might lead to. We need to give pupils a proper idea of what a subject entails, how it is used and what careers it leads to, if they are to make a balanced decision about the choice of LC subjects, which will have a major effect on the direction of their future lives.

What is chemistry?
Chemistry is the study of the transformation of ordinary substances into useful things – it literally turns sow's ears into silk purses, turning crude oil into dyes and polymers, cosmetics and perfumes. Chemists design new medicines, invent smart materials, develop new batteries and provide solutions to our energy and environmental problems. The LC course lays a foundation of theory and practical skills to help understand the material world we live in. The diagram below show some of the connections that Chemistry makes.



http://www.csc.edu/sci/chemistry/

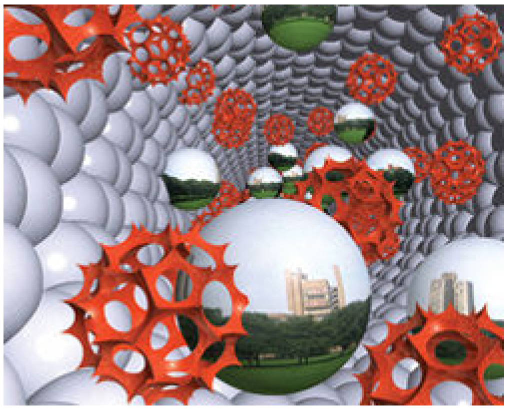
Chemistry provides the underpinning for many courses and careers, from medicine to engineering, from nursing to food science, from environmental science to forensic science. Chemists solve problems and provide solutions, and they help build the fabric of the modern world. Not all chemists end up wearing white coats in laboratories, and a degree in chemistry equips a graduate with a valuable set of transferable and highly employable skills.

Teachers and careers guidance teachers need to be given the information to present chemistry (and other subjects) correctly, so that they can properly explain the excitement of modern chemistry and the important careers it can lead to.

It is chemists who are working to provide cures for cancer and Alzheimer's disease; they are designing new materials and molecular motors; they are inventing the future, making the medicines and materials that will improve the quality of and lengthen our lives. It is not an easy subject, but it can be mastered with application; it is worth mastering because of its potential benefit to humanity and the challenge a career in chemistry presents.

Chemistry makes a difference in every aspect of our daily lives: the chemist doesn't sell medicines (that's a pharmacist), they are the ones who invent the new drugs that will save lives in the future. That's a goal worth working for.

The future is looking small, as nanoscience (often another name for chemistry) becomes more and more important. As Richard Feynmann reminded us many years ago: **"There is plenty of room at the bottom!"**



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CheMiscellany

Fuelproof idea

Daily Telegraph 8/11/10

The waste company Sita is planning to build up to 10 plants converting waste plastic into diesel fuel. The planst will use end-of-life plastics i.e. those contaminated with food which cannot be recycled back into plastic products. Each plant will deal with 6,000 tonnes, located close to the supplies, a total 0f 60,000 tonnes, ~17% of the total available. The plastic-to-diesel conversion is based on technology from the Irish company Cynar, and Sita holds the European licence for the technology.

The first plant is likely to be built in the London area and the company hopes to open 2-3 plants a year, each creating 12 jobs.

www.cynarplc.com/

"Cynar has the first fully permitted operational plant situated in Portloaise, Ireland.

This unique Technology converts mixed Waste Plastics into synthetic fuels which are cleaner, lower in sulphur and in the case of the diesel, a higher cetane than generic diesel fuel. The key elements of the Technology involve pyrolysis and distillation. Cynar plans to establish up to 30 plants across the UK and Ireland to recover synthetic fuel from a variety of used plastic sources. ..

Cynar's Technology is a truly sustainable waste solution, diverting plastic waste from landfill, utilising the embodied energy content of plastics and producing a highly usable commodity."

Pyrolysis

"Pyrolysis is a process of thermal degradation in the absence of oxygen. Plastic waste is continuously treated in a cylindrical chamber and the pyrolytic gases condensed in a specially-designed condenser system to yield a hydrocarbon distillate comprising straight and branched chain aliphatics, cyclic aliphatics and aromatic hydrocarbons. The resulting mixture is essentially equivalent to petroleum distillate. The plastic is pyrolised at 370ºC-420ºC and the pyrolysis gases are condensed in a 2-stage condenser to give a low sulphur content distillate."

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Waste to energy plant

Financial Times 8/11/10

The UK firm Sterecycle has a plant in Rotherham, South Yorkshire, converting unsorted black bag waste into energy. This has been running since June 2008 and processes 100,000 tonnes of waste each year. It has got planning permission for new plants in Harlow, Essex and Cardiff, Wales, and has plans for one in Croydon. The plants use autoclaves using high pressure steam to sterilise the waste, that can then be sorted into glass, metal and plastics for recycling. The resulting clean biomass can be used as a compost or it could be burnt to generate energy in a waste-to-energy CHP plant. Alternatively the biomass could be fed into an anaerobic digester to produce methane, which could be burnt to produce energy. A major advantage of the process is that it reduces the volume of the waste significantly, reduces health hazards and allows for recycling and energy recovery.

The company claims the following advantages for their process (http://www.sterecycle.com/):

"The sterecycle® system is capable of recycling and recovering up to 80% of domestic waste with a sterile and environmentally-friendly process. The system is cleaner, safer, more cost effective and more efficient than other technologies.

- *No incineration*
- *No smell or eyesore – the system is enclosed in a warehouse type building*
- *Recycling is dramatically increased, diverting 70-80% of black-bag waste from landfill*
- *Plastics recycled : 1 tonne of plastics recycled means 1.5 tonnes of carbon saved*
- *Aluminium recycled : aluminum cans produced from recycled aluminum instead of raw materials use 95% less energy*
- *Flexible and robust system – residual domestic and commercial wastes are inputted directly into the process without pre-sorting*

• Valuable recyclables are recovered for reuse (metals, plastics, wood, aggregates, glass), plus a high biomass organic fibre (sterefibre®)
• Sterilising process - removes health hazards associated with landfill and standard Mechanical Recycling Facilities
• Resource efficient - Sterecycle's patented autoclaving system is energy and water efficient – it has a beneficial carbon footprint and allows significant process control.
• Cost Effective - able to offer attractive gate fees"

Unfortunately in January 2011 there was an explosion at the Rotherham plant and one man was killed and another injured, which closed the plant down.
http://www.bbc.co.uk/news/uk-england-south-yorkshire-12164365

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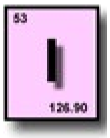

Isotopes matter in real life

One of the difficulties in teaching about atomic and electronic structure is that the topics seem irrelevant to our pupils. The nuclear accident in Japan gives an opportunity to make the topic of isotopes relevant. The media are full of talk about the emission of radioactive isotopes and their health hazards: caesium-137, iodine-131, strontium-90 and plutonium-230. Isotopes are different forms of the same element with the same atomic number but different numbers of neutrons in the nucleus and thus different mass numbers. The 131 in iodine-131 refers to the mass number and is one way of writing and identifying isotopes of an element. Carbon (Z=6) has three common isotopes: carbon-12, carbon-13 and carbon-14. Carbon-12 is the most abundant isotope with 6 protons and 6 neutrons. Carbon-14 is radioactive (6 protons, 8 neutrons) and is formed by bombardment by cosmic rays in the upper atmosphere. It is taken into living organisms, which have a fixed ratio of carbon-12 to carbon-14, but when the organism dies no more exchange occurs with the atmosphere and the carbon-14 starts to decay. This is the basis of the carbon-14 dating method as half the radioactivity disappears every 5,730 years. Radioactive isotopes have unstable nuclei due to too many neutrons and they spontaneously decay into more stable isotopes, often of different elements. Radioactivity is a natural process and small levels of radioelements are present all around us in the air, water, food and the soil.

Get your pupils to work out for iodine-131 and other isotopes mentioned above, the number of protons and neutrons they have, using their Periodic Table. The atomic weight given underneath the element symbol in the Periodic Table is the weighted average of the masses of the isotopes present. Thus the atomic weight of carbon is 12.01 due to the small amount of heavier isotopes present.

The chemistry of the radioelement determines how it is taken up by the body; the type of radiation and the half-life of the radioelement determine how hazardous it is in the body.

Iodine-131 if ingested in food or drink is taken up into the thyroid gland, where it concentrates and can then produce cancer. Taking iodine pills (see p.**) overloads the body with iodine so the radioactive iodine is diluted and is then swept out of the body and excreted. Iodine-131 has a short half-life (8 days) and so is not a long-term hazard. Strontium-90 is an isotope of strontium, a group 2 element, and so it resembles calcium chemically. When ingested it tends to end up in the bones, like calcium, as insoluble phosphate and becomes concentrated , where it can cause leukaemia. It has a half-life of 28.9 years and thus is a long-term hazard in the body.

Caesium-137 is an isotope of a group 1 metal and so it resembles sodium and potassium, particularly the heavier potassium. If ingested it is found in the body's fluids as group 1 metals are found in solution. It can thus be carried around the body into almost every part, but the bonus is that it is readily excreted. Cs-137 has a half-life of 30.2 years and so it is another long-term hazard. The Cs-137 emitted by Chernobyl has only decayed by about half, whereas the I-131 is long gone. Pu-239 is the most toxic of the four radioisotopes. It is usually ingested as airborne particles of oxide, which lodge in the lungs and cause lung cancer.

A recent article on 'Fear goes nuclear' in *Time* magazine by J. Kluger (28/3/11) said this:
"Death by radiation has always been humanity's great self-inflicted wound. Nature may have cooked up the unstable elements that contain and emit radioactive energy, but it also took care to hide the stuff away — burying it in mountains, sealing it in planetary cores. Humans had to work very hard to pick that natural lock. It wasn't until

the past seven decades that we understood the elemental energy of radioactive rocks well enough to distil it into pellets, rods and lumps and, in our first demonstration of our newfound power, use it to incinerate two Japanese cities at the end of World War II"

Read more: http://www.time.com/time/magazine/article/0,9171,2059639,00.html

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Quotations on thermodynamics

"Thermodynamics is a funny subject. The first time you go through it, you don't understand it at all. The second time you go through it, you think you understand it, except for one or two small points. The third time you go through it, you know you don't understand it, but by that time you are so used to it, it doesn't bother you anymore."
Arnold Somerfield

"A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the second law of thermodynamics. The response was cold: it was also negative. Yet I was asking something which is the scientific equivalent of: 'Have you read a work of Shakespeare's?'"
C.P. Snow 1959
Rede Lecture, "The Two Cultures and the Scientific Revolution".

"All kinds of private metaphysics and theology have grown like weeds in the garden of thermodynamics."
Erwin Hiebert, 1966
"The Uses and Abuses of Thermodynamics in Religion".

"In this house, we obey the laws of thermodynamics!"
Homer Simpson (after Lisa constructs a perpetual motion machine whose energy increases with time, in *The Simpsons* TV series.)

"If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations—then so much the worse for Maxwell's equations. If it is found to be contradicted by observation - well these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation."
Sir Arthur Stanley Eddington, 1927
Gifford Lectures (1927), *The Nature of the Physical World* (1928), 74.

"Ludwig Boltzmann, who spent much of his life studying statistical mechanics, died in 1906, by his own hand. Paul Ehrenfest, carrying on the same work, died similarly in 1933. Now it is our turn to study statistical mechanics.
Perhaps it will be wise to approach the subject cautiously."
David Goodstein, "States of Matter" (2002)

"Nothing in life is certain except death, taxes and the second law of thermodynamics."
Seth Lloyd

Laws of Thermodynamics (paraphrased)
1) You cannot win, you can only break even.
2) You can only break even at absolute zero.
3) You cannot reach absolute zero.
Anon

You can hear Flanders and Swan's famous song on 'The second law of thermodynamics' at http://www.haverford.edu/physics/songs/links.html and read the lyrics at http://www.iankitching.me.uk/humour/hippo/entropy.html

Teaching teachers to teach about the Nature of science: *Concerns regarding the teaching and learning of science*

Cliona Murphy

Centre for the Advancement of Science and Mathematics Teaching and Learning (CASTeL) St Patrick's College, Drumcondra, Dublin 9. Cliona.Murphy@spd.dcu.ie

There are many national (and international) concerns regarding the teaching and learning of primary and post-primary science. These include concerns regarding: scientific literacy; achievement in science; lack of interest in and negative attitudes towards science; poor uptake of science at upper post-primary and tertiary levels; infrequent employment of inquiry-based approaches to science at primary and post-primary levels; and lack of provision of long-term professional development practical courses for teachers. (De Boo and Randall, 2001; Smyth, McCoy and Darmody, 2004; Mc Comas, 2007; Rocard et al, 2007; Minner et al, 2009; Varley et al, 2008; Murphy et al, 2011).

In a bid to address some of these concerns there has been a drive towards the use of inquiry-based approaches in science education (IBSE). Linn, Davis and Bell (2004) define 'inquiry' as "the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models debating with peers, and forming coherent arguments". The benefits of employing IBSE methodologies are also high highlighted in the research literature. These include: the development of students' understanding of scientific knowledge, scientific processes and the nature of science; higher attainment in science; increased confidence and motivation in science; more positive attitudes towards science; and more opportunities to consider and to reflect on various scientific ideas during science class. (Schwartz, Lederman and Crawford, 2000; Rocard et al.,2007; Murphy et al., 2011).

In recent years international curricula have been adapted to place stronger emphasis on more inquiry-based approaches to the teaching and learning of science. In Ireland, primary and post primary curricula have been revised and developed and now incorporate significantly greater emphasis on the application and development of students' scientific skills and on making the scientific content more relevant to the everyday lives of the students. It is hoped that these revised science curricula will increase interest in science amongst students - leading to an increase in the uptake of science subjects at senior level and third level.

The primary science curriculum appears to be having a positive impact on pupils' interest in and attitudes towards school science. A recent review of the curriculum indicated that Irish primary children are extremely positive about school science and many are being provided with opportunities to engage in hands- on science (Varley et al., 2008). However, for some children hands-on experiences in science are infrequent and for some do not appear to be happening at all. There also still appears to be an emphasis on teacher demonstration, reading and writing in science in Irish primary classrooms (Murphy et al., 2011). One of the reasons for this apparent infrequent employment of hands-on, inquiry-based approaches may have to do with the fact that, like their counterparts in other countries, Irish primary teachers are not experts in science (Waldron et al 2009), and therefore may lack the confidence and competence to afford their pupils opportunities to engage with the IBSE approaches advocated in this revised science curriculum. In addition many Irish teachers do not have the scientific conceptual or pedagogical knowledge to facilitate IBSE classrooms (Waldron et al 2009; Murphy and Smyth in presentation).

The revised Junior Cycle Syllabus also appears to be having a positive impact on students' interest and attainment in science. The results from the Programme for International Student Assessment [PISA] in 2006, for example, reported that just under half of Irish 15-year-olds indicated that they had “fun learning science topics”. Over 75% of the Irish respondents indicated high interest in learning biology, however, less than 45% of participating Irish 15 year olds indicated high interest in learning chemistry and physics (Eivers et al., 2007, p. 26). It is important to note however, that only about 50% of the respondents were working within the revised Junior Cycle Syllabus. Ireland's ranking in science rose from 20th in PISA 2006 to 18th in PISA 2009 and all of these Irish participants had engaged with the revised Primary Science Curriculum and were engaging with the new Junior Certificate Science curriculum. The authors of the PISA 2009 report suggested that such levels of attainment might be linked to the implementation of these new curricula (Perkins et al., 2010).

However, there still remains concern in Ireland regarding students' interest in science. Although higher percentages of Irish pupils took science related subjects to Leaving Certificate Level in 2010, including 52% taking Biology, the percentages of students who took Physics and Chemistry to Leaving Certificate last year were still relatively low at 12% and 14% respectively. So the numbers of students taking science to Leaving Certificate level does not appear to be considerably higher than pre-revised curriculum times. This is despite the fact that recent Leaving Certificate candidates would have done at least two years of the revised primary science curriculum, and would have engaged with the new Junior Certificate Syllabus. Teachers still do not appear to be employing the more inquiry-based approaches advocated in Primary and Junior Certificate curricula on a frequent basis. This may have to do with overloaded curricula, or pressure to cover content for exams. However, another contributing factor could be that teachers do not have sufficient pedagogical and / or conceptual knowledge to implement the new methodologies of these revised curricula. And while primary and post-primary pupils alike indicate that they like doing science in school, science or science related subjects do not appear to have significant appeal to the majority of our students. This is reflected in the low percentages of our students who are opting to take Physics and Chemistry to Leaving Certificate level.

I would strongly argue therefore that one way to address these concerns regarding the teaching of science and regarding students' apparent lack of motivation and interest in science would be to facilitate teachers and their pupils in developing more sophisticated conceptions of Nature of Science (NoS). This I believe would have a considerable impact on improving the teaching and learning in primary and post-primary science in Ireland.

What is NoS and why is it important in science education?

The nature of science [NoS] is knowledge about what science is and how it works. It is an understanding of science as a reliable body of knowledge that provides information about the world. It accepts that scientific knowledge is testable, developmental and therefore subject to change. 'Contemporary' or 'sophisticated' conceptions of NoS affirm that there is not one 'scientific method' that comprises a fixed set of steps and procedures that all scientists follow when addressing all scientific questions but rather there are numerous accepted processes that are utilised throughout the scientific community. Those who hold contemporary conceptions of NoS understand that science is a human activity involving subjectivity, creativity and imagination. (Abd-El-Khalick, & Lederman, 2000; Lederman, 1998; Mc Comas et al., 1998; Akerson et al., 2000; Murphy et al 2011)

Much research has been conducted on the importance and benefits of teachers and pupils having sound conceptions of NoS, (Abd-El-Khalick & Lederman, 2000; Craven et al., 2002; Akesron et al 2010; Brand and Moore, 2010; Murphy et al in presentation). Some research suggests that the incorporation of NoS as part of a curriculum makes pupils more aware of the developmental NoS and humanises science therefore making science more interesting and relevant to them (McComas, Clough, and Almazora, 1998). Others contend that students who leave school with contemporary understandings of NoS have a better understanding of science concepts and scientific inquiry, a greater interest in science and have a better appreciation of science's role in contemporary society (Matthews, 1994: Lederman and Abd-El Khalick,1998; Murphy et al., 2011). So it would appear therefore, that one way to develop our students' interest in science, and encourage them to pursue higher education courses and careers in science is to facilitate them in developing a better understanding of NoS.

However, there are a number of factors impeding this proposal. Firstly, many primary and post-primary teachers tend not to possess elaborate NoS conceptions, and their science backgrounds are not necessarily pertinent to their conceptions of science (Lederman et al., 2002; Matthews, 1994; Pomeroy, 2003). Secondly, even where teachers do possess contemporary NoS conceptions, we cannot assume that they will teach about NoS when implementing curricula. Thirdly, we cannot assume that students (and teachers) will automatically acquire contemporary NoS conceptions implicitly, as a by-product of 'doing' science-based activities (Akerson et al., 2000; Akindehin, 1988; Lederman, 1998). I would concur with Bell and colleagues, (2003) and maintain that teachers should plan, explicitly teach, provide opportunities for discussion and reflection on and indeed specifically assess the development of their students' conceptions of NoS.

So where to start? We cannot expect teachers to teach something about which they have no knowledge. So the starting point to me is obvious. We have to provide our teachers with opportunities to develop their conceptual and pedagogical knowledge regarding Nature of Science. That is, we have to teach our teachers to teach about NoS. Such knowledge, I would argue could have a significant impact on addressing some of the aforementioned concerns regarding the teaching of science and regarding students' apparent lack of motivation and interest in science.

In an effort to provide some substance to my argument I will provide a brief overview of some of the findings from a recent Irish longitudinal study. This explored the impact a nature of science programme had on: primary teachers' experiences of and attitudes towards teaching science and on their pupils' experiences of and attitudes towards school science (Murphy et al 2011; Murphy et al., in presentation). In this qualitative study the experiences of teaching science between teachers who had taken a Nature of Science (NoS) elective course[1] in their final year in college (test group) and beginning teachers who had not taken this elective (control group) were compared. Having qualified as teachers and obtained teaching positions, the two cohorts of teachers recorded their science teaching experiences in reflective diaries in the second and third terms of their initial teaching year. The findings revealed that, in addition to the expected emphasis on NoS activities, evidence in the diaries of the 'test teachers' (who had completed the NoS programme) revealed that there were considerable differences between the 'test' and 'control' teachers (who had not complete the NoS programme). These differences were related to the level of reflection on teaching approaches and on children's learning. The findings revealed that the test teachers were more advanced reflective practitioners and employed more inquiry-based approaches to implementing the science curriculum than those who had not taken the NoS course (control group).

The test teachers' written responses indicated that their intrinsic conceptions regarding teaching and learning in science were more in keeping with inquiry-based approaches to science and that they provided their pupils with more frequent opportunities for reflecting on different aspects of inquiry in science than the control teachers. The test teachers utilised more innovative and inquiry-based approaches to teaching science, more group work and fewer teacher demonstrations. On the other hand, the control teachers' reflections on teaching and learning tended to focus on their pupils' understanding of scientific concepts, characteristic of the more traditional, behaviourist models of learning. The test teachers also revealed greater levels of interest, enthusiasm and confidence in teaching science than those of the control. (Murphy et al., in presentation)

It is important to note that during the second year of their undergraduate degree the four teachers who participated in this qualitative study had taken a year-long (48 hours) curriculum science methodology course. This course advocated reflective constructivist approaches to teaching science. Both test and control teachers had similar teaching practice experiences and had attained high grades in their final teaching practice. However, the NoS elective provided the test

[1] The nature of science elective course was a module in the final year of a Bachelor of Education degree and was aimed at non-science specialist pre-service teachers. During this elective the participants were provided with opportunities to engage in practical inquiry-based activities that were aimed at facilitating the development of their conceptual and pedagogical knowledge of NoS (Murphy, Murphy and Kilfeather, 2010).

teachers with frequent opportunities to engage with and reflect on inquiry-based approaches to teaching about NoS in the classroom. It would therefore seem it that the NoS elective appears to have been the primary factor in the differences that emerged between these two cohorts of beginning teachers' reflections on, experiences of and attitudes towards teaching science (Murphy et al., in presentation)

The same longitudinal study also gathered data from the pupils via questionnaires and focus groups. The findings revealed that the primary children who had been taught by the NoS-educated teachers (test pupils) and who had engaged with activities that were directly targeted at developing more elaborate NoS conceptions, revealed more sophisticated understanding of nature of science and scientific inquiry and expressed more positive attitudes about their science lessons than those from non-NoS classes. The researchers asserted that there appeared to be *added value* in including NoS activities as part of science lessons as they seem to have helped the children make sense of science and scientists as well as making sense of school science in terms of scientific inquiry. This was apparent in the way the children in the NoS group frequently referred to their experiences of school science, when considering and discussing NoS issues whereas the non-NoS group largely provided examples from experiences outside school to substantiate their answers. (Murphy et al., 2011). Generalisations were not drawn from this qualitative study. However, if it was replicated on a wider scale and similar findings emerged, this could have a significant impact on the teaching and learning of science in Ireland particularly in terms of the employment of more inquiry-based methodologies and developing students' interest in science.

The process of justifying knowledge tends to dominate science education today. That is, students tend to learn facts, hypotheses and theories in relation to how they have contributed to current knowledge. While this information may be necessary in a curriculum, it is important that knowledge regarding the discovery and development of knowledge claims is not omitted. Students need to be made aware of issues surrounding the tentative and developmental nature of science. To omit such information could lead students to believe that science is a static subject that is absolute. There could be consequences if students left the science class with the perception that science is absolute and the only way of providing us with information about the world. For example, this inaccurate perception of science could be used in a selective or biased way by politicians as a means of influencing peoples' opinions on various issues (Eichinger, Abell & Dagher, 1997).

As mentioned earlier, there are concerns in Ireland about students' apparent lack of interest in science and the relatively low numbers of students taking science to Leaving Certificate or pursuing science careers. The research also highlights the importance of inquiry-based approaches to teaching science in the development of students' interest and motivation in science and in the development of students' scientific content knowledge and science skills. The recent Irish research reported in this paper revealed that the inclusion of explicit approaches to teaching about NoS as part of the primary science curriculum had a considerable positive impact on the teaching and learning of science in Irish primary schools. These included the employment of more inquiry-based approaches to teaching science, more frequent opportunities for problem solving, discussion and critical thinking in science class and increased interest and motivation in science amongst pupils who had engaged with NoS activities in school. I would argue therefore that providing students with frequent opportunities to engage with NoS during school science, would have a significant impact on increasing students' interest and achievement in science.

It is vital therefore that science curricula explicitly include the development of NoS understanding amongst their aims. I feel that if appropriate curriculum change that reflects the importance of the development of contemporary NoS conceptions is to be achieved, the importance of what is presently seen as 'peripheral' (eg developing students' understanding of NoS) in curricula needs to be made more explicit, that less emphasis should be placed on the acquisition of scientific content knowledge and that the curriculum content should be reduced to ease the strain of teachers trying to 'cover' the curriculum. I also maintain that teachers would be more inclined to teach NoS if it were explicitly addressed in curriculum documents and if it were explicitly assessed. However, even if NoS is explicitly addressed in curricula, to reiterate a point made earlier, if teachers are not aware of what NoS is, they cannot be expected to teach about it. It is therefore vital that we teach the teachers to teach about Nature of Science.

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Appendix 1
Some quotes from primary school teachers

- *Teaching the children about NoS helped me to understand its true meaning as it was my job to teach it to the children and I needed to learn more about the content before bringing it to the class*

- *Teaching about NoS in the class provides teachers with opportunities to think outside the box and foster an attitude of ownership on the children's behalf.*

- *(As a result of engaging with the NoS activities) The children's thinking I feel did change on the idea of science. They began to understand that they too are scientists as they were making observations, and using prior knowledge by inferring to create their end products. They began to understand how scientists can interpret things differently as each group made a different parachute and helicopter based on the one sketch. I feel the children are more confident in their work as 'scientists' and therefore interact better during science*

- *(As a result of engaging with the NoS activities) I think the children are more prepared to have a go and get stuck in. They are questioning and looking at science with an open mind, using their powers of observation and inference. They are prepared to test their results and are conscious of fair testing. They are very accepting of experiments that don't' actually work and see no problem with starting again or simply moving on.*

- *Since I have started teaching about NoS the children and myself are enjoying science so much more. I have found myself being more organised and less worried about the children becoming giddy. The lesson is more child-centred with them finding out for themselves by observation and practising their theories wherever possible.*

- *The children learned that their ideas must be tested and therefore needed to be measurable repeatable and reliable*

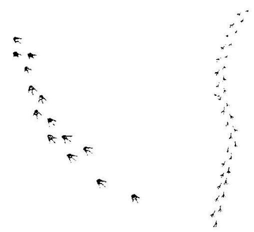
- *The class participated well in each lesson ... they observed a phenomenon, made up questions and understood more that science is subjective*

Appendix 2
Exemplar of 'decontextualised' NoS activity

(Exemplar taken from Lederman N. & Abd-El Khalick F. (1998). Avoiding de-natured science: Activities that promote understanding of the nature of science. In, Mc Comas W.F. *The Nature of Science in Science Education: Rationales and Strategies*. pp 83-126, Kluwer Publications)

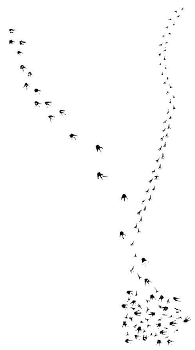
Tricky Tracks

This activity provides students will the opportunity to be able to distinguish between an observation and an inference. They should begin to realise that based on the same set of evidence several answers to the same question may be credible. Active participation is vital.



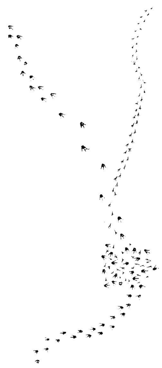
Picture 1

1. ***Picture 1:*** Show the picture to the pupils and ask them to write a brief account of what they think may have happened in the picture. Discuss these accounts with the class.



Picture 2

2. ***Picture 2:*** Show pupils picture 2 and ask them *"What do they observe"?* Record their answers on board. Then ask them *"How they can tell that these tracks are left by birds"?* The fact that they can't see the birds makes their statements 'inferences' rather than 'observations'. Ask them *"Can you give me an observation"?* A possible observation might be; two sets of black marks of different shapes and sizes printed on white background. Then mention to the pupils that based on this observation and their familiarity with animal tracks, that they have 'inferred' that birds made these tracks. However, it could have been something else. E.g. Mother and child of same species, or two different sized bird of same species. Then you could ask the pupils *" Why were the animals heading to towards the same spot"?* They could come up with a number of possible explanations (inferences).
   Discuss with the pupils that (similar to scientists) based on the same set of 'evidence' they came up with several but 'equally plausible' explanations (inferences) to the same question.



Picture 3

3. ***Picture 3:*** Show pupils picture 3 and ask them "*What do you observe?*" (black marks on white background) and *'What do you infer?"* (birds having fight, battling over food, mating ritual). Record observations and inferences.

4. ***Picture 1****:* Then show pupils picture 1 again. Ask them to make observations and inferences. Note these on the board. Then ask pupils to discuss their initial written accounts and what they think about what has happened in the picture now. Encourage pupils to reflect on whether they can ever know, based on the evidence available, what has 'really' happened in the tricky tracks picture. Compare this activity with the work of scientists highlighting the fact that scientists make similar inferences as they attempt to derive answers to questions about natural phenomena. Scientists' answers will be consistent with evidence available to them, however, no single answer may solely account for that evidence. Similar to 'Tricky Tracks', scientists may never find the answer as to what has really happened. Inferences should be based on evidence. Scientific knowledge should be based on and consistent with empirical evidence.

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□

Acid Mine Drainage (AMD)

An orange-red colour in streams, rivers or canals is an indication of acid mine drainage (AMD). The cover picture of the Trent and Mersey canal at Harecastle tunnel, near Stoke-on-Trent, is an example of AMD. The canal drains old coal mines under the hill, which were linked to the main canal by side tunnels. Coal usually contains iron pyrites, FeS2. In the presence of air and water, often catalysed by bacteria, iron pyrites is converted into iron(II) sulphate (green) and sulphuric acid.

1) $2FeS_2(s) + 7O_2(g) + 2H_2O(l) = 2Fe^{2+}(aq) + 4SO_4^{2-}(aq) + 4H^+(aq)$

The process is slow but is accelerated a million times by acidophile bacteria, particularly *acidithiobacillus ferrooxidans*. These bacteria have also been used in bacterial mining to release valuable metals like copper from low grade ores and waste tips. The resulting metal-laden, acidic solution, which drains out of old mine workings, is known as acid mine drainage – it has a low pH and high iron content. When it enters a waterway it is diluted, the pH rises and fresh oxygen is available. Iron(II, green, is first oxidised to iron(III), yellow.

2) $4Fe^{2+}(aq) + O_2(g) + 4H^+(aq) = 4Fe^{3+}(aq) + 2H_2O(l)$

However, at a higher pH iron(III) precipitates as iron(III) hydroxide, which is an orange-red solid. This is sometimes known as yellow boy or ochre and is the source of the colour in the water polluted by AMD. The exact colour depends on the hydration of the iron(III) hydroxide.

3) $Fe^{3+}(aq) + 3H_2O(l) = Fe(OH)_3(s) + 3H^+(aq)$

The solid forms a suspension in water which slowly settles out coating the bottoms of streams, rivers and canals with iron(III) hydroxide, killing aquatic life. It is only when all the solid has settled out that the river clarifies and eventually recovers.

Rio Tinto river in Spain (Wikipedia commons; Carol Stokes, NASA Ames Research Centre)
http://en.wikipedia.org/wiki/File:Rio_tinto_river_Carol_Stoker_NASA_Ames_Research_Center.jpg

AMD is a major pollution problem associated with old mining sites – both coal and metal mines, as both often contain iron pyrites and other metal sulfides. In Ireland the Avoca river is a classic case of AMD pollution from the old Avoca copper mines. The Rio Tinto is Spain is so called because of AMD from the old copper mines, which has stained the river orange-red for centuries. AMD is a major pollution problem both from the high acidity (low pH) and the high metal content. The acidity leaches metals out of the rocks so that AMD has a high heavy metal concentration, in addition to the high iron levels.

Treatment of AMD

It is too late to treat AMD once it enters a river or stream: by then it has had its harmful effects and it has become diluted. Two main methods have been used, apart from the physical approach of blocking up the exits from old mines to stop the flow: chemical and biological treatment. Chemical treatment uses a cheap base, such as limestone, to neutralise the acid and at the same time precipitate the metals as hydroxides. The chemistry is simple but the process is expensive for large volumes of AMD and there is a solid waste disposal problem. He biological processes involve allowing the waters to percolate through a wetland, when acidity is neutralised, heavy metals or removed by a mixture of chemical and biological reactions. This requires a large acreage of wetland depending on the flow of AMD.

Mine water discharge from the deep adit outfall, at the point at which it joins the Avoca River

http://www.fishingireland.net/environment/avocareport.htm

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The Element Makers: 11

Baron Carl Auer von Welsbach_1858 – 1929

Adrian Ryder tutorajr@gmail.com

Carl Auer von Welsbach was born on the 1st of September 1858 in Vienna, the youngest child and second son of Therese Neuditschka (24th Sept. 1831 – 22nd June 1910) and Alois Ritter Auer von Welsbach (11th May 1813 – 10th July 1869), the Director of the Imperial Printing Press of the Austro-Hungarian Empire. Alois Von Welsbach was created a hereditary Baron in 1860 and stepped back from his Directorates in 1864. Carl's siblings were named Alois, T. Leopoldine and Amalie.

Carl was educated, at secondary level, at the Gymnasium in Mariahilf (6th district of Vienna) (1869 to 1873) and then at the Realschule in Josefstadt (8th district in Vienna) (1873 to 1877), where there was a greater emphasis on scientific studies. Carl graduated in 1877, after which he did his military service, ending as a second Lieutenant. In 1878 he attended the Vienna Polytechnic where he studied general Chemistry, Engineering Physics, Thermodynamics and Mathematics. After which, in 1880, he attended the University at Heidelberg where he studied under Robert Bunsen (no. 5 of this series). Here Carl received intensive training in spectroscopic techniques and began his own researches on the rare earth minerals. Carl was conferred with his Ph.D. on the 5th of February 1882.

Carl, having finished his initial studies, moved back to Vienna and began his life-long researches on the rare-earths, working as an unpaid assistant in Professor Adolf von Lieben's laboratory and gaining experience in chemical separation techniques. In 1885 he succeeded in separating 'didymium', discovered by Mosander (No. 4 of this series) in 1840 into two separate portions, one green the other pink, containing two new elements, as the oxides, which he named praseodymia (green twin) and neodymia (new twin), keeping the 'twin' of Mosander in the names. The pure elements themselves were not to be isolated until 1925. Carl's method of extraction involved repeating, many times, the fractional crystallization of the ammonium double nitrates of the lanthanum – 'didymium' mixture in concentrated nitric acid, by which means the lanthanum separates first and finally the 'didymium'' breaks up to its constituents.

Carl Auer von Welsbach and his coat-of-arms with its motto of *Plus Lucis*, (Latin: more light), which certainly fits in with Carl's career.

In this same year Carl patented his gas-mantle, the Welsbach mantle, which prolonged the usage of gas lights in spite of the inroads of the new electric lighting initiated by Edison in 1879. Lighting at the time was by means of candles, oil or town gas all of which gave luminous flames but were hot, smoky and smelly. Initial experiments for the Welsbach mantle were made with an asbestos base impregnated with salts and then heated, but his first patent was for a guncotton base with the solution impregnating it being 60% magnesium oxide, 20% lanthanum oxide and 20% yttrium oxide. This was heated strongly, burning away the guncotton and leaving a crust of oxides, which were then made incandescent by the burning gas. The light given off had a greenish tinge and Carl's factory, which produced the mantles, folded commercially in 1889.

In 1890, collaborating with Dr. Haittinger, Carl produced a new version using a mixture of thorium and cerium salts, which were then strongly heated to leave a residue of 1% cerium salt and 99% thorium salt. This mantle, when heated by gas, became incandescent and produced a much better light than before. The patented mantle was prepared from a cylinder of cotton soaked with thorium nitrate and cerium nitrate with, the cotton burned off to leave a fragile frame of the metal oxides. This effort was successful and the new gas-mantle spread throughout Europe. In 1892 some 90,000 of these mantles were produced, rising to 300,000 in 1913. This is the mantle still found today in outdoor and camping lamps. In 1895 the Auer lights, as they were called, were introduced as the street lighting in Berlin.

A modern gas mantle

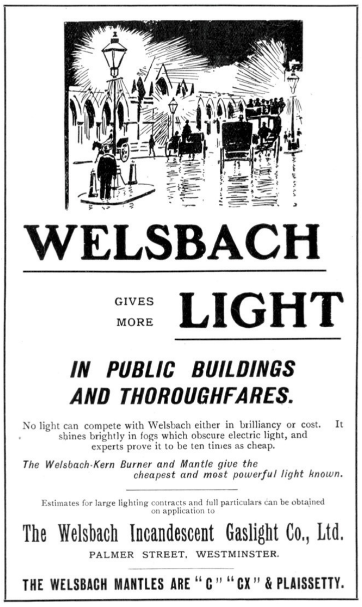
In 1898 Carl purchased industrial property in Treibach, some 200 km South-West of Vienna, and it was here that he sited his various factories. The Treibacher Chemical Works still provide the major industry and employment in this region of Austria.

The Auer industrial complex in Treibach

In the same year Carl undertook research to try and improve the electric lamps by replacing the carbon filament; initially with platinum and then with metallic osmium, which has a melting point of some 2,700 °C. Carl presented the first of his new bulbs at the World's Fair held in Paris during 1900. Carl opened his new factory producing the bulbs, Auer-Oslicht, in 1903. Initially the bulbs cost 5 marks each, some ten times the cost of the carbon filament one, but had a burn-life of at least 1,000 hours and an electricity consumption of just 1.5 watts per candle power, just half that of the carbon filament bulb. Later on, when conditions made the supply of osmium scarce, used bulbs were bought back at 75 pfennig and the osmium recycled.

Questioned on the difficulties of the bulb's production and the possibility of there being some other more suitable metal for the filaments Carl, with the highest regard for his own opinions, said: *"No, I have tested all the metals which could be considered, there is none which can be used for the purpose and which is superior to osmium. The difficulties will gradually be overcome, and sufficient of the material will be found somewhere in the world. Nature has decreed that osmium shall serve the human race as its incandescent substance for electric light."*

While osmium filaments were a distinct improvement over the carbon ones, they were to be completely superseded by the use of tungsten filaments with their melting point of 3,410 °C in later years. Modern filament lamps, now being phased out in favour of low-energy bulbs, contain tungsten filaments.



Advertisement for Welsbach lamps, 1912

In 1903 Carl was elected the first Honorary Member of the Association of Austrian Chemists in Vienna (VŐCH). This Association had been founded in 1897 and prior to 1914 only two such Members had been honoured.

After this Carl did research on finding a use for waste ceria (cerium(IV) oxide, CeO_2) which, at the time, had very little practical use. He remembered an oddity that he had met with during his time in Bunsen's laboratory: that cerium when struck emitted sparks. This led Carl in 1907 to invent a new alloy, Auer metal, (also known as Mischmetal, German for mixed metal). This was composed of iron alloyed with 30 to 35% cerium. This alloy is the everyday flint of cigarette and gas lighters. The alloy, now called **Ferrocerium,** is a man-made metallic material that gives off a large number of hot sparks when scraped against a rough surface such as ridged steel. This was to be a most profitable enterprise and by 1929 the world-wide production of lighter flints was some 100,000 kg. This alloy is also used as a deoxidizer in vacuum tubes and as an alloying agent for magnesium.

On the 31st of December 1898 Carl married Marie Nimpfer (14th July 1869 – 3rd May 1950) from Heligoland and had four children by her: 3 sons and a daughter. In the following year, after the death of his Heidelberg Professor, Robert Bunsen, on the 16th August, Carl purchased Bunsen's library of books.


Carl Auer von Welsbach about 1900

In 1901 Emperor Franz Josef I bestowed the title Freiherr (Baron) on Carl, who while speaking to him, noted that some 40,000 jobs had been created through his (Carl's) discoveries.

By 1913 some thirteen lanthanide (rare earth) elements, from cerium to lutetium, were recognized by the scientific community. The last element, lutetium, had been isolated in the years 1906-1907 by Carl and Georges Urbain (France, 12/4/1872 – 5/11/1938), as also was ytterbium, both obtained from the mixed oxide known as erbia. Mosander (No. 4 of this series) had isolated erbia, but in the year 1878 Jean Charles de Marignac found that erbia itself was composed of the oxides of two similar elements; to one he gave the name ytterbia and retained the name erbia for the other. Carl called the two new elements aldebaranium and cassopeium, while Urbain called them neoytterbia and lutecia. Priority claims for recognition as discoverers of the new elements were made by both men and even today which man is given the honour of discovery depends on the country of origin of the writer.

At the time a number of other possible rare earth metals were being put forward as elements from spectroscopic evidence, including Carl's 'thulium II' and Urbain's 'celtium', amid much personal infighting for recognition. Henry Moseley's X-ray machine, (Henry Gwyn Jeffreys Moseley, England, 23/11/1887-10/Aug/1915), was resorted to in order to settle matters but while initially accepting Carl's thulium II as a new element and rejecting the claim of Urbain, after further work with the X-ray machine Moseley was also to reject Carl's thulium II as a new element.

The Auer von Welsbach gravestone

Between 1910 and 1924 Carl was active with the large scale separations of radioactive substances, providing uranium and thorium samples to research laboratories all over the world. In 1920 Carl was awarded the Werner-von-Siemens-Ring award, one of the highest German awards for industry. This was only the second time the award had been given, the first time was in 1916 to Carl von Linde (1842-1934).

For the rest of his life Carl wrote papers on chemical separations and spectroscopy and indulged his interests in photography and ornithology.

The Auer von Welsbach Museum in Althofen, near Schloss Welsbach

The Auer von Welsbach Museum in Althofen has an unique exhibition of the first metal filament lamps, as well as the earliest gas mantle lights and a superb collection of rare lighters. It also displays colour photographs taken by Carl in 1908, which were the first colour photographs to be taken in Austria. Carl's laboratory, complete with his original equipment and tools, is also on show.

From 1910 von Welsbach became increasingly involved with the 'new' radioactive elements. In that year, using some 30,000 kilograms of Joachimathal pitchblende, he was able to produce concentrated mixtures containing radium, which allowed for the exact determination of its atomic weight in 1911. From the extracts von Welsbach also produced a mixture of thorium isotopes, although he failed in his attempts to isolate the individual isotopes in the mixture. Over the following years von Welsbach was to prepare radioactive samples for laboratories throughout the world.

World War 1 did not make great changes in the production of the von Welsbach factories, as his lights and lighter flints were essential items. However he did produce gas-masks and helmets for the army, and his company is still today a leading world producer of these. His factories also produced bricks and electricity. In 1916 von Welsbach oversaw experiments in the preparation of alloys of steel, in particular molybdenum-iron, for general use, but with the defeat of the Austro-German alliance in 1918 these experiments were not continued. In 1922 von Welsbach produced a major paper on the preparation and properties of radioactive materials, but after this no major new work is recorded.

Carl died at his home, bought in 1893, Schloss Welsbach, 5 km west of Treibach, Austria, on August 4th 1929. He has been honoured by having his portrait printed on the 1956 20 schilling Austrian banknote, on a silver 25 schilling coin, on the 2008 silver and niobium 25 euro coin and on the Austrian, 1936, 40 pfennig and the 1954, 1.50 schilling postage stamps. During his life he was awarded gold medals for his work from France (1893), Austria (1894), United States (1900) and Birmingham, UK (1919). In 1918 the Kaiser presented him with the Knight's Cross, 1st Class. A mineral, auerlite, a hydrous silico-phosphate of thorium (ThO_2) was named after him. He also received five honorary doctorates from various Universities in recognition of his works.

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Diary

2011

IOSTE - NW Europe
Contemporary Issues in Science and Technology Education
Mini-symposium June 20-21
http://ioste-nwe.wikispaces.com/
Reading, UK

July 24-28, 2011

ChemEd 2011
July 24-28
Western Michigan University, Kalamazoo, USA
http://www.wmich.edu/chemed/

Eurovariety in Chemistry Education (EiCE)
September 1-4
Bremen, Germany
http://www.uni-kassel.de/hrz/db4/extern/Eurovariety/index.php?SID=50eae5481675719a8f14b97717cb4f1a&action=cms&id=74

Variety in Chemistry Education (ViCE)
September 1-2
York, UK
www.heacademy.ac.uk/physsci/events/detail/2011/vice_2011

9th. ESERA
September 5- 9
Lyon, FRANCE
http://www.esera2011.fr/

30th. ChemEd-Ireland
October 22
UCC, Cork
d.kennedy@ucc.ie

2012

22nd ICCE/11th. ECRICE
Stimulating Reflection and Catalysing Change in Chemistry Education
July 15-20
Rome, Italy
www.22icce.org/home.htmL