Contents #104

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: Ray Boyce, Alphaset Ltd., Limerick
Cover photo: Science Foundation Ireland Research Image of the Year, by SSPC researcher Dr Anthony Maher (Photo: UL/SSPC) Image Title: Starship Enterprise, Description: Optical Micrograph of a metastable Form II piracetam (rough dissolving crystal) undergoing a solution mediated polymorphic transformation to Form III (smooth growing crystal) in methanol at 25 ° C.

Editor: Peter E. Childs **Assistant editors:** Marie Walsh, Maria Sheehan, Sarah Hayes, Anne O'Dwyer

Editorial #104

How not to change a curriculum

The dispute with the second level teachers' unions over assessment and certification of the new Junior Certificate of Secondary Attainment (JCSA) rumbles on into 2015. After two one-day strikes there is no sign of a settlement. The Minister of Education and Skills, Jan O'Sullivan, had compromised on 60% exam-based external assessment and 40% school-based internal assessment, down from the 100% school-based assessment proposed by her predecessor, Ruairi Quinn. The problem is not about teachers assessing their own pupils – they do this all the time – but in using these teacher-awarded marks for national certification. The teachers want to have no role in assessing their pupils for an external award, stating that this would fundamentally alter the nature of the teacher-pupil relationship and would leave them open to pressure.

The latest compromise, proposed by Dr. Travers, an independent arbiter, has been rejected by the teachers' unions: Dr Travers proposed retaining the 40% as just a school-based, not a national, assessment, based on a pupil portfolio, but this was also rejected.

Apart from assessment issue, teachers also have legitimate concerns about the speed of change, the lack of real consultation and the lack of resources and inadequate CPD to support a major curriculum change, not to mention the increased paperwork and form-filling that would result from school-based assessment.

Teachers are currently boycotting CPD workshops provided by PDST and the target of introducing the new science specification in September 2015 now seems unlikely and 2016 has been proposed as a new date. This will only be feasible if the problems are resolved. The teachers have shown their willingness to take strike action, despite its unpopularity with parents. It is hard to see how the Minister can force through curriculum change against the opposition of the teachers. Their cooperation is essential if change is to be implemented successfully. At the same time that Ireland is trying to introduce teacher assessment, the U.K. is abandoning it, due to its potential abuse and effect on raising grades, but in this case against the opposition of the teachers' unions. The teachers' unions in the U.K. and Ireland take an opposite stand on teacher assessment - for in the U.K. and against in Ireland.

Sadly the Irish JCSA experience is a lesson on how not to introduce curriculum reform: have minimum consultation with teachers; rush reform through to meet political objectives; implement without providing enough CPD to support major change; and fail to provide additional resources to support the new curriculum's demands. (The same problems arise with the LC science revisions.)
The NCCA held a consultation on the new science specification on October 14th 2014 in Dublin and the report on this has been published. (http://www.juniorcycle.ie/NCCA_JuniorCycle/media/NCCA/Curriculum/Science/JCScience-Consultation-Report_Web.pdf)
The meeting was well attended by a range of stakeholders and was well organised but second-level science teachers were not able to attend due to the boycott. Their omission rather undermined the value of the day. One small achievement was to get the 'Materials' strand renamed 'The chemical world', to match the 'The physical world' and 'The living world', thus ensuring that chemistry has equal visibility to biology and physics.

On p.6 I look at what are the big or core ideas in chemistry. Surely bonding is one of these and the topic should be introduced in the JCSA science course.

Peter E. Childs
Hon. Editor

"I have just returned from a short vacation for which the only books I took were a half-dozen detective stories and your 'Chemical Bond'. I found yours the most exciting of the lot."
G.N. Lewis. Letter to Linus Pauling. August 25, 1939.

Education News and Views

The Editor welcomes contributions and news of interest to chemistry teachers in this section.

A new name for NCE-MSTL

The National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL) has changed its name to reflect the wider brief of STEM education, with the appointment of Professor Sibel Erduran as Professor of STEM Education and Director of the Centre. (See the article about Professor Erduran in issue 103.) The new name is EPI*STEM, The National Centre for STEM Education. This reflects a wider brief including Engineering and Technology as well as Science and Mathematics. Epistemology is the theory of knowledge and epistemic means relating to knowledge.

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JC Science consultation

The NCCA organised a conference of stakeholders on October 14th 2014 and a summary of the findings of the consultation were published online in Dec. 2014.
http://www.juniorcycle.ie/NCCA_JuniorCycle/media/NCCA/Curriculum/Science/JCScience-Consultation-Report_Web.pdf
The NCCA are to be congratulated on the prompt publication of the discussion, but unfortunately due to the industrial dispute with the unions second-level science teachers were not officially present, although some were there in other capacities. You should read the report in full but the main findings are given below.

Due to the continuing industrial action which does not seem to be anywhere near resolution, the introduction of the new Science courses, due to start in September 2015, has been delayed to 2016.

Summary of findings emerging from the consultation

1. In general terms, the initial response to the draft specification is positive.

2. The response to the rationale and aims is also positive. Participants welcome the focus on encouraging enjoyment, developing scientific literacy and nurturing creativity.

3. There is strong consensus that the new course structure represents a welcome development.

4. There is a guarded welcome for the learning outcomes, there are genuine fears and constructive concerns about them too.

5. The annotated examples included in Appendix 1 are a positive development and welcome support for teachers. However, some examples were better received than others.

6. The vast majority of respondents to the online survey expressed the view that the glossary of action verbs in Appendix 2 contributes in a significant way to developing a shared understanding of the learning outcomes.

7. There is a strong welcome for the sample assessment items in Appendix 3. There is consensus that they support and reinforce inquiry-based learning and have the potential to be instrumental in influencing pedagogy in a positive way.

8. Those attending the consultation conference emphasised that the specification has the potential to be more engaging and to capture the imagination of students. The flexibility of the learning outcomes and the absence of prescribed practical activities contribute to this.

9. There is a broad welcome for the emphasis on inquiry in the specification and for how the specification has been designed to facilitate varying degrees of inquiry.

10. The value of collaboration emerged as an important theme of the consultation.

11. Assessment for certification will have a very significant influence on the pedagogical approaches adopted in science classrooms.

12. It will be important that textbooks are aligned with, and underpin, the spirit of the specification.

13. The main theme of the consultation conference was the central importance of continuing professional development (CPD) for the introduction of the specification in schools.

The draft specification is a welcome but radically innovative change which may require different teaching methodologies and classroom practice for some teachers, and they will need to be fully supported in making this transition.

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9th Chemistry Demonstration Workshop

The dates for this annual workshop have been revised to the 15-19 June 2015. This is a 4 day residential course, a chemical demonstration fest, to give teachers more confidence in doing chemical demonstrations in class, extend their repertoire of demonstrations and equip them to put on a science magic show. Everyone who has been on previous courses has found them beneficial and energising. The course costs €150 but this includes tuition, materials and 4 days full board on the UL campus. If you are interested in attending the 2015 course, please email Sarah Hayes at sarah.hayes@ul.ie
Numbers are limited so please apply early.

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STEM Review report expected soon

We had hoped that the report of the STEM Review Group, which was set up in November 2013, and was due to report in mid-2014, would be available by now. I hear it is finished and with the Minister, and we hope to review its main findings in the next issue. It is a pity that such a review was not conducted before the JCSA science LC science courses were revised and finalised.

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RIA and STEM education

Following the RIA-ALLEA Joint Efforts in Science Education Forum held in Academy House in November 2013 and the discussion forum on STEM Education also held in Academy House in April 2014, the Review Group requested that the Academy make a formal submission to it. Accordingly the Academy established a working group to formulate its submission. The Academy's working group was chaired by Professor Alan Smeaton, MRIA, DCU and supported by Professor Han Vos, MRIA, DCU, Professor Peter Mitchell, MRIA, UCD and Professor Daniel O'Hare, MRIA,DCU.

The Key points raised in the Academy's submission included:

- Initial teacher education (ITE) and continuous professional development (CPD) programmes need to continue to adapt more inquiry-based approaches to teaching science and mathematics.
- Higher Education Institutions (HEIs), in combination with the network of Education Centres (originally Teachers' Centres) and MOOCs (Massive Open Online Courses), could deliver STEM education CPD.
- The primary and post-primary STEM curriculum should be shortened to make room for a more in-depth form of engagement with students, a richer student experience and alternative forms of assessment, so that students have more opportunities to apply and develop their scientific skills.
- The Teaching Council should be given the responsibility for recognising and registering discipline-specific teaching accreditation in the STEM area.

Furthermore it was recommended that existing IBSE initiatives could be better coordinated at a national level to even out what is currently a very mixed student experience. The Academy's official Advice Paper on STEM Education in Ireland is available at:

http://www.ria.ie/getmedia/843a5414-a70a-46c6-92e6-b6d591d48bbf/Royal-Irish-Academy-Advice-Paper-no-3--Submission-to-the-STEM-review-group-.pdf

Beijing Declaration on Science Education and Science Literacy

The IAP – the global network of science academies, of which the Royal Irish Academy is a member of, has called on IAP member academies, governments, the private sector and UNESCO to strengthen science education around the world - with a focus on the proven methods of inquiry-based science education (IBSE).

At the close of the recent IAP Science Education Programme (SEP) Biennial Conference, held in Beijing, China from 28-30 October 2014, members of IAP's SEP Global Council prepared the 'Beijing Declaration' which calls on:
• All IAP member academies of science to redouble their commitment to IBSE/STEM education, including reaching out to their national ministries of education, their national UNESCO commissions and their national missions in UNESCO.
• Industry to assist national academies of science and their national governments to enhance IBSE/STEM education policies and initiatives to ensure the formation of the creative and innovative human capital that will enable their own enterprises to remain competitive in the increasingly fast-paced science and technology-based development environment.
• Foundations, charities and donors to sponsor the roll-out of IBSE/STEM practices, especially in developing countries.
• China, the host nation of the Beijing Conference, and other nations with rich experience in IBSE/STEM and science outreach activities to share their experiences with the world and to assist in capacity building efforts in other countries, especially developing countries, wishing to implement IBSE/STEM.
• The United Nations Educational, Scientific and Cultural Organization (UNESCO) to include IBSE/STEM in the programme of the UNESCO World Education Forum in Incheon, Korea, in May 2015, and to incorporate IBSE/STEM for quality education and lifelong learning into the United Nations post-2015 development agenda.

In November 2014 to coincide with Science Week the Royal Irish Academy and Silicon Republic collaborated to produce an opinion series authored by selected members of the Academy around the topic of STEM Education, particularly focusing on primary and post primary level. Authors outlined their respective opinions on the current practices and future initiatives that may advance STEM Education in Ireland.
http://www.ria.ie/getmedia/b2314699-34d2-4450-af10-d04117da004a/stem-series_1.pdf

□

2015 Science on Stage

http://www.science-on-stage.eu/page/display/4/14/0/festival-2015
Ireland will be well represented at the 2015 Science of Stage meeting in Queen Mary College, London from 17-19 June. The Irish team will be:

- David Keenehan, Gonzaga College, Dublin
- Maria Sheehan, Saint Caimin's Community School, Shannon, Co. Clare
- Brigid Corrigan, Mount Sackville Secondary School, Dublin
- Richard, Moynihan, O'Carolan College, Co. Meath
- Patrick Dundon, Castletroy College, Co. Limerick
- David Doherty , Coláiste na Carraige, Donegal
- Dorothy Fox, Scoil Chonglais, Wicklow
- Helen Ní Chríódáin, Gael-Choláiste Chill Dara, Kildare
- Rory Geoghegan, PDST Science
- Leanne Hawthorne, Belfast Boys Model School, Ballysillan Road, Belfast

□

What are the big ideas in chemistry?

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Introduction

What should be in an introductory chemistry course at school? This is an important question because it affects what will be taught and what foundation there will be for future studies in chemistry. The majority of students (~85%) will **not** study chemistry beyond the junior cycle and so their first exposure will probably be their last. Only ~15% students take chemistry in the senior cycle and again for many of them this will be their final experience of chemistry, because they will choose non-science related courses or science/technology courses that don't involve chemistry. However, many third level students find that although they didn't do chemistry for LC they still have to take at least first year chemistry, sometimes even more. This can be a big shock and often they struggle and do poorly in chemistry, due to an inadequate foundation and lack of exposure to the basic ideas and language of chemistry. Even when they survive they may not understand the chemistry they have covered and it may just be crammed for the exam and then forgotten.

The question I am asking here is: 'What are the basics of chemistry, the big ideas, the irreducible minimum, that a student needs to know for future life as part of their scientific literacy?', whether or not they do further chemistry courses or use chemistry in later life. We have to get this right in the junior cycle, and for physics and biology as well, since this may be all the chemistry (or physics and biology) they ever get. (More students carry on with biology for LC, ~ 55%, so it is not quite so crucial in biology to get it right in the junior cycle.) When we look at the current JC science course and the proposed science specification for JCSA, we should ask the questions: 'Is this a good foundation for scientific literacy (for the majority)?' and 'Is it a good foundation for LC chemistry (for the minority)?'

The importance of big ideas

There is a helpful guide to identifying and using Big Ideas in Science at http://tools4teachingscience.org/tools/Big_Idea_Primer.pdf, which is worth reading. It defines a big idea as follows.

> *"Big ideas are about the relationship between some class of **natural phenomenon** and a **causal explanation** that helps us understand why that class of phenomena unfolds the way it does. Although explanations are the most important part of big ideas, we will start by describing natural phenomena, since they are most familiar to you and to students.*
>
> ***Phenomena** are events, things, properties, or situations that are observable by the senses, or are directly detectable by instruments.*
>
> *• If you are a biology teacher, examples of phenomena might be the different shapes of finches' beaks, water moving into or out of a cell, or the invasion of non-native species into a habitat.*
>
> *• If you are teaching earth science, examples of phenomena might be earthquakes, sedimentation, or lunar eclipses.*
>
> *• If you are a chemistry teacher, examples of phenomena might be phase changes in samples of water, the diffusion of dye in a beaker, or the rusting of iron.*
>
> *• If you are teaching physics, examples of phenomena might be motion of a pendulum, the changing temperature of a cup of coffee left on a countertop, or the way light behaves when it passes though lenses.*
>
> *In contrast to phenomena, **causal explanations**—also known as **explanatory models**—are not directly observable. Causal explanations or explanatory models have the following characteristics:*
>
> *• They are storylines about why observable events happen, not just descriptions of **how** they happen or **that** they happen.*

• They almost always involve a cast of unseen characters, events, and processes that operate at a more fundamental level than the phenomenon itself. These characters, events, and processes may not be directly observable for several reasons:
- they exist at such a small scale (atomic bonding)
- they happen so quickly (electricity moving through a circuit)
- they happen so slowly (evolution, glaciations)
- they are inaccessible (the interior of the earth, neurons firing in the brain), or,
- they are abstract (like forces, concentration gradients, or alleles).
• These causal explanations may take several forms, they may be labeled drawings, written paragraphs, flow charts, or physical models.
• The causal storyline—or the "why" explanation—is powerful in science because it helps us understand a whole ***range of observable phenomena*** *in the world.*

At this point we want to be clear—Big ideas are always developed out of some type of explanatory model. Even though it is phenomena that tend to capture the students' interests—like the exploding hydrogen balloon, the tornado video, the dilating pupil of the eye—your instruction should focus on what unseen mechanisms are at work. By the end of the unit, you want your students to have linked explanatory models to these phenomena and to other related phenomena. This is what makes an idea or model powerful in science—its ***generalizability****—that it can be used to explain and even unify a range of different phenomena."*

http://tools4teachingscience.org/tools/Big_Idea_Primer.pdf

An important movement in science education says that science teachers should concentrate on getting over the big ideas as an organising framework, rather than on lots of often disconnected facts and concepts. Thus Wyn Harlen in 2010 identified 10 big ideas for general science (covered in *Chemistry in Action!* issue #, 93, Spring 2011). Her big 10 ideas are shown in Table 1, and I criticised their lack of chemistry in *CinA!* #93. The whole of chemistry is squashed into point #1!

Table 1: Ten big ideas of science education
http://www.ase.org.uk/documents/principles-and-big-ideas-of-science-education/

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.

At the other extreme we have lists focusing only on chemistry. Peter Atkins, a prolific UK textbook writer and third level chemical educator, has identified 9 principal or central ideas in chemistry. Some of these are relevant to introductory courses in chemistry, but all 9 are probably only suitable for third level courses or for demanding senior cycle courses like the UK A-levels. (Peter Atkins' *Education in Chemistry* article in the link below is well worth reading.)

Table 2: Peter Atkins' 9 central ideas in chemistry

(See http://www.rsc.org/Education/EiC/issues/2005_Jan/skeletal.asp and also http://nzic.org.nz/chemed-nz/issue-archive/ChemEdNZ_Nov2010_Hill.pdf)

1. **Atoms**: Electronic structure, core/valence electrons, most important atoms – H, C, N, O – because of biological significance, elements (solid, liquid and gaseous).
2. **Periodic Table**: Structure – periods and groups, periodic and group trends (electronic structure and chemical properties), named groups, transition elements (variable oxidation state).
3. **Bonds**: Bonds between atoms lead to molecules, difference between 'ionic' and 'covalent' bonding. Some important molecules: ionic – sodium chloride, hydrochloric, sulphuric, nitric acids: covalent – water, carbon dioxide, ammonia, methane, ethylene, acetylene, ethanol, acetic acid, ethylamine, glucose, the concepts of bond length and bond energy.
4. **Shape**: Simplified application of the VSEPR theory to determine molecular structure of water, carbon dioxide, ammonia, methane. Ionic structures – sodium chloride, graphite.
5. **Residual Forces**: The concept of 'hydrogen bonding' and the explanation of the structure of ice, the solubility of ethanol in water and the folding of proteins.
6. **Energy**: First Law of Thermodynamics, Hess's Law/enthalpy calculations, examples of exo and endothermic reactions.
7. **Matter and Energy Disperse**: Second Law of Thermodynamics/Free Energy/reaction driving force, chemical equilibrium.
8. **Barriers to Reaction**: Chemical Kinetics, Activation Energy, Arrhenius equation, first order rate law, catalysts/enzymes. Explanation of radiocarbon dating in terms of half-life of radioisotopes.
9. **4 types of reaction**: Acid/Base; Electron Transfer (Redox); Radical; and Proton Transfer

The Atkins' schema has been simplified into 6 big ideas by Philip Hampton at the California State University Channel Islands for their introductory chemistry course (Table 3):

Table 3: The six big ideas of chemistry
(http://chemistry.csuci.edu/big_ideas.htm)

1. Geometric Structure: The three dimensional arrangement of atoms in a molecule results in a unique shape which can affect the properties, reactivity, and stability of a molecule, as well as its ability to interact with or bind to another molecule.
2. Electronic Structure: The energies and extent of filling of atomic orbitals and molecular orbitals in an atom or molecule affects the properties, reactivity and stability of an atom/molecule. Electronic structure includes the nature of bonds between atoms and the interaction between orbitals on neighboring or remote atoms.
3. Forces between Molecules: Interactions between groups in a molecule or between molecules can occur over a distance through dispersion forces, dipole-dipole interactions, hydrogen bonding, and crystal packing forces.
4. Thermodynamics: The stability of an atom/molecule influences its reactivity and determines whether an atom/molecule will react with another atom/molecule.
5. Kinetics: The rate at which one atom/molecule reacts with another atom/molecule is influenced greatly by the concentrations of the individual species undergoing the reaction, the rate of collisions between molecules, and by the energy needed for atoms/molecules to react individually or with one another.
6. Reactions: There are four basic ways that molecules react: (1) Electron-transfer (redox reactions); (2) Lone electron sharing (radical reactions); (3) Electron pair sharing (i.e., acid-base reactions, electrophilic/ nucleophilic reactions); and (4) Concerted Reactions (i.e., pericyclic reactions).

The most recent version of AP Chemistry in the USA has six ideas of chemistry (Table 4). This is a course for pre-university students in US high schools and is the most demanding of the various American high school chemistry courses.

Table 4: The 6 big ideas in chemistry from the AP Chemistry Curriculum Framework 2013-2014 (http://media.collegeboard.com/digitalServices/pdf/ap/11_3461_AP_CF_Chemistry_WEB_110930.pdf)

Big Idea 1: The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.
Big Idea 2: Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.
Big Idea 3: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.
Big Idea 4: Rates of chemical reactions are determined by details of the molecular collisions.
Big Idea 5: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.
Big Idea 6: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.

These big ideas have been visualised in a word cloud (Figure 1).

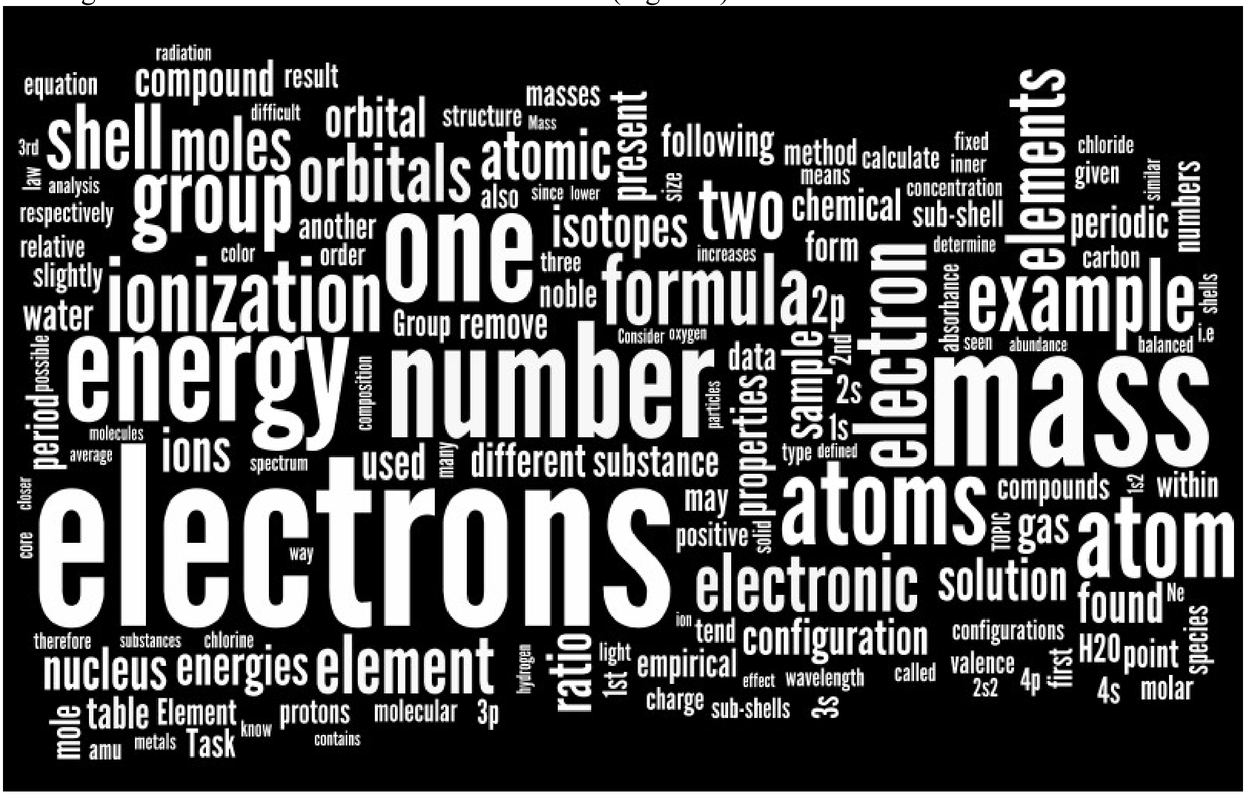

Figure 1 The big ideas in AP chemistry.
http://www.adriandingleschemistrypages.com/ap/word-clouds-for-big-ideas-1-6/

The American Chemical Society (ACS) has defined what needs to be in a high school chemistry course and what they consider to be the big ideas in chemistry (Table 5).

Table 5: The Big Ideas in Chemistry (ACS, 2012)
ACS Guidelines and Recommendations for the Teaching of High School Chemistry
http://www.acs.org/content/dam/acsorg/education/policies/recommendations-for-the-teaching-of-high-school-chemistry.pdf

Conservation of matter and energy	• Atoms are not destroyed in chemical reactions; they are rearranged • Forms of energy; energy changes in chemical reactions • Stoichiometry and balancing chemical reactions
Behavior and properties of matter	• The periodic table of elements as the master organizer of chemistry • Gas laws • Distinguishing among elements, compounds, and mixtures • Chemical bonding • Intermolecular forces
Particulate nature of matter	• Kinetic Molecular Theory • Structure of atoms, ions, and molecules
Equilibrium and driving forces	• Le Chatelier's Principle • Reaction rates • Thermodynamics (entropy and enthalpy) • Acid-base reactions • Redox reactions • Combustion

SCORE specification for GCSE chemistry

The closest parallel in the UK to JC/JCSA is GCSE science. This is offered as double award science (2/3 award in each science) or single award science (1 award in each separate science.) By comparison chemistry in the JCSA specification is 1/3 award, so clearly there can be much less coverage of chemistry in the JCSA course, or the current JC Science course, because of the smaller amount of time allowed. The following is the outline specification for single award chemistry at KS4. This specification for chemistry was developed in 2013 by SCORE (Science Community Representing Education) and is available at http://score-education.org/media/12525/ks4%20guidelines%20final%20version.pdf. The chemistry specification identifies 6 big chemical ideas at this level, which are shown in Table 6, defining chemistry in this way:

"Chemistry is the science of the composition, structure, properties and reactions of matter. The science of chemistry can be described in terms of core concepts, e.g. atoms and atomic structure, as detailed below. However, chemistry is a practical science, and we would expect students to appreciate that chemistry is not just about abstract concepts; it is also about making (synthesis), measuring (analysis) and identification (characterisation).
Chemistry enables us to understand the world around us, and provides solutions to challenges we need to address in the 21st century, e.g. health, food, water and future energy resources.
During KS4, we expect students to study the fundamental chemistry concepts, and to explore modern and sometimes historical contexts which are locally and globally relevant. This is illustrated in detail in the RSC Global Framework for Education 14-16 Age Range."

Table 6: Big Ideas in chemistry from SCORE (http://score-education.org/media/12525/ks4%20guidelines%20final%20version.pdf)

Below outlines the core concepts of chemistry and the application of this knowledge to the endeavour of chemistry (synthesis, analysis and characterisation).
States of matter: *Matter can exist in different states; solid, liquid or gas, at different temperatures or pressures* Use of kinetic theory to explain the properties of solids, liquids and gases; description of solutions, solubility and precipitates; factors which affect volatility; colloids and their properties.
Atoms, elements and compounds: *Matter is made of atoms, compounds are formed when atoms of different elements are chemically bonded* Atomic structure and the properties of protons, neutrons and electrons; relative atomic mass; ions and how they are formed; properties of different elements are related to the structure of their atoms; chemical bonds including ionic bonds, covalent bonds and metallic bonds; bonding affects the physical properties of substances.
The periodic table: *The periodic table displays all the elements and organises them according to their atomic structure* Elements are listed in the periodic table in order of increasing atomic number; elements react according to their atomic structure; groups and periods; elements in the same group have similar atomic structures; properties of metals and non-metals; the reactivity series and displacement reactions; trends and patterns of the periodic table.
Chemical formulae: *Chemical formulae are used to represent elements and compounds* Chemical formula as a means of expressing the number and type of atoms that make up a particular compound; identification of elements and compounds from their chemical formulae; the formulae of some simple compounds; relative formula mass; empirical formulae.
Chemical reactions: *Chemical reactions involve rearrangements of atoms to form new substances* The principle of the conservation of mass; rearrangement of atoms during chemical reactions; collision theory relating to rate of chemical reactions – catalysts, concentration, surface area, temperature and pressure; balanced symbol equations to represent simple chemical reactions; use of state symbols; reversible reactions and equilibria; activation energy; use of the terms endothermic and exothermic; chemical reactions as the basis of biological systems; complete and incomplete combustion; redox reactions; monomers, polymers and polymerisation; neutralisation reactions; electrolysis.
Acids, bases and salts: The terms 'acid', 'salt', 'base' and 'alkali'; equations to represent neutralisation reactions; pH of solutions is used to classify them as acidic, alkaline or neutral; indicators; why pH changes during a reaction between an acid and an alkali; acids and alkalis are classified as strong or weak according to their pH

The new JCSA science specification

Originally chemistry was lost in **The material world** but has now been reinstated in **The chemical world**, which is a good step forward. However, the building blocks for the chemical world are still inadequate. Table 7 shows the four strands of the science specification and the corresponding learning outcomes for 'The chemical world'. I think it is clear from the various descriptions of key ideas in chemistry described above, that chemical bonding is a major omission. Substances are classified but what holds them together is never mentioned.

Table 7: Learning outcomes for The Chemical World (JCSA Science Specification)

Building blocks
1. Investigate whether mass is unchanged when chemical and physical changes take place.
2. Develop and use models to describe the atomic theory of matter; demonstrate how they provide a simple way to account for the conservation of mass, changes of state, physical change, chemical change, mixtures, and their separation.
3. Describe and model the structure of the atom in terms of the nucleus, protons, neutrons and electrons; comparing mass and charge of protons neutrons and electrons.
4. Classify substances as elements, compounds, mixtures, metals, non-metals, solids, liquids, gases and solutions.
Systems and interactions
5. Use the Periodic Table to predict the ratio of atoms in compounds of two elements.
6. Develop and use models to describe the atomic theory of matter; demonstrate how they provide a simple way to account for the conservation of mass, changes of state, physical change, chemical change, mixtures, and their separation.
7. Investigate the properties of different materials including solubilities, conductivity, melting points and boiling points.
8. Investigate the effect of a number of variables on the rate of chemical reactions including the production of common gases and biochemical reactions.
9. Investigate reactions between acids and bases; use indicators and pH scale.
Energy
10. Consider chemical reactions in terms of energy, using the terms exothermic, endothermic and activation energy, and use simple energy profile diagrams to illustrate energy changes.
Sustainability
11. Evaluate how humans contribute to sustainability through the extraction, use, disposal, and recycling of materials.

Conclusion

My purpose in writing this article is to ask whether the JCSA science specification gives a sufficient introduction to chemistry and its big ideas; given that for many it will be their last exposure to chemistry and for a few it needs to form a good foundation for LC chemistry. It is clear from the different versions of the 'Big Ideas in Chemistry' given above that bonding is a key idea in chemistry and one which comes early in the list i.e. it is fundamental and foundational. This should not be a surprise to chemists, although it seems to be to the NCCA syllabus committee. The JCSA Science specification for chemistry is good as far as it goes, but it needs to include bonding as a building block. I hope that the JCSA Science syllabus committee will think fit to include chemical bonding as one of the building blocks of the chemical world, having now agreed to rename Materials as The Chemical World. My suggestion for an extra building block was to include: *To describe the nature and role of chemical bonding in determining the physical properties of elements and compounds and materials.* This missing building block could turn out to be a foundation stone.

The large jump in content and depth between the present JC Science course and LC Chemistry will be even larger in the new scenario, unless LC Chemistry is also thinned down to fit. In a separate article I look at the question as to whether one can introduce chemical bonding in a simple but satisfactory way in an introductory course like JC or JCSA.
□

Your comments on this article and on chemistry in the new JCSA Science specification would be welcome.

A Limerick Periodic Table #4 Beryllium

Created by Peter Davern
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Beryllium, Be

The alloys of beryllium – so elastic, strong and light…

…help watch-springs keep their steady beat throughout both day and night.

With emeralds all a-sparkling,

And with spanners all non-sparking,

But dust so toxic to the lungs, in time your breath grows tight!

Notes:
The alloys of beryllium – so elastic, strong and light…
…help watch-springs keep their steady beat throughout both day and night.
These physical properties make beryllium alloys an ideal raw material for making watch springs.

With emeralds all a-sparkling,
Emeralds are crystals of beryl, a mineral composed of beryllium aluminium silicate, $Be_3Al_2(SiO_3)_6$.

And with spanners all non-sparking,
Beryllium-copper alloys are used to make spanners, wrenches, etc. that do not produce sparks when dropped on the ground or on other hard surfaces. These non-sparking hand tools come in very 'handy' where the generation of such "impact sparks" could act as a source of ignition in the potentially explosive atmospheres (i.e. atmospheres containing flammable solvent vapours, gases or dusts) that may occur in chemical plants.
But dust so toxic to the lungs, in time your breath grows tight!
Though a small and light metal, beryllium is often included as part of the rather loosely defined family of 'Heavy Metals', which include the much heavier transition metals like chromium (Cr), lead (Pb), mercury (Hg), tin (Sn), etc. Exposure to excessive levels of heavy metals may have toxic consequences, and the inhalation of beryllium compounds as dusts or vapours can result in berylliosis, a chronic and possibly fatal allergic response in the lungs.

Be-A-Bond: An interactive demonstration for teaching organic chemistry

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Introduction

Mechanistic understanding lies at the heart of organic chemistry, yet curved arrow mechanisms can present a major challenge to students and teaching this topic may be considered to be one of the most difficult aspects of organic chemistry courses [1]. Students often use curved arrows in a very different way than the teacher intends [2-6]. Some may draw out a whole mechanism, but only add in arrows at the very end, almost as an afterthought [7]. Others detach all meaning from the arrows, using them simply to represent direction [8]. There is clearly a need to better demonstrate that curved arrows in chemistry are being used differently from arrows in everyday life. They do not just denote position or direction, but rather the specific direction of electron flow. This disconnect between the symbol and its meaning leads to common student mistakes such as arrows going in the wrong direction, or incorrect bonds breaking, or extra carbons appearing. A few methods have been developed to aid understanding of curved arrows, including notably Straumanis and Ruder's "bouncing arrow" [9-11]. We wanted to create a means of students being able to "see" electrons moving. This led to the development of Be-A-Bond, a demonstration where students act out mechanisms, passing electron cards between one another, visually reinforcing the symbolism of the curved arrow.

Setting up the demonstration

Students are selected, given atom headbands and arranged in the shape of a molecule. This shape can be masking-taped to the floor prior to the lesson to act as a guide for where students should stand. The students hold cards between each other that have two large circles on them, representing two electrons. All the equipment was made from coloured card and tape, with the atomic symbols and electron circles drawn on, as shown in Figure 1.

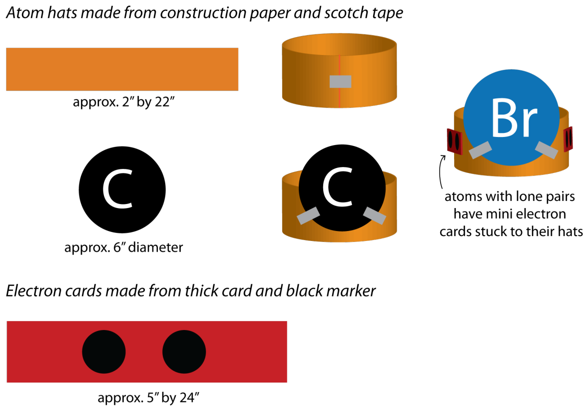

Figure 1: Equipment needed for the demonstration

As a starting point to get students used to this new representation, polar diatomic molecules can be acted out. This requires just two volunteers, for example a hydrogen and a bromine forming hydrogen bromide as shown in Figure 2. With the two volunteers stood at the front of the class, questions can be posed such as: *What type of bond is shown? What is the valency of each atom?* (This also highlights the "lone pairs" on the Br hat) *How can the polar nature of the bond be demonstrated?* (This introduces the notion that the demonstration is a tunable activity, and that students can use their bodies to represent chemical ideas. In Figure 2, the bromine is shown pulling the electron card towards her as a means of showing the dipole.)

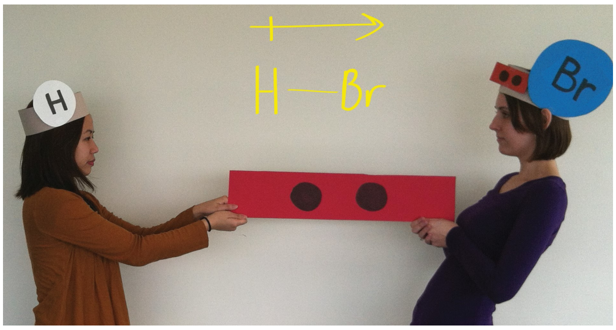

Figure 2: Students can lean back to indicate polarity

Electrophilic Addition Reactions

Following on from these simple molecules, mechanisms can be acted out. Students were first taught mechanisms traditionally using curved arrow formalism, and the Be-A-Bond demonstration was used subsequently to assess and deepen their understanding. As an example, the electrophilic addition reaction between propene and hydrogen bromide is described. This requires eight students to be arranged as shown in Figure 3. The molecule shape was taped to the floor before class as described above. It is important to note that to avoid crowding, one student represents a methyl group rather than just a single atom. Additionally, since the students we worked with only possessed two arms, not all the bonds could be held at both ends! Therefore some bonds which are not involved in the mechanism are represented by a single volunteer holding the electron card towards another volunteer's back. It should be emphasised to the class that these still represent covalent bonds, and in a perfect world we would all have four arms! Throughout the demonstration, the associated line diagrams are shown on the board for clarity.

- 8 students
- 4 H hats
- 2 C hats
- 1 CH_3 hat
- 1 Br hat
- 7 electron cards

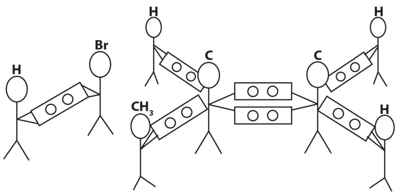

Figure 3: Set-up for demonstrating an electrophilic addition reaction

Once the two molecules have been arranged, the class discusses the mechanism. Students offer suggestions as to how the atoms and electrons should move, and the volunteers act these out. The class then discusses the feasibility of these ideas. A critical feature of Be-A-Bond is that it is a dynamic means of demonstrating a mechanism. Thus it can be easily manipulated in order to target misconceptions that are revealed in the discussion. For instance, the demonstration can be used to generate both the Markovnikov and Anti-Markovnikov products, leading to a discussion of the regiochemistry of the reaction. The left side of Figure 4 shows the route to the Markovnikov product through the secondary carbocation, whereas the right side shows the formation of the Anti-Markovnikov product through the primary carbocation.

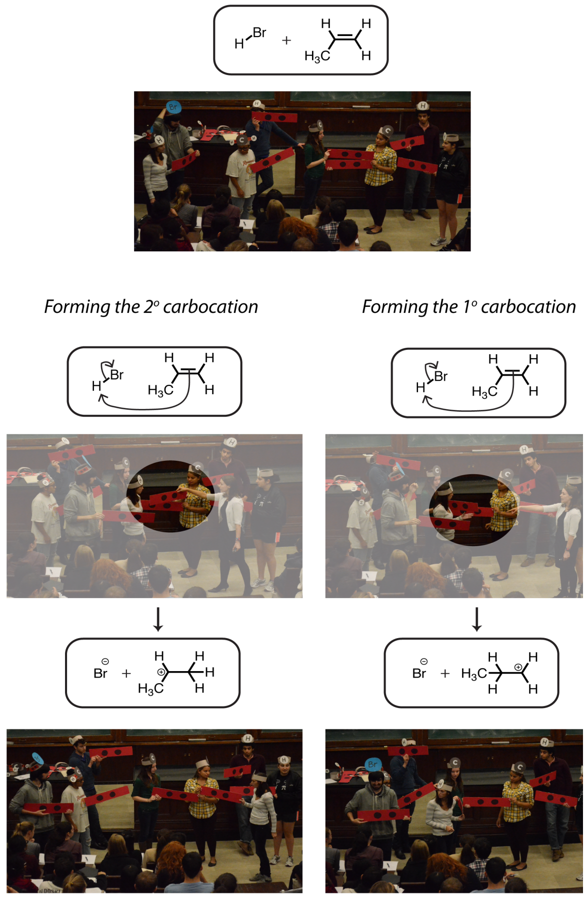

Figure 4: Using the demonstration to form both the Markovnikov and Anti-Markovnikov products in an electrophilic addition reaction

It is interesting to note that the curved arrow notation is identical for both first steps. The arrow from the double bond to the electrophile is the same, regardless of whether the more or less stable carbocation is formed. In contrast, in the demonstration the two options are visually distinct. Depending on which carbocation is formed, a different vinylic carbon lets go of his/her end of the bond. Another strength of Be-A-Bond is that the valency of the carbocation obvious in the demonstration; the carbocation has only three electron pairs surrounding it, thus making it clear to the students that this is an electron deficient site, and helping to cement the idea that an arrow must flow from an electron rich to electron poor region. To help explain why the secondary carbocation is more stable than the primary, alkyl groups can lean in to the carbocation, representing the alkyl inductive effect, again utilising the dynamic nature of the representation.

In addition to using the demonstration with class discussions, it was also used after a homework assignment to target student errors. Mechanistic mistakes that were seen in the homework were compiled into a powerpoint presentation (they were redrawn to anonymise the errors and emphasise that the purpose of the task was to improve the class's understanding rather than to point out individual weaknesses). These incorrect mechanisms were then acted out using the Be-A-Bond technique, and students discussed why these mechanisms were improbable. Often these mistakes involved arrows going in the wrong direction and students could immediately "see" that the electrons could not move in this way. Another common mistake was a five-bonded carbon. The demonstration clearly shows ten circles around a carbon, allowing students to easily determine that carbon has exceeded its possible valency.

Student Feedback

Although students were a little hesitant initially to put on the headbands and act out the mechanisms, by the end of the first class the students overwhelmingly stated that the activity was fun and engaging. One factor that helps to encourage participation is that the students forming the molecule are not in charge of what happens in the mechanism - they are instead guided by the class discussion. This helps to stop students feeling like they have been put on the spot. The demonstration takes some time for students to get used to, mostly in terms of how they need to hold and pass the electron cards, but after starting with simple molecules, the class responded well to acting out whole mechanisms. We were also initially worried that the structures of the molecules may be hard to see, but with the students standing on the taped shapes on the floor, this was not a problem. One of the main benefits that we noticed was that the demonstration reinforced the idea that mechanisms are sequential processes that happen over a period of time:

"I'd never really thought about why we need to draw them [mechanisms] out bit by bit before...now I have to think, what's going to happen first?"

Many students also appreciated the visualisation of the double bond opening, and how it could be attacked on either side. It was revealed through using the demonstration that a few students had not understood what the arrow starting at the double bond was representing, and they were simply drawing it from memory. Afterwards, some students said they now considered the double bond as like a door that could swing open on either side to bond to the electrophile.

Conclusion

The Be-A-Bond demonstration was developed as a novel means of explaining the movement of electrons, allowing students to explicitly watch "electron" flow, and follow the stages of a reaction. Since the demonstration is dynamic, multiple options can be acted out, allowing student misconceptions revealed both through class discussion and homework assignments to be directly targeted. In addition to electrophilic addition reactions as described here, the demonstration can be tuned for substitution and elimination reactions. Furthermore, organic chemistry teaching can often rely heavily on chalk and talk. Not only does Be-A-Bond reinforce mechanistic understanding, it acts as an entertaining, interactive and discursive tool for engaging students.

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□

Measuring the Concentration of Free Chlorine using a Smartphone

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A digital picture is a collection of boxes of different colours called pixels. Each colour of each pixel is a combination of Red, Green and Blue. The intensity of each colour red, green and blue is represented by a value between 0 and 256. The three colours are combined in different combinations (intensity) to create each colour represented in a picture.

Objective

The purpose of this experiment was to determine:

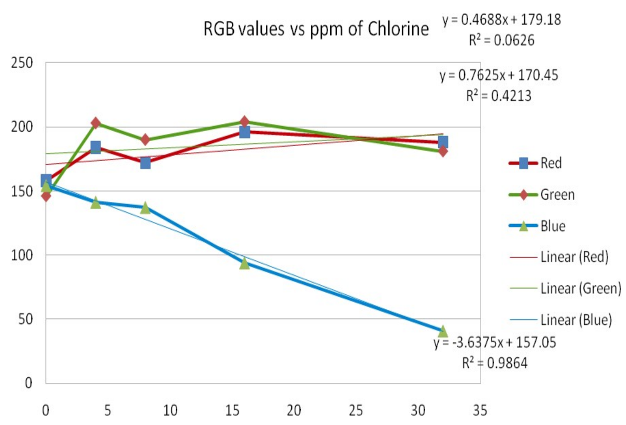
1. Whether the intensity of the Red, Green or Blue colour varies with the concentration of the free chorine.
2. Can a calibration model be built which can predict the concentration of the free chorine?

Procedure

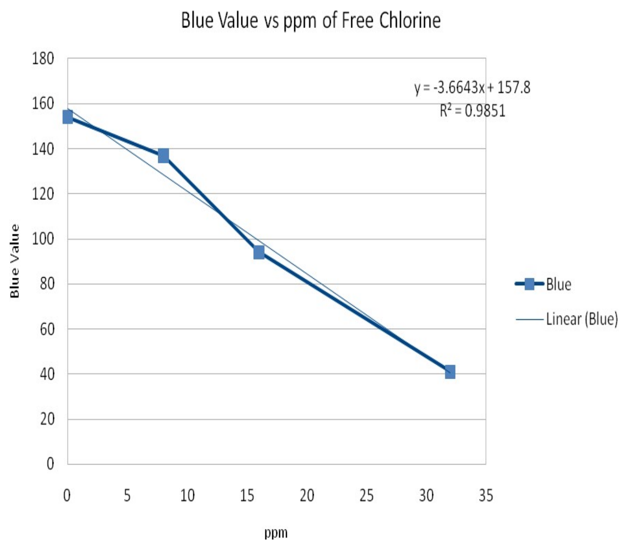
1. Prepare the standard solutions as per Understanding Chemistry by Jim McCarthy and Terence White.
2. A yellow Colour develops proportional to the concentration of free Chlorine.
3. Use colorpicker to determine the RGB values and record note readings
4. Plot RGB readings vs concentration.
5. Identify if the intensity of any colour that varies with the concentration of the free chorine.
6. Calculate the line of best fit to the colour that changes with the concentration of free Chlorine.
7. Get the concentration of unknown sample from graph.

Results

From the diagram it is clear that only the intensity of the blue colour changes in a linear fashion with the change in yellow solution of the calibration samples.



Therefore we can measure the intensity of the yellow I_2 in solution by tracking the intensity of the blue colour as determined by the colorpicker app. This is directly related to the concentration of the free chorine.



The calibration line was built with the following values. A trend line was added using Microsoft Excel. This line has a good fit (R^2= 0.98). We want a value of R^2 close to 1 or -1. We can test our calibration graph using the sample that was not used to build the calibration curve. This has a known free Chlorine concentration of 4ppm and a blue value of 141. We simply find where the blue value 141 intersects with the trend line to determine the amount of free chlorine. From the graph, **we estimate that the free chlorine is 4.6ppm**. From the dilution factor of fifty (1cm^3 of diluted bleach was made up to 50cm^3) we estimate that the diluted bleach had a free Chorine of 230 ppm. The concentrated bleach has a free chlorine content of 23,000 ppm. This method gives up a good rough estimate of the free chlorine in the diluted beach sample. In an exam situation, due to the different methods you can use determine the free chlorine, they will probably give you the free chlorine content and ask you to convert to g/l etc.

To improve this experiment:

1. Identify a free app that can measure RGB colours in photos. Therefore it would be possible to take a photo of all the samples under the same lighting, distance, and angle. This would eliminate this variability from the experiment.

2. Take RGB values in triplicates and average the values.
3. Ensure the distance of the smartphone to the sample is kept at a constant value and angle.
4.
5. Use more samples of different concentration when building the calibration model.

Conclusions

1. The intensity of the Red and Green colour **does not vary with the concentration** of the free chorine.

2. The intensity of the Blue colour **does vary with the concentration** of the free Chlorine.

3. A calibration model was built which predicted the concentration of free Chlorine in the unknown solution.

4. The calibration model predicted a free chlorine value of 4.6 ppm. This compares favourably with the known concentration of the free Chlorine which was 4.0 ppm

□

Michael Faraday and education

“There is in the chemist a form of thought by which all ideas become visible in the mind as strains of an imagined piece of music. This form of thought is developed in Faraday in the highest degree, whence it arises that to one who is not acquainted with this method of thinking, his scientific works seem barren and dry, and merely a series of researches strung together, while his oral discourse when he teaches or explains is intellectual, elegant, and of wonderful clearness.”
Justus von Liebig

“If the term education may be understood in so large a sense as to include all that belongs to the improvement of the mind, either by the acquisition of the knowledge of others or by increase of it through its own exertions, we learn by them what is the kind of education science offers to man. It teaches us to be neglectful of nothing — not to despise the small beginnings, for they precede of necessity all great things in the knowledge of science, either pure or applied.”
Michael Faraday
'Science as a Branch of Education', lecture to the Royal Institution, 11 Jun 1858. Reprinted in *The Mechanics Magazine* (1858), **49**, 11.

It is on record that when a young aspirant asked Faraday the secret of his success as a scientific investigator, he replied, 'The secret is comprised in three words— Work, Finish, Publish.'
Michael Faraday

J. R. Gladstone, *Michael Faraday* (1872), 122.

Innovating chemistry learning with PREZI

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This article discusses the potential use of the presentation software PREZI for the creation of student-centered learning environments. The examples discussed focus learning about the particulate nature of matter and career orientation in chemistry education. The discussion shows that PREZI can be considered a valuable tool for the development of modern and dynamic multimedia learning environments that can be designed by teachers even if they do not possess advanced skills in computer programming.

1. Introduction

Continuous development in ICT causes permanent change in ways of presenting content and availability of software for structuring and presenting information. Where presentation of content in the past was predominantly static, with recent development of ICT it became more and more dynamic in use and appearance both in the Internet und any other kind of digital devices. This development goes hand in hand with a growing availability of smartphones and tablet PCs that changed the styles and experiences running current ICT devices. The use of new ICT gadgets is increasingly detaching from traditional input by keyboard and mouse towards interactive screens and interfaces reacting to movements of the hands or the body.

ICT learning environments for science education need to keep pace with general developments in ICT. This is necessary for not losing perception of modern appearance of science education learning environments based on ICT among the learners. Since educational software for science education is not always available or cheap to obtain this point of view raises the question of how learning environments for science education can be designed by teachers by themselves having a modern appearance without by the same time needing the teachers to have professional computer programming skills.

One answer might be the use of PREZI. With PREZI even novice computer users can design dynamic learning environments without advanced programming skills. In this article, the creation of learning environments using PREZI is described and illustrated by two examples from chemistry curriculum innovation in Germany. The examples deal with learning about the particulate nature of matter and career orientation in chemistry education.

2. Design learning environments with PREZI

PREZI is software developed in 2007 for presentations. It was presented to the public in 2009 by the Hungarian artist Adam Somlai-Fischer and the computer scientist Peter Halacsy. PREZI can be considered as being a more elaborated and interactive version of traditional presentation software, like Microsoft PowerPoint. Different to PowerPoint, PREZI allows presenting information in a better networked way under inclusion of a more dynamic appearance.

The idea of PREZI is a big desktop. On the desktop different slides can be generated and filled with information. Every slide allows for integrating text, pictures, videos or downloads that directly can be accessed from the PREZI slides. The slides can be arranged quite freely on the desktop, nevertheless, they also can be connected to a specific sequence of appearance. While organizing the slides on the desktop they can be addicted to different layers. That means that slides not only can be arranged in a specific sequence the author can also decide where information needs to be deepened by using the different layers below any of the slides. Thus, PREZI allows a three-dimensional structuring of information. In use PREZI technology allows for presenting information in a specific order or sequence but nevertheless zooming into the information in as many points the organizer of the information prepared for. In use it is possible to visit the slides, and thus the information, following a pathway prescribed by the author. However, it is also possible to flip from one point on the desktop to another as well as to decide on which point a deeper contention with the corresponding aspect is considered to be useful.

The user can decide to follow a given path, to leave it or to come back to it at any time.
PREZI creates a dynamic impression of its use because the different slides and media are approached in a way as if the user would drive or walk through the information. This impression is in line with experiences today's students have using their smartphones and it differs much from more static impressions in traditional technologies, like PowerPoint or HTML-based environments often have. In using PREZI, either with the PREZI software or as a stand-alone tool in any Internet browser, we find a highly networked, dynamic and multimedia supported tool for presenting information. The use on tablet computers is also possible like in smartphones. However, for iPads the free PREZI app is needed.

3. Examples from curriculum innovation in German chemistry teaching

From the year 1999 a group of teachers and chemistry educators started the project "New ways towards the particle concept" (Eilks, 2013). The project aimed at organizing alternative approaches towards the sub-micro level in chemistry education under thorough consideration of empirical research findings on students' alternative conceptions and learning difficulties. The group tried to develop a coherent curriculum structure without permanent change between historical models for particles, atomic structure and bonding theory (Eilks, 2013). This was operated by using different textual approaches (e.g. Eilks, Möllering & Ralle, 2004), student active and cooperative forms of learning (e.g. Eilks, 2005), or the use of modern ICT.

In a period of about five years the project group designed a wide variety of lessons, corresponding teaching and learning materials and published their ideas in numerous articles. An overview is given by (Eilks, 2013). One idea was to approach the particle level based on the scanning tunneling microscopy (STM). This step was suggested to be implemented by a multimedia learning environment on the basis of HTML (Eilks *et al.,* 2003). This learning environment, written in the year 1999, was considered at the time of its creation being quite modern. Videos were integrated and animated representations of the particle level were made available to learners via animated GIF pictures. In the following a whole set of HTML-based modules was developed, e.g. states of matter change, dissolution, diffusion and osmosis, chemical reactions, up to atomic structure, the periodic system of the elements and bonding theory.

All the original learning environments were based on HTML. The content was structured by single pages, which were connected to each other through various links. Images, animations and videos were embedded. However, technical progress over the coming years led to increasing functional limitations, since players for some media items were no longer available. Additionally the chosen layout corresponded less and less to the ICT experiences of the learners and was perceived by them to be old-fashioned. For the time of creation the design was timely and innovative, now this learning environment is hopelessly outdated and thus perceived as unattractive in the eyes of the learners.

PREZI offered a solution for the dilemma that normally a complete new software development is needed without often having sponsor or sufficient resources for it. Without any redeveloping of content, pictures, videos and animations, based on PREZI the learning environments have now been completely redesigned. The original content and media elements were transferred to PREZI. The original connections were used to keep the learning pathway, however, presentation with PREZI allows for approaching every part of the information also directly. Figure 1 shows a screenshot with the newly designed learning environment, based on the original design for scanning tunneling microscopy. In contrast to the first learning environment, all the contents and sections are recognizable at first glance. So it is immediately apparent that the topic is divided into different sub chapters that can be dealt with one after the other or in any sequence the user wishes to.

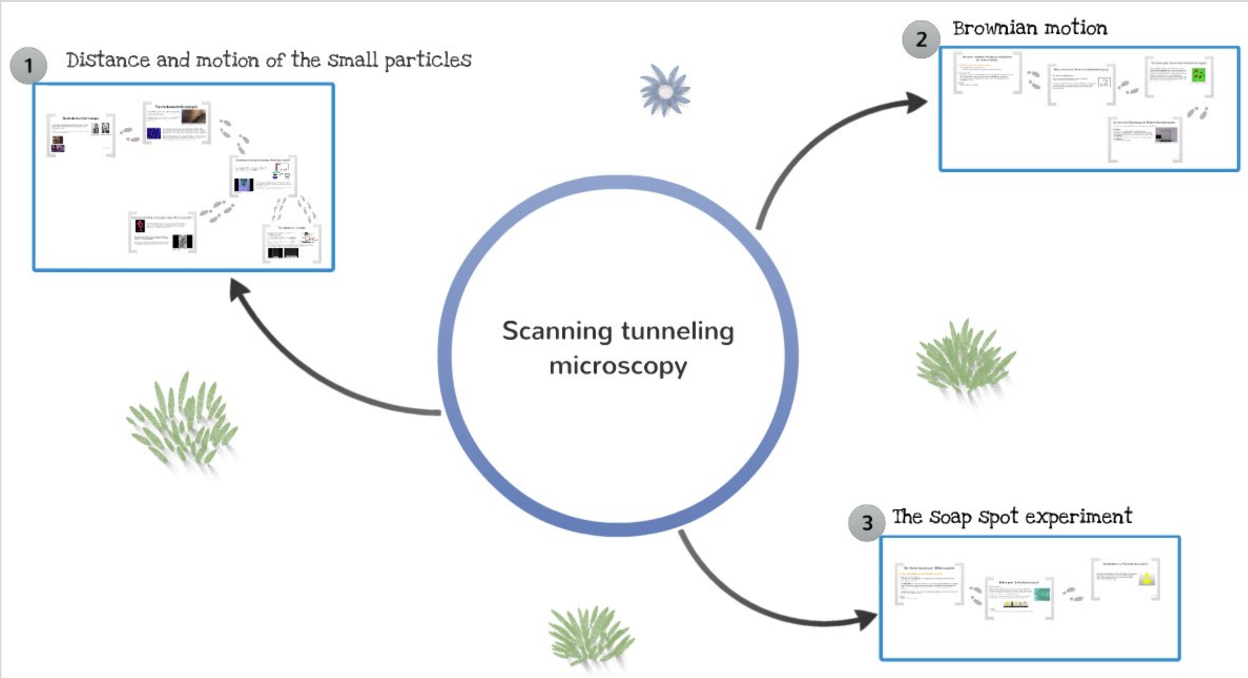

Figure 1: Learning environment for scanning tunneling microscopy (translated).

Navigation through PREZI environments can be done in many different ways. By the arrow keys at the bottom the proposed pathway can be followed forth and back. But, the user can also decide to begin in any subchapter or by going directly to any sub-slide in each of the sub-chapters. Zooming in leads to more detail, zooming out gives immediately the overview how the learning content is related to one another. On their way of learning the students may encounter crossroads, which include access to additional content. For example, in the STM module the students might have studied the function of a STM and can then decide whether to continue or visiting an extra loop about a model of STM (Figure 2).

Each slide contains text, images, videos and/or animations. The advantage is that the videos and animations are embedded directly into the medium and can be viewed without any additional player or plug-in. Also tasks for self-assessment can be included that can also be differentiated to various levels of complexity. The learners themselves decide which level they want to try. Figure 3 shows a differentiated task: The students have studied the Brownian motion on the example of liquids and their knowledge should now be applied to smoke. The task is the same in all three levels, but supportive information is graded. In Level 1 sentences have to be organized to a sound sequence to explain a figure, in Level 2 keywords are given as help to create the text, in Level 3 learners need to describe the figure freely.

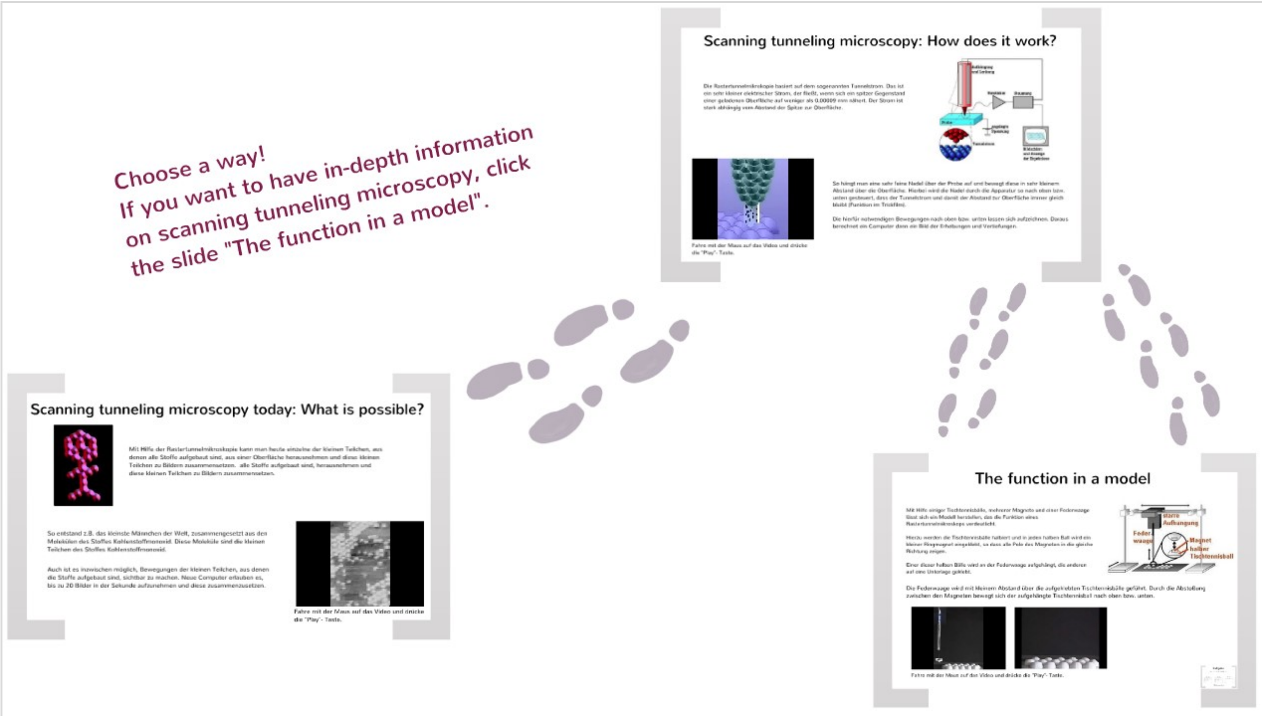

Figure 2: The students can decide at that point for deepening (translated).

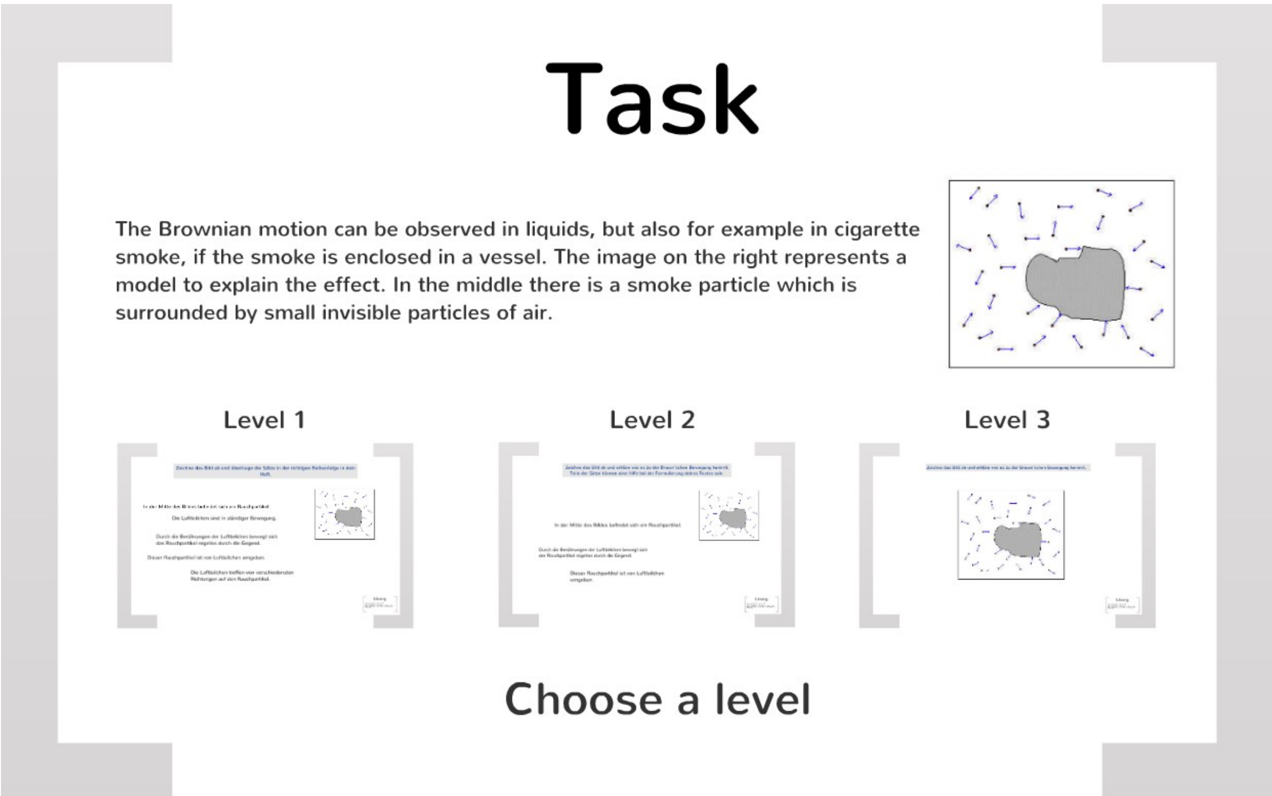

Figure 3: A differentiating task with three levels of difficulty (translated).

In a second example PREZI was used to create an interactive mind-map for career orientation in chemistry education. At the center of the PREZI mind-map (Figure 4) is chemistry that branches into different topics typical for the German junior high school curriculum. From each of the curriculum topics the student can move to certain jobs that are related to the corresponding content. The professions are presented in a slide. The slide contains a photo, a brief description about the job and explains the reference to chemistry. By zooming into the PREZI slides the students can learn about necessary qualifications, requirements of training for the job, and potential future salaries (Figure 5.) The slides also include video links to the respective profession. The deeper the students zoom in the more details they get. However with the home symbol the students can zoom out from any point and start a new search again. In contrast to the learning environment on the particle concept in this lesson plan PREZI is used as an interactive mind map without any prescribed learning pathway. This approach even more uses the idea of PREZI to arrange content freely on a large work surface with the chance to network any information to another and to various levels of detailedness behind.

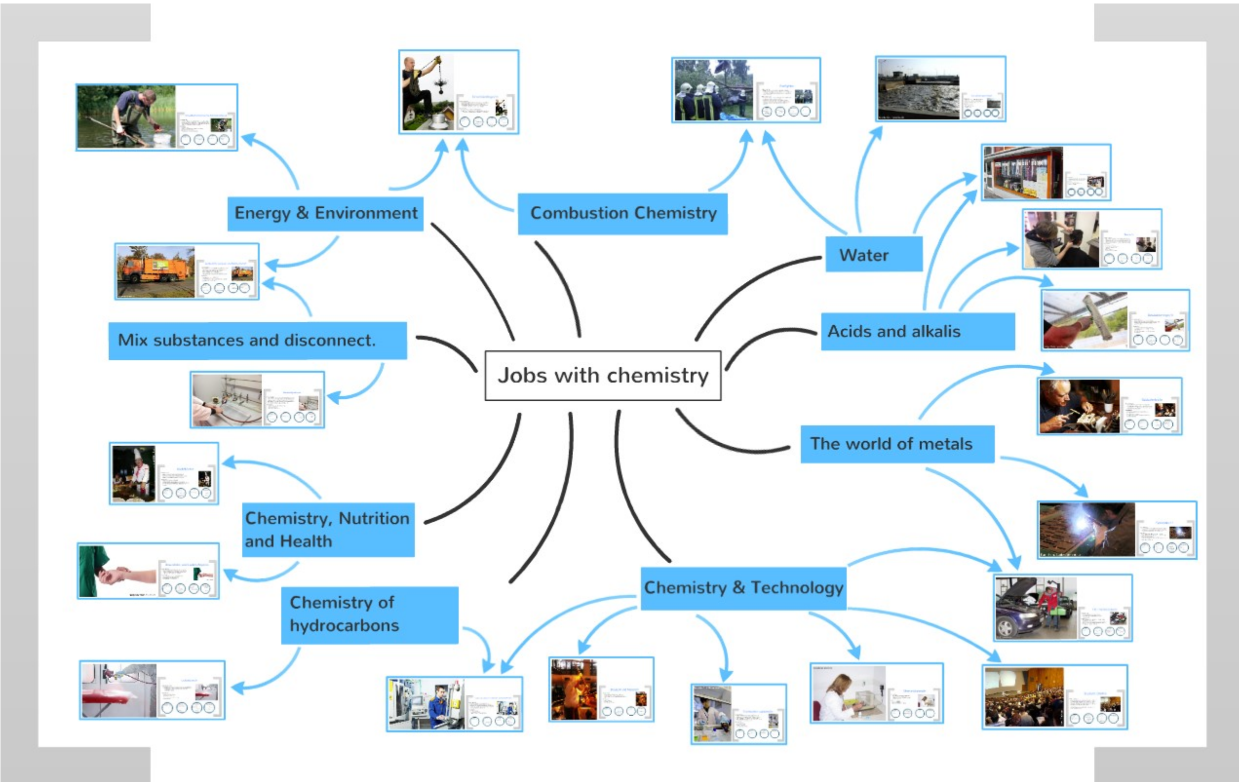

Figure 4: Interactive PREZI mind map to occupations with chemical reference (translated).

The work on the computer can be assessed by a game. The students will receive tickets to the featured jobs. One of the jobs from the PREZI mind map is given on each card. A student shall present the respective profession to other players. He has to explain the job in terms of the game taboo, five terms on the card may not be used in the declaration. One player from the group might act as a referee. However, there are many other potential scenarios for using the PREZI in class and beyond.

Figure 5: Information element to the occupation "firefighter" (translated).

4. Experiences and conclusion

The use of PREZI as a tool to create multimedia learning environments for science learning in schools got very positive responses among students. In their feedback, the students considered the use and operation of PREZI intuitive and easy. Appearance was recognized being modern and the use dynamic. A majority of students indicated that they liked the mix of animations, videos, images and texts as it was operated by PREZI. From the students PREZI supports self-directed and explorative learning. They appreciated the opportunity to work at their own pace, to find their own path through the content and to deal with the contents individually or in small groups. This was the case for both of the above mentioned examples as well as for other classroom interventions based on PREZI, e.g. on bionics (Krause, Ostersehlt & Eilks, 2015) or a virtual tour for visiting hubs of industry and SMEs operating chemistry related businesses.

PREZI was considered by teachers and students to be an interesting pedagogical enrichment for science classes. PREZI allows for a new way to access science content in a more networked, layered and interactive way without the need that the organizer of the information possesses professional computer programming skills. PREZI provides a very modern and contemporary appearance of information presentation, which is clearly superior to traditional presentation tools or classical HTML, but can still be created and used with reasonable effort.

This paper presented two initial ideas about how to use PREZI for creating interactive presentations of information for autonomous and self-directed learning. Embedded in more complex and elaborated learning environments connection to practical work and assessment can be made to guide students to whole projects of inquiry learning and operating complete lesson plans (Krause et al., 2015).

The learning environments are available for free at:
www.chemiedidaktik.uni-bremen.de/multimedia.

Even although the learning environments are in German language the examples might serve also non-German speaking teachers as a potential inspiration to create own learning environments with similar structures and appearance.

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Using Tarsia Puzzles to teach Science

Michelle Downes

Tarsia is a software you can download to your computer and use to make some triangular, hexagonal or rectangular puzzles to use as an assessment tool in the classroom. The word itself comes from the Italian word *intarsio* which is the name given to a decorative or pictorial mosaic of inlaid wood. The free software can be downloaded from: http://www.mmlsoft.com/index.php/products/tarsia.

Originally created for maths, it can be used across various subject areas. I have used it for science by including important definitions and key words at the end of a chapter. You simply type in your words and definitions, chose a particular puzzle and it will make it for you instantly! Pupils must match the word to the definition of another triangle and continue down the triangle. I usually give the pupils the first triangle at the top of the triangle.

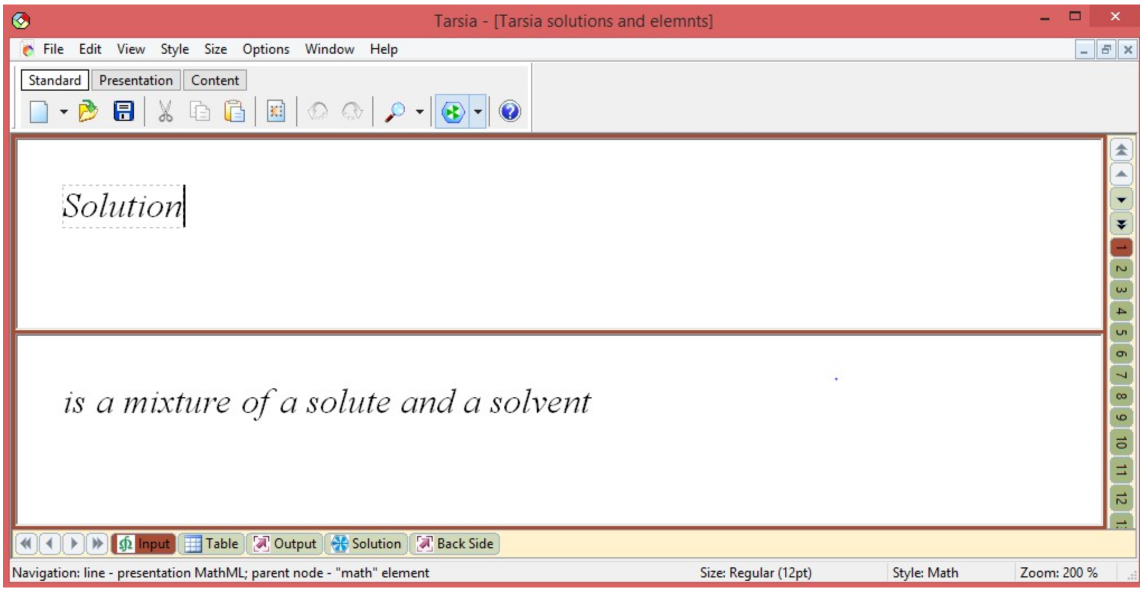

Figure 1: The input view on the website

The image above is the input view, where you type in the information you want for the activity.

Then you can click output and this is what you will print and cut up for the pupils to put together.

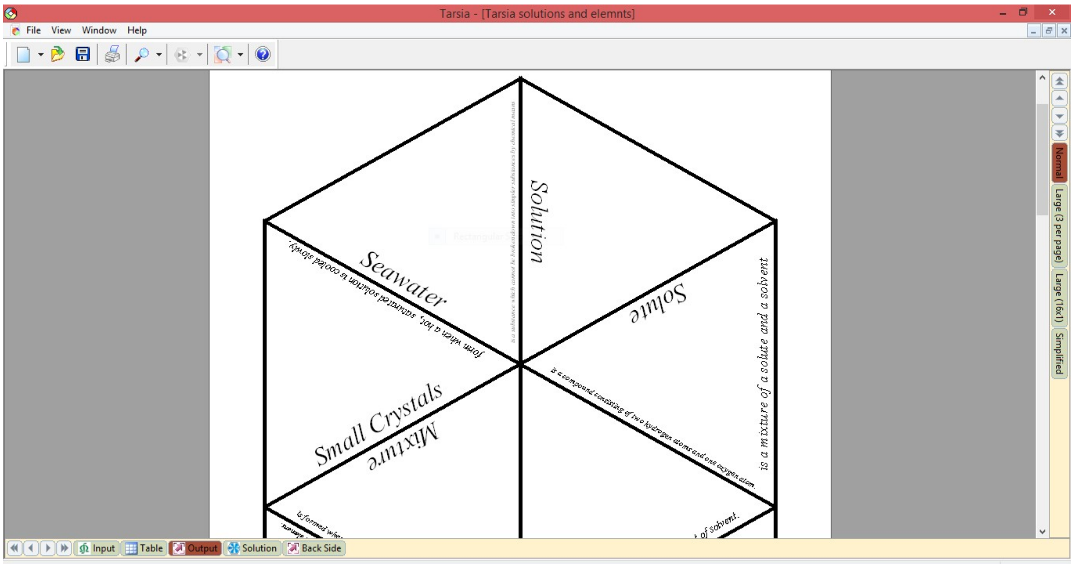

Figure 2 A hexagonal puzzle on solutions

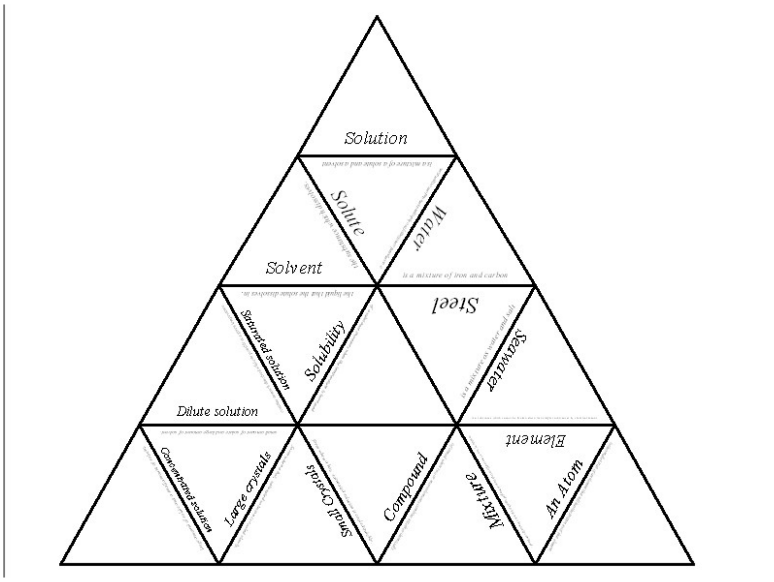

Figure 3: A triangular puzzle about solutions

It also gives you the solution which you can use yourself or give to the pupils after they have attempted the puzzle.

I have found this assessment activity very useful as it keeps the pupils engaged as they want to finish the puzzle first and want to get it right. It applies what they have learned in a particular topic and if they get one part wrong they won't be able to finish their puzzle which makes them work hard to get it right. I have used this for first years and second years and they have all loved it and want to take pictures of their finished puzzle to help them learn it. Also once you have it done once you can reuse the resource over and over again. I have three made for different topics and I plan on using them again to conclude a particular topic and have given some to my cooperating teachers as they thought they were a handy tool for differentiation in the classroom.

Michelle Downes is a final year science education student at the University of Limerick and used Tarsia on her final teaching practice in Autumn 2014.

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From Applications to Atoms: Teaching Chemistry in Context

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Introduction

There is much anecdotal evidence to suggest that Chemistry is avoided by second-level and third-level learners due to its 'difficult' nature. There is evidence from those teaching and learning Chemistry at both second-level and third-level that it is considered a difficult subject (O' Dwyer *et.*al 2011, O' Dwyer & Childs 2012). In a survey of 334 Irish Science teachers, 40% agreed that pupils' negative attitudes to the physical sciences may be driven by a perception of their difficulty (ASTI, 2009) and this a barrier to the uptake of Chemistry for the Leaving Certificate. 50% of teachers surveyed felt pupils perceived the subject as too theoretical and removed from everyday life, and 41% said pupils are unaware of career options in Chemistry (ASTI, 2009). Chemistry is often viewed as an unattractive and difficult subject in comparison to Geography, Biology, Business, Art and French. Anecdotal evidence suggests that the latter subjects are more popular because pupils do not 'fear' them. These subjects are often taught in a more context-based fashion, which interests pupils and facilitates understanding. In comparison to Chemistry, these subjects are not as demanding in terms of pupil time and effort (Engineers Ireland, 2010).

In considering how best to teach Chemistry, we need to consider how learners perceive, process and store information. Many learners cannot see any connection between what they learn in the Chemistry classroom or do in the laboratory with their everyday lives. Learners are often better able to see the relevance of Biology to their own lives. It is often more challenging for teachers to make Chemistry relevant.

The International Maths and Science Study (TIMMS) and the Programme for International Student Assessment (PISA) have found that every learner constructs their own knowledge. The Information Processing Model (Johnstone, 1997) shown in Figure 1 provides a summary of how learners perceive, understand and learn information.

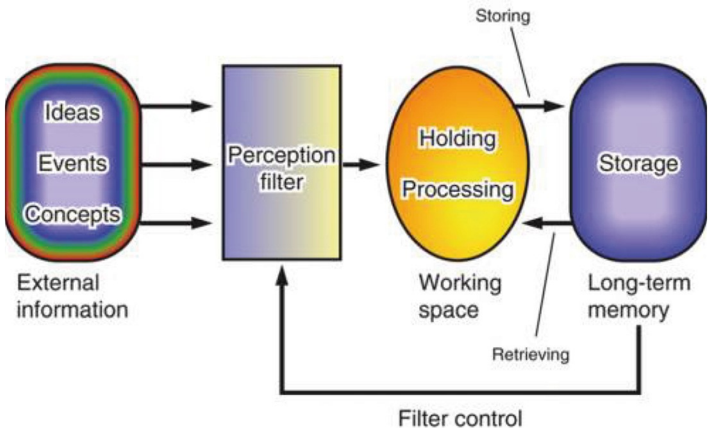

Figure 1 The Information Processing Model [Johnstone 1997)

Effective teaching needs to be able to activate and stimulate the learners' perception filter. Knowledge must be based on the learners' perceptions of the real world for constructive understanding (Bodner 1986). The learner can only perceive what is familiar to them, so if a new concept is rejected at this stage, it may never pass through the Working Space to Long Term Memory and understanding.

The perception of new information depends on what the learner already knows (Ausubel 1968). Beginning with a topic that the learners already find interesting ensures there is an anchor in the learners' Long Term Memory for attaching this new knowledge. Pupils need to be able to connect the new information presented and their prior knowledge. If the Long Term Memory has familiar anchors for such topics, the Working Memory Space is less likely to become overloaded when such applications are used to introduce a topic or lesson. Many curricula teach the fundamentals, and applications are an after-thought. An applications-led approach makes it easier for learners to perceive new topics and make links with their previous knowledge and information. Such an approach of introducing new concepts and ideas through contexts and applications that are familiar to the learners, facilitates their ability to link these with previous knowledge, and thus develop clear frameworks for understanding in their Long Term Memory.

Applications and contexts

Teaching Chemistry should be determined by the learners' needs and what is perceived by them to be relevant to their personal context and lifestyle (Reid 2009). Applications-led and context-based curricula base their content and in particular their introduction of new topics on real examples and situations relevant to the learners' lives. They help the learner to make sense of the world.

In an applications-led curriculum, the destination is the same as the traditional curriculum but the route to the destination is totally different. With this approach, a problem depending on the application of Chemistry can be the starting point. In a context-led approach, learners are introduced to Chemistry through learning how experts, chemists and industrialists use Chemistry in today's world. Chemistry taught in this manner is determined by life and the psychology of the learner, rather than the traditional logic of the discipline of the subject.

Embedding contexts in the Curriculum

"*It's not the topics that are being taught that makes Chemistry dull, but the way that they are taught"*
(Bodner, 1992, p. 187)

Poorly designed Chemistry courses offer no relationship with the real world (Bodner 1992). Reid (2000) has also criticised how the applications and contextual examples are added in towards the end of a chapter or topic in traditional Chemistry curricula. Previous revisions of the Irish Chemistry syllabi and even recent syllabi continue to teach the fundamentals that have little relevance to the lives of the learners.

However, it is possible to approach a topic from its application, leading to an explanation, and then working onwards towards the fundamental scientific concept. Introducing content that has social meaning and value to the learners assists their appreciation of the wonder and excitement of Science. Too often, the boring fundamental concepts can take up so much time, and very little is left for the excitement of contemporary Science. In applications-led Chemistry, a real-life problem could be the starting point. This makes for a very interesting set induction to a lesson. The traditional teaching of the chemical concepts can then follow through a guided inquiry approach. This context-approach is illustrated in Figure 2. The Triangle of Chemistry (Johnstone 2006) is at the centre of Figure 2. This triangle illustrates the multi-level thinking required in learning Chemistry. *Macro* represents the marcoscopic dimension of Chemistry (i.e. what we can see, touch and smell), *sub-micro* represents the sub-microscopic dimensions of Chemistry (i.e. the molecules and atoms that make up the macroscopic materials) and *symbolic* denotes the representational dimension of the subject (i.e. symbols, equations and formulae). By starting with the macroscopic dimension as illustrated by the arrow on the right in Figure 2, a context-based approach involves beginning with the applications and contexts and then using these to move towards an understanding of properties and reactions etc. The arrow on the left in Figure 2 is representative of many common text-book based approaches.

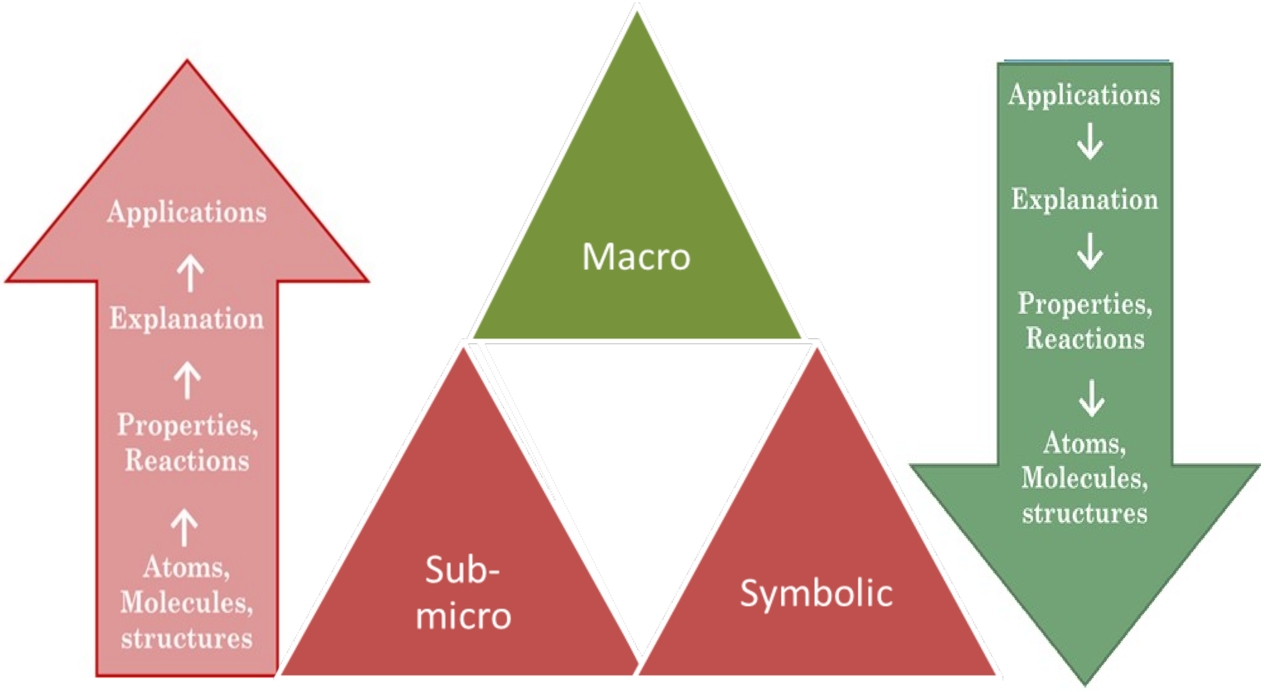

Figure 2. A context-based approach:From applications to atoms

Examples of Successful Context-based curricula

Salters Advanced Chemistry (SAC)

The SAC course is a two-year course which leads to the A- Level (Advanced Level) examination (age 18) in the UK. This course and examination has been nationally validated and qualifies candidates for third-level courses. The two-year course is divided into 14 teaching units. Each unit focuses on modern applications of Chemistry and important chemical principles are only introduced when they help learners understand the application. Each unit is made up of three parts: story, chemical concepts and activities (Burton *et al.* 2000). This course is structured to unfold as a series of 'Chemical stories' as illustrated in storylines. The SAC course uses contextual examples to teach chemical concepts.

SAC has the following outcomes:

- To show the ways Chemistry is used in the world and in the work that chemists do;
- To broaden the appeal of Chemistry by showing how it relates to people's lives;
- To broaden the range of teaching and learning activities used; and
- To provide a rigorous treatment of Chemistry to stimulate and challenge a wider range of learners, laying the foundations for future studies yet providing a satisfying course for those who will take the study of Chemistry no further.
- (Bennett and Lubben 2006)

ChemCom

'*ChemCom: Chemistry in the Community*' is an example of a US context-based initiative. This was developed for second-level (high) schools by the American Chemical Society (ACS). From this initiative, a similar curriculum was developed at third-level in the US, *Chemistry in Context* (Schwartz 2006), where "*students are exposed to the inquiring, experimental, and often tentative nature of Science*" (Schwartz, 2006, p. 983). The goals of this context-based programme are:

- To motivate learners to learn Chemistry and understand its societal significance.
- To teach them fundamental concepts of Chemistry.
- To lead them to discover the theoretical and practical significance of Chemistry.

- To equip them to locate information and address technical issues.
- To develop analytical skills, critical judgement, and the ability to assess risks and benefits and evaluate information.
- To provide hands-on experience with chemical phenomena.

(Schwartz 2006)

Chemistry in the NEWS

Another US initiative relating Chemistry to the learners' lives is '*CHEMISTRY is in the NEWS*'. This programme enables learners to see the connections, to understand Chemistry and its role in society, and to use this knowledge in the evaluation and in making judgements about choices presented in everyday life (Glaser 2004). This programme has a particular focus on Organic Chemistry.

Chemie in Kontext

'*Chemie im Kontext' (ChiK)* is a context-based Chemistry curriculum which has been developed in Germany by Chemistry teachers, school authorities and Science educators for all grades and types of schools. *ChiK* links three conceptual principles with a four phase lesson structure. The three contextual principles are:

- Context orientation
- Cross-linking knowledge to basic concepts
- Methodological diversity

Context orientation refers to the introduction of topics using personally or socially relevant topics e.g. Hydrogen-fuel call cars. One of the units named 'Plastic in cars' is an example of how Organic Chemistry concepts can be presented in a contextual manner for the learner. The cross-linking of knowledge to basic concepts offers a structure to the learners for the systematic and cumulative development of knowledge and understanding. Finally methodological diversity refers to the more active role of the learners.

The four phases in the lessons are:

1. Contact Phase- learners become familiar with the new context.
2. Curiosity and Planning Phase- learners participate in planning and structuring future work.
3. Elaboration Phase – Independent learner activity supported by the teacher as little as possible.
4. Final Phase – freshly acquired chemical subject knowledge is extracted from the original context and applied to new contexts.

(Parchmann *et al.* 2006)

Organic Chemistry in Action!

Organic Chemistry in Action! (OCIA!) has been introduced and outlined in a previous issue of *Chemistry in Action!* (Issue 95) (O'Dwyer & Childs, 2011). Organic Chemistry provides a useful introduction to other Chemistry topics (Reid 2000), and itself provides many relevant application areas.*OCIA!* is an evidence-based resource designed to facilitate the teaching and learning of second-level and introductory third-level Organic Chemistry. This programme includes the content of most of sections 5 and 7 of the current Leaving Certificate Chemistry syllabus (DES, 1999). A number of key design criteria were incorporated into the development of the programme to make the Chemistry more accessible and more relevant to the learners' own lives and experiences. One of these was a focus on chemistry in context and everyday applications. Chemistry Chronicles (Figure 3) were two-page 'magazine-type' articles, which included applications and uses of the Organic Chemistry principles from the syllabus. Interesting Insights were also included throughout the lessons: these presented interesting facts, motivating questions and problems. Video clips of real-life applications and laboratory investigations using everyday materials were also effective in enhancing the pupils' experience and understanding of Organic Chemistry.

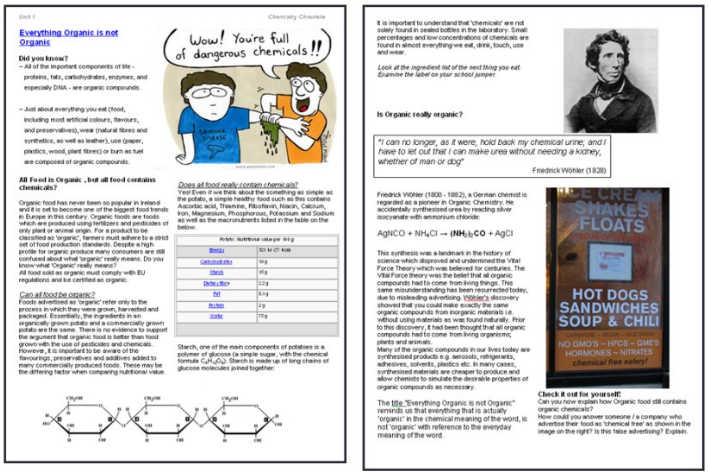

Figure 3. Example of a two-page Chemistry Chronicle – Everything Organic is not Organic!

Contexts

It is important that the context used is relevant to the learners. Different applications will be more appropriate for different societies and cultures:

- School setting (e.g. rural, urban)
- Pupil interests (e.g. sport, fashion)
- Gender
- Local Industry
- Local heritage and culture

Reid (2000) and De Jong (2007) have outlined domains describing the origin of contexts for teaching Chemistry that can improve the learners' attitudes if incorporated into teaching. These are presented along with examples in Table 1.

Table 1. Possible contextual domains and examples.

Domain	Examples
Personal	• Cosmetics • Drugs • Cleaning agents • Food
Social	• Fuels • Economic implications • Moral issues
Professional practice	• Chemical engineers • Industry • Medicine
Scientific & technological	• Historical models • Theories

Conclusion

From the examples illustrated in this short review, it is evident that there is much potential and benefits in including contextual links and real-life applications in our Chemistry lessons. It is important the contexts used are relevant and engaging for the specific cohort of learners.

One criticism of context-based learning is that the concepts may be so closely linked to the issues used to introduce them, that learners do not acquire the ability to generalise and transfer those ideas (Schwartz 2006). While there is some evidence that context-based approaches are effective in motivating learners and enhancing their attitudes to Science, there is also some evidence that such approaches can adversely affect learners' understanding of scientific ideas (DeJong 2007, Ramsden 1997). For this reason, it is also important that the learners recognise that the content and concepts learned are generalisable. Appropriate extension and evaluation activities are important for this purpose. Finally, it is important to acknowledge the factors contributing to the difficulties of learning Chemistry for novice learners are multi-faceted. The context-based approach is useful to enhance learners' interest in the subject and to facilitate understanding. However, it is not a uniform solution to learners' difficulties and may be most effective in tangent with other methodological approaches e.g. Inquiry Based Learning, Problem-Based Learning, group work etc.

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*Dr Anne O'Dwyer did her PhD in chemical education at the University of Limerick under the supervision of Dr Peter Childs. For 2 years she has been working as a Postdoctoral Fellow at the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL), now renamed EPI*STEM, National Centre for STEM Education. In August he takes up a post as lecturer in Science Education at Mary Immaculate College, Limerick.*

Diary

2015

1st International Baltic Symposium on Science and Technology Education (BalticSTE2015)
15-18 June
Siauliai, Lithuania

9th Chemistry Demonstration Workshop
15-19 June
Sarah.hayes@ul.ie

Science on Stage
17 – 19 June
London, U.K.
http://www.science-on-stage.eu/page/display/4/14/0/festival-2015

6th Eurovariety 2015
29 June – 1 July
Tartu, Estonia
https://sisu.ut.ee/eurovariety/avaleht

41st ChemEd
28 July – 1 August
Kennesaw, Georgia, USA
http://ccpe.kennesaw.edu/chemed/

Variety in Chemistry Education (ViCE) and the Physics Higher Education Conference (PHEC)
20-21 August
University of Nottingham,

11th ESERA
Science Education Research: engaging learners for a sustainable future
31 August – 4 September
Helsinki, Finland
www.esera2015.org

45th IUPAC World Chemistry Congress
9 - 14 August
Busan, S. Korea (KR)

ChemEd-Ireland
17 October
UCC, Cork
d.kennedy@ucc.ie

If you know of any relevant conferences or events of interest to chemistry teachers, please send in details to:
peter.childs@ul.ie

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Chain Reaction: Promoting a Sustainable Approach to the use of Scientific Inquiry in the Chemistry Classroom

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Introduction

Chain Reaction: A Sustainable Approach to Inquiry Based Science Education (IBSE) is a European (FP7) funded project focused on facilitating the professional development of teachers towards the practice of scientific inquiry in the classroom. Twelve partner countries from across Europe are involved with EPI*STEM located within the University of Limerick serving as the Irish partner in the project. The project runs from 2013-2016 and within this space of time teachers from across Ireland (10 each year) will engage in professional development through a series of dedicated workshops and support in the classroom by other team members within the project.

The Focus of Chain Reaction: Professional Learning Community

In Ireland the focus was to establish a Professional Learning Community (PLC) where the teachers are scaffolded in their own professional development. Previous attempts to develop PLCs have focused on typecasting teachers as *"passive consumers of pre-packaged knowledge"* (Lieberman and Woods 2002, p.316) instead of being active agents in the development of their knowledge base for teaching. Teacher educators from within the University of Limerick, pre-service teachers and practicing teachers and scientists also facilitate the project teachers by offering them support initially through dedicated workshops and then by supporting them within the classroom setting. The practicing scientists serve as role models. These role models visit schools and discuss their research with the aim of showcasing how science is approached in the real world.

Pupil Research Briefs

At the first workshop, teachers are introduced to a selection of Pupil Research Briefs (PRBs) which serve as a resource to engage in exciting inquiry activities in the classroom. Each PRB offers a practical problem which can be solved through the use of inquiry based methods. They cover topics from space science to environmental education.

The PRBs are available and free to access on the Chain Reaction project website: http://www.chreact.eu/ They can be modified over the lifetime of the project in response to new developments in national curriculum and the reaction from participating teachers. These PRBs are being used by all partner countries however a number of briefs related to the Irish science syllabi are currently being trialled and adapted for later dissemination. The PRBs are being developed on a number of topics in chemistry such as solubility, acids and bases, organic chemistry, chemical equilibrium and redox reactions.

Once teachers are confident in the inquiry process, they will be asked to either adapt the exemplar PRBs to their context or develop their own to be tried out in the classroom setting with a particular class group.

Some of the PRBs focus on the investigative, experimental feature of scientific inquiry. However inquiry can be simply a paper and pencil exercise therefore a number of PRBs focus on this and provide teachers with activities centred on students analysing data and drawing conclusions.
During recruitment of the role models, the aim is to choose a scientist engaging in research similar to the PRB topic that the students would have carried out.

National Conference

Once the PRB classes and role model visits are carried out, the year culminates in students developing posters which they subsequently showcase at a *National Express Yourself Conference* held each year at the University of Limerick. One group is chosen to represent Ireland at *the International Express Yourself Conference* which in year one was held in Sheffield, year two will be held in Heidelberg and year three will be held in Jordan. Ultimately the National Conference is a celebration of the students work and acknowledgement of the learning they have experienced through their involvement in the project.

Teachers' Responses

Teachers from year one of the project have shared how involvement in this project has developed their confidence, awareness and practice of inquiry based strategies in the classroom. This is echoed in one particular teacher's response *"As a teacher involved in chain reaction, I can honestly say it has been one of the most rewarding experiences of my career. The collegiality of our learning community was a joy and the support from the UL team was exceptional. It was great to have the space and freedom to construct my own understanding of the nature of inquiry with my students and the teachers involved in the project. The space to experience productive failure, to try new ideas and to test my own assumptions with new classroom practices and reflection was a refreshing escape from the everyday confines of the science syllabus.*

This teacher places particular emphasis on the importance of working within the learning community and how this has been a particular support to him as he constructed his own understanding of scientific inquiry.

One teacher from year two remarked on how initially she was concerned about how she would perform in the inquiry classroom but quickly understood that the students' reactions to engaging in the activity were more important. All teachers have reported on students' enhanced engagement, motivation and interest during these PRB classes.

Students' Responses

Students have also advised how involvement in the project has been "*interesting*" and "*lets the student take the wheel and find out for themselves*". Some students also reported that the most enjoyable part of being involved in the project was that "*the student was in control*" while others have reported on their enjoyment from working together in groups. An example of this is given by one student who shared that *"(I enjoyed) working together as a team"* (Student A). This student is hinting at his enjoyment of engaging in co-operative learning and as such speaks of the opportunity for social engagement through the inquiry process.

Another student considered the enhanced enjoyment he got doing this more student- led investigation*"(1 enjoyed) the way you could teach yourself"* (Student B). Essentially he is intimating his enjoyment at being able to construct his own understanding without being told the information. The latter is reminiscent of the traditional mode of learning. Indeed one student suggested enhanced understanding after engaging in the PRB lessons
"Stuff was easier to understand cause we were going away putting it into our own words and bringing it back" (Student C)
Here this student is proposes an enhanced understanding because of the opportunity to construct his own understanding in his own words, again suggesting the perceived benefit of engaging in this constructivist orientation towards learning.

How can we make Inquiry a sustainable Practice in the Irish Classroom?

The aim is to promote a sustainable approach to inquiry in the classroom. It is the author's contention that several components of the Chain Reaction project can help promote the use of inquiry on a sustainable level. We have in response to teachers' suggestions from year 1, decided to develop PRBs more reflective of the Irish context. To that end we have 6 pre-service teachers designing, implementing and redrafting these PRBs during their school placement experience and these additional PRBs will be ready for dissemination early next year. We have provided plaques to participating schools and have developed a professional development folder for teachers to keep track of their learning. This folder also provides a record to policy makers of their involvement in School Self-Evaluation (SSE) which is a new initiative that schools must abide by. Finally we have promoted the use of inquiry in the regular classroom setting in order to show that engaging in such problem solving activities do not necessarily require experimentation and expensive resources to be deemed as student led inquiry.

The cascading model for the project is a key aspect of sustainability and by having the focus on creating support networks and on promotion of the project, the cascading model can prove effective in facilitating teacher professional development towards the use of inquiry in the classroom.

Recruitment for 2015-16

We are currently in the process of recruiting teachers for year three of the project. Participating schools receive €2,000 for working with Chain Reaction. If you are interested in taking part or would like some additional information on the project, you can email Louise at Louise.Lehane@ul.ie.

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The University of Limerick is one of the Chain reaction partners and the UL team is led by Dr. John O'Reilly, together with Dr Louise Lehane, Dr Joanne Broggy, Dr Anne O'Dwyer and Ms Michelle Starr.

Some quotes on inquiry in science

"[Justus] Liebig was not a teacher in the ordinary sense of the word. Scientifically productive himself in an unusual degree, and rich in chemical ideas, he imparted the latter to his advanced pupils, to be put by them to experimental proof; he thus brought his pupils gradually to think for themselves, besides showing and explaining to them the methods by which chemical problems might be solved experimentally."
Herman Kolbe

"Most of the time I've worked in labs if I didn't encounter something in a week entirely unexpected and surprising I'd consider it a lost week. Lots of that is due to mistakes and stupidity, but it could open a new line of inquiry. Something really good turns up once in a hundred times, but it makes the whole day worthwhile."
Lewis Thomas

"Scientists are skeptics. It's unfortunate that the word 'skeptic' has taken on other connotations in the culture involving nihilism and cynicism. Really, in its pure and original meaning, it's just thoughtful inquiry."
Michael Shermer

"If boys and girls left school properly aware what an experiment is, what is involved in making one, how far from easy it is to make a real experiment; if they acquired a true sense of exactness in work and argument: the teaching given in schools would be of great value in after-life, as life is one big never-ending experiment. I see no reason why there should be school laboratories if the main purpose of them be not to give training in the art of inquiry."
Henry E. Armstrong

The Instrument Makers No. 7: Karl Friedrich Mohr

(November 4, 1806 – September 28, 1879)

Adrian J. Ryder
tutorajr@gmail.com

Karl Mohr was born in Koblenz (about 92 km southeast of Cologne) to a well-off family. His father, also named Karl, was a highly respected druggist. Karl had 5 sisters but these and his mother died while he was still a child so he was to spend much of his early life in his father's company. While receiving his early education at home he had the opportunity to experiment with chemicals in his father's laboratory. This early exposure to chemicals and the apparatus of the time was to influence his entire life.

He began his formal education in the Koblenz Gymnasium and after eight years graduated with his class. In 1823 he became an apprentice in his father's pharmacy and at the age of twenty-one he went successively to Heidelberg, Berlin and Bonn, taking courses in philosophy, the natural sciences, pharmacy and was drawn to chemistry, returning to Koblenz in 1831 with a Ph.D. to work with his father. In 1832 he passed the state examination as an apothecary and became his father's assistant.

Shortly after his return to Koblenz Karl devised an analytical balance in 1832, to measure specific gravity, which combined accuracy and simplicity of design. (Figure 1 below)

Figure 1: Mohr's 1832 specific gravity balance

On May 30th 1833 Karl married Jocobine Derichs (1812-1892). The couple were to have five children, three boys and two girls. They were: Karl, later an industrial chemist in France and Belgium; Maria, who married Apotheker Niewhans. (Karl was a silent partner in Niewhans' vinegar works (more below).); Emil, later an industrial chemist in Paris; Anna, who stayed at home unmarried; and Bernhard, who studied with Kekulé in Bonn and Kolbé in Leipzig.

After Karl Jr, obtained his Doctorate from Heidelberg he moved to England, where he became a Consulting Chemist and Metallurgist. In 1896/97 he applied for a patent on his invention of "Treatment of sulphide ores for the separation of zinc from lead and other metals." His address in London is given as No. 69a Parliament Hill, Hampstead, Middlesex.

During his time working with his father Karl invented the burette, Figure 2 below, which had a tip closed by a clamp, known as Mohr's clip, to regulate the discharge. The clip was changed to a glass tap in later years giving what is now the most recognizable piece of apparatus to be found in every school laboratory.

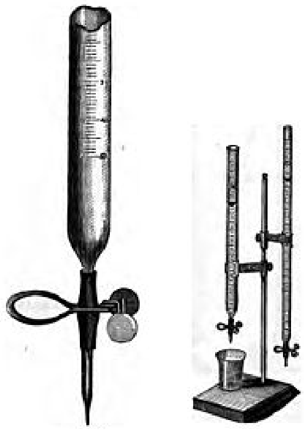

Figure 2: Mohr's clip on a burette

Karl's first published work was a paper entitled 'Über die Natur der Wärme', 'On the nature of heat' (1837), published in *Baumgaertner's Journal.* In it Karl gave one of the earliest general statements of the doctrine of the conservation of energy:
"besides the 54 known chemical elements there is in the physical world one agent only, and this is called Kraft (energy). It may appear, according to circumstances, as motion, chemical affinity, cohesion, electricity, light and magnetism; and from any one of these forms it can be transformed into any of the others."

Karl's father died in 1840 and Karl took over the running of the business. He researched and wrote on his findings widely and invented new apparatus for analysis, which changed the course of pharmaceutical research for the generations ahead.

From 1836 Karl researched the pharmaceutical and chemical preparations of the various European and American pharmacopeias in use during the previous eighty years. This was published in 1845 and was, essentially, the second part of the work of Professor P. L. Geiger, who died in 1836, shortly after the first part, which dealt with the crude drugs and simple chemicals was published.

About the same period Karl introduced oxalic acid and iron (II) ammonium sulfate, $(NH_4)_2Fe(SO_4)_2.6H_2O$, (Mohr's salt) as primary standards for acid/base and redox titrations respectively; and developed classical methods for the determination of chloride and other substances. He also invented the cork borer and the graduated pipette.

Karl's methods of volumetric analysis are given in his *Lehrbuch der chemisch-analytischen Titrir-methode* (1855) (Instructional Book of Titration Methods in Analytical Chemistry), which won special commendation from Justus Liebig and ran to many editions.

Karl ran the business for seventeen years and in 1857 sold it as a going concern and moved to the country, where he immersed himself in scientific studies including geology. This new area of interest arose from his attendance at a meeting of German scientists and naturalists which was held in Bonn in 1857. Karl was to present a number of papers in the area of geology over the following years.

In 1864 his son in law's, Apotheker Niewhans, vinegar plant failed and Karl lost the vast sum he had invested in it. He was ruined financially and moved first to Berlin where he became a junior lecturer (*privatdozend*), and then to Bonn as lecturer (*dozent*), in order to keep himself and his family. His new position encouraged Karl to continue with his writings and his *Geschichie der Erde, eine Geologic auf neuer Grundlage* (1866), was well received and widely circulated.

In 1867 Karl was appointed extraordinary professor of Pharmacy in Bonn, by the direct influence of the government. In a laboratory explosion Karl lost an eye in 1873 but continued to give public lectures up to his final year; these lectures were attended by many of the nobility, among whom the Empress of Germany was a devoted hearer. He continued his scientific writings right up to the end of his life and had over 250 articles published in scientific journals. This is a remarkable achievement by any standard.

Karl died on September 28, 1879 and was buried in Alter Friedhof, Bonn, Nordrhein-Westfalen, Germany.

References

http://en.wikipedia.org/wiki/Karl_Friedrich_Mohr
http://www.rsc.org/chemistryworld/Issues/2008/March/MohrsBurette.asp
Popular Science Monthly Volume 17 July 1880

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Everyday Chemistry

The uric acid connection

Peter E. Childs

What do kidney stones and gout have in common? They are both painful complaints and the cause is the formation of crystals of uric acid and its salts (depending on pH).

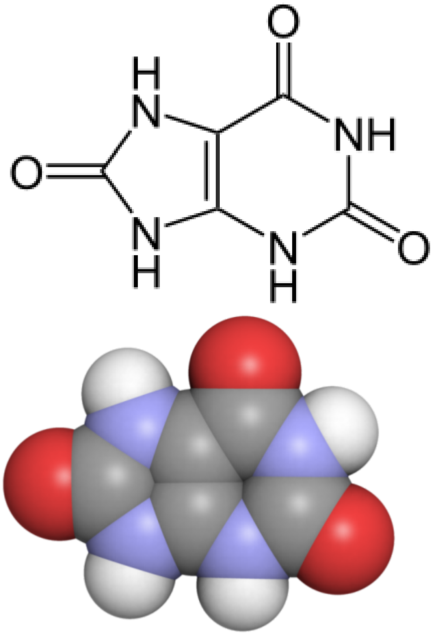

Figure 1: Uric acid structure

Uric acid is produced by the breakdown of purines (from food) in the body. Purines are nitrogen-containing aromatic heterocyclic molecules. (A heterocycle is a cyclic molecule with atoms other than carbon in the ring.) The word purine (pure urine) was coined by the German chemist Emil Fischer in 1884. Purines are a family of compounds and they are very common in food, Examples of purines include caffeine, theobromine (in chocolate), adenine, guanine and uric acid. They are common in meat and meat produces, especially offal.
(see http://en.wikipedia.org/wiki/Purine)

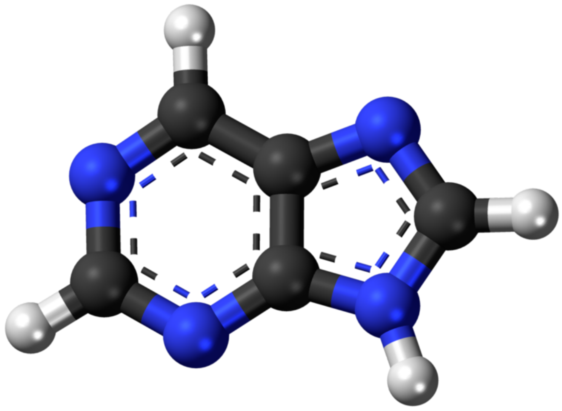

Figure 2: Structure of a purine

Uric acid is usually removed in the body by the kidneys and excreted in the urine, hence the name. If there is an excess uric acid or it is too concentrated (due to dehydration), or if the kidneys are not working properly, then it can crystallise out as painful kidney stones or be deposited as needle-like crystals in joints, causing severe pain and it is then known as gout. Uric acid is a weak acid and at the pH of the body exists as its sodium salt and thus the crystals that form are usually those of the sodium salt. Ethanol increases the production of uric acid and decreases its solubility. Uric acid is less soluble in cold water than in hot and this may explain why gout attacks the extremities at night, when they are cold.

Uric acid was first isolated from kidney stones by Scheele in 1776. Other sparingly soluble salts are more common in kidney stones than urates, like calcium oxalate. Uric acid is less soluble than its salts so the acid is more likely to crystallise. It is also less soluble in ethanol than in water and this is why drinking alcohol is a contributory factor to gout. High uric acid levels in blood confirm a diagnosis of gout. Normal values range between 3.5 and 7.2 mg/dL.

Gout used to be associated with a rich diet and heavy drinking, as in Gilray's 18th century cartoons below, but with the improvement in people's diets and higher alcohol consumption, gout has become an equal opportunity disease. [The author has recently suffered from gout and this topic is of personal interest.] Doctors recommend avoiding or reducing the intake of red meat and red wine to minimise the incidence of gout. Foods rich in purines include:
Gout affects ~1 in 200 people and men are more susceptible than women.

Figure 3: James Gillray 1799 'The Gout'

Allopurinol is widely used to reduce uric acid levels over time as it inhibits xanthine oxidase, which breaks down xanthine into uric acid. Acute attacks of gout can be treated with colchinine, a drug originally obtained from the Autumn crocus.

Kidney stones

(http://en.wikipedia.org/wiki/Kidney_stone)

Kidney stones are solid, crystalline deposits in the kidney produced when sparingly soluble salts and compounds crystallise out. This problem is also known as *Nephrolithiasis*. These include calcium salts such as oxalate and phosphate and uric acid. Kathleen Lonsdale made some pioneering X-ray studies of the structures of kidney stones. (See 'Human stones', *Scientific American*, Dec. 1st, 1968) Kidney stones can vary in size from a grain of sand to a golf ball but in 2009 surgeons in Hungary removed a stone 17 cm in diameter and weighing 2.5 lb from a man! Sometimes the stones can be dissolved away but the most common treatment today is ultrasound (lithotripsy), which breaks the stones up into small pieces so they can be flushed away. The best defence against kidney stones is to avoid oxalate-rich foods (like rhubarb) and to drink plenty of water. Kidney stones and gout are both examples of solubility and precipitation. Kidney stones occur in ~ 1 in 20 and are more common in men than in women.

For some photos of kidney stones see http://www.herringlab.com/photos/.
Typically 70% of stones are made of calcium oxalate, 10% of calcium phosphate, 5-10% of uric acid and 10% of struvite (magnesium ammonium phosphate).

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The importance of experiment

Upon the whole, Chymistry is as yet but an opening science, closely connected with the useful and ornamental arts, and worthy the attention of the liberal mind. And it must always become more and more so: for though it is only of late, that it has been looked upon in that light, the great progress already made in Chymical knowledge, gives us a pleasant prospect of rich additions to it. The Science is now studied on solid and rational grounds. While our knowledge is imperfect, it is apt to run into error: but Experiment is the thread that will lead us out of the labyrinth."

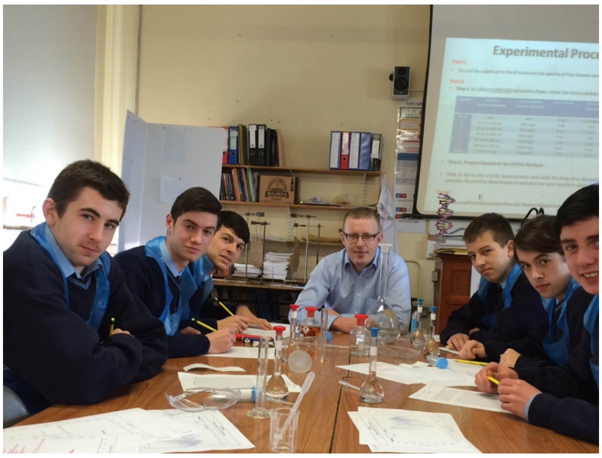
Joseph Black

UCC Chemistry on its Travels with Spectroscopy in a Suitcase (SIAS)

Trevor Carey, Department of Chemistry, University College, Cork
t.carey@ucc.ie

L-R: Dr. Trevor Carey, Rose O'Mahony, Fiona O'Donovan and Dr. Dave Otway.

Spectroscopy in a Suitcase (SIAS), a Royal Society of Chemistry outreach activity which gives school students the chance to learn about spectroscopy through hands-on experience, is now available from the Chemistry Department in University College Cork. UCC cover the Munster region, and so far it has received a fantastic response from schools in the area. Launched at the beginning of March, SIAS sessions have been delivered in Killarney (Kerry), Ballingarry (Tipperary) and Ballyvourney (cork) with a busy schedule ahead in April with trips already planned for Youghal (Cork), Hospital (Limerick), Crescent (Limerick) and Spanish Point (Clare).



Dr. Trevor Carey and students from St. Brendan's College, Killarney

oint co-ordinators in UCC for SIAS are Dr. Dave Otway and Dr. Trevor Carey. Trevor explains how the scheme has worked so far. "The response from schools has been terrific and wherever we've gone, we've got a fantastic welcome. We put on a two hour session for the students, which gives them hands on use of the equipment and its potential applications to real life. The programme also gives students good practice in preparing standard solutions and problem solving using calibration plots. The feedback so far has been very positive from teachers and students. We are also on hand to talk to the students about third level education and answer any queries they may have as they prepare for the college life."

SIAS is a free scheme for schools. "We bring everything with us – the equipment, glassware, chemicals, spectra and some free gifts from the Royal Society of Chemistry! Schools simply need to book us for a two hour slot and we do the rest. Teachers have used SIAS to promote chemistry to Transition Year students but we have also delivered the scheme to 5th and 6th year students who cover IR and UV spectroscopy as part of the Leaving Certificate chemistry course."

ISTA Conference, UCC, March 2015

The equipment, which was on show at the 2015 Irish Science Teachers Association Conference in UCC, consists of ATR Infra-red spectrometer and a UV spectrometer. During a school visit, students use this equipment to solve a 'murder mystery' in the area of Forensic Chemistry. "It captures their imagination and the crime scene approach has proven to be popular given the success of CSI type programmes on TV for students of this age group. Each class of students is split up into 3 groups, with each group completing the 'murder mystery' under the guidance of myself and two current PhD chemistry students (Rose O'Mahony and Fiona O'Donovan) who accompany me on the trips", said Trevor.

Fiona O'Donovan and students from Coláiste Ghobnatan, Ballyvourney, Cork

SIAS aims to:

- Promote science as a subject to young people, and to show the excitement of hands-on spectroscopy
- Provide a simple and versatile equipment to schools for the demonstration of optical spectroscopy
- Cover a range of experiments to allow coverage of topic for 4th years to 6th years
- Supply full teacher training and support from University staff

Rose O'Mahony and students from Presentation Secondary School, Ballingarry, Tipperary

Marie Lawlor is a chemistry teacher in St. Brendan's College, Killarney and explains the benefits of the scheme which was delivered to her 4th, 5th and 6th year students. "The students were on task for two hours and they commented that the workshop was very enjoyable and insightful. As well as appreciating the monetary value of the spectrometers, the students gained a valuable insight into the concept of spectroscopy as a tool for qualitative and quantitative analysis of an unknown substance. The application of the workshop was fascinating because of their interest in CSI. The class was divided into small efficient groups that were able to carry out the tasks as required and the spectra graphs obtained were well explained. The quality of the equipment that we used was much appreciated by everybody as was the competitive nature of the task."

UCC chemistry provides an excellent website for their SIAS scheme. The website contains all you need to know about the scheme; how to book, photos of previous school visits, testimonials from teachers, videos and a location map showing schools that they have travelled to. Full details can be found at:
UCC Chemistry SIAS:
http://www.ucc.ie/en/chemistry/outreach/sias/
Online booking Form:
http://www.rsc.org/Education/sias/siasbooking.asp
Facebook: @uccchemistry / Twitter: @uccchemistry
Contact: t.carey@ucc.ie / sias@ucc.ie
Tel: 021 4902150

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Conference and Workshop Reports

8th Chemistry Demonstration Workshop 23-27 June 2014

Learning to engage students through demonstrations

Sarah Hayes and Beulah McManus

The final week of June 2014 saw over 10 delegates from around the country, including a number of trainee science teachers, attended the 8th annual Chemistry Demonstration Workshop. The Science Demonstration workshop is an annual event in the Science/Chemistry Education calendar. This year the 8th Annual Chemistry Demonstration Workshop was organised by the Synthesis and Solid State Pharmaceutical Centre (SSPC)the Department of Chemical and Environmental Sciences (CES), University of Limerick, and supported by PharmaChemical Ireland and the Professional Development Service for Teachers (PDST). Attended by science teachers and educators from across Ireland, the workshop aims to develop science teaching skills, which will engage and stimulate thinking.

Orlaith Shinners gives us her take on the methane mamba (Photo: SSPC/Seán Curtain)

The workshop opened on the 23rd of June in the laboratory and the first sessions were illustrated talks on 'Why do demonstrations?' and 'Safety in doing demonstrations' by Peter Davern (SSPC/CES). This introductory session was followed by a slightly different coffee break, as the Department of Chemical and Environmental Sciences (CES Department) had a delicious surprise in store: Liquid nitrogen ice-cream whipped up by Leo Kirby and Mark Barrett, who hosted us so well! It was the perfect refresher after the heat of the lab and the scorching weather outside!

Then it was back to the lab to welcome Paul Nugent and David Keenahan from the Institute of Physics (IOP) to the course and learn all we could from then and their wonderful circuit of Physics demonstrations. As Paul and David took us through the vast array of Physics demonstrations and their applications we frantically tried and tested them, taking notes about their relevance to the various aspects of the curriculum.

Good vibrations: Mark Barrett and David Keenahan look at some wave motions (Photo: Sarah Hayes, SSPC)

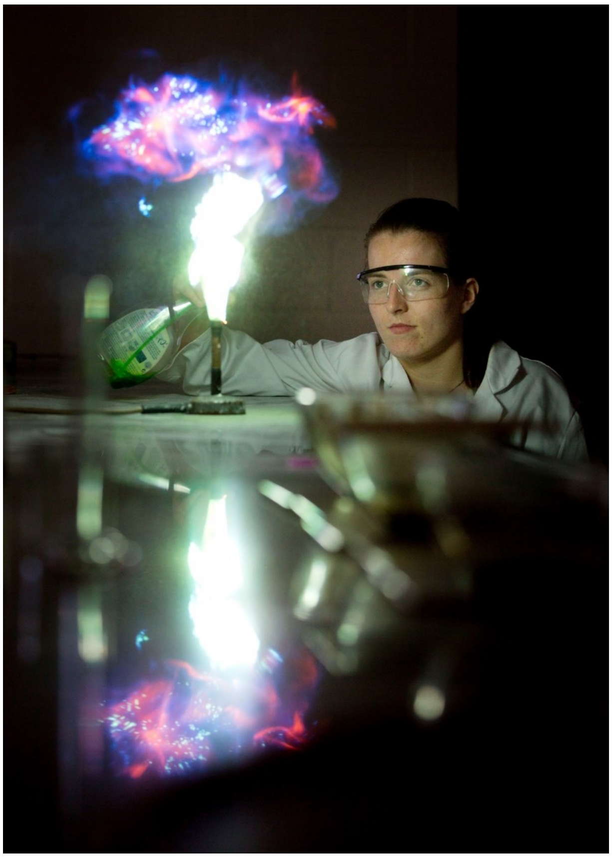
The following morning it was back into the laboratory to see how a real 'Science Magic Show' operates! The show was presented by Sarah Hayes, SSPC Education and Outreach Officer. The University of Limerick delivers a travelling 'Science Magic Show' to schools throughout Munster and will continue to do so in the 2014-15 school year.

Once the show was over it was time for the teachers to get their hands (and lab coats) dirty. A series of demonstrations were set up that have been used in our courses and Science Magic Shows and the teachers got a chance to try out all of them and add them to their own portfolio of demonstrations. This was great as it allowed the teachers to build up their confidence through trying out tried-and-tested demonstrations that they had already seen in the 'Science Magic Show'. It also meant that all participants started off with a basic set of chemical demonstrations that they could do and take away to use in their schools or science magic shows.

The 2014 workshop participants (Photo: Sarah Hayes, SSPC)

The importance of this course is well recognised by sponsors and members of the scientific community: *"Science is all around us and bringing it to life for students can make the difference in terms of their long-term engagement with the subject. It is important that we continue to nurture students' interest in the sciences to help build our culture of innovation, enquiry and the future knowledge economy."* explains SSPC General Manager, Jon O'Halloran

The course programme is designed to provide science teachers and educators with the confidence to promote problem and inquiry-based learning and to conduct over 40 engaging and interactive science demonstrations, which are linked to real world science applications. After the circuit of demonstrations teachers were encouraged to try out some demonstrations that they would like to do from the course materials provided in their folder, from the Royal Society of Chemistry *Classic Chemistry Demonstrations* book or from the internet. Once these demonstrations were assessed for safety and availability of materials, the teachers were good to go and this approach allowed for a large number of demonstrations to be tried out and shared among the group.



Amazing flame tests. (Photo: Sarah Hayes, SSPC)

The guiding principle behind this workshop is to use the first two days to get the participants really comfortable with doing demonstrations (no matter how flaming or explosive they are), and to then allow them to use their new found confidence to research and try out new demonstrations in a safe environment. The goal is to build confidence and expertise based on knowledge and an awareness of safety, and learning from mistakes. You can do spectacular demonstrations if you know what you're doing and take the proper precautions. We also want teachers by the end of the course to have the confidence and skills to take a demonstration from the literature and to do it safely themselves. The workshop included a session from the Institute of Physics Ireland, along with a session from the PDST focusing on the integration of information technology into science education.

Event organiser, Sarah Hayes, SSPC Education and Outreach Officer explains: *"This workshop is an important event on the science education calendar. During this workshop we work with teachers and educators to help them develop the skills to teach using inquiry and problem-based learning by utilising spectacular attention grabbing science demonstrations, which have the ability to engage pupils and stimulate thinking."*

Peter Jackson from the Professional Development Service for Teachers (PDST) came in on the third day of the course to give a session on using the PDST website and other IT-based chemical resources in the classroom. This session was given in the new IT suite in the Physical Education and Sports Science (PESS) Department.

Liquid nitrogen demos are always a hit. (Photo: Sarah Hayes, SSPC)

Once this session was over, it was back to the grindstone and the teachers continued trying out new demonstrations in the laboratory, while preparing for their own 'Science Magic Show' in pairs. The participants were allocated to pairs and had the brief to devise, script, practise and finally present their own Science Magic Show at the end of the workshop to the other teachers (and invited guests). These shows were videoed so that teachers could learn from their's and other's performances after the workshop was over. These videos are only circulated to participants and sponsors – they are not for public consumption! Peter Childs said *"Teachers need the opportunity to step back from teaching and to develop new skills and new ways of presenting science. These workshops give them the time to build their confidence and expertise, to share ideas with fellow teachers, and we find that they return to their schools invigorated and more enthused about teaching chemistry."*

The workshop has been developed upon the foundations of Student Active Learning in Science (SALiS), an international project, which utilises best-practice within science education, funded by EU-TEMPUS. On-going research in this area is continuing through the EU FP7 funded project TEMI (contact peter.childs@ul.ie). For further information about SSPC or the workshop contact Sarah Hayes, SSPC Education and Outreach Officer email: sarah.hayes@ul.ie.

he programme is designed to help teachers put fun back into teaching and learning science in school and allow participants develop confidence in developing spectacular but safe chemical demonstrations.

Sarah Hayes shows that the diet coke and Mentos reaction is best done outside. (Photo: Sarah Hayes, SSPC)

Bridget Ryan does a spectacular flame test. (Photo: Sarah Hayes, SSPC)

This workshop is residential and most of the costs are covered by the sponsors – the SSPC, the CES Department, the Professional Development Service for Teachers (PDST), and Pharmachemical Ireland (through Siobhan Dean). The workshop was also supported by the course organisers and presenters were Sarah Hayes (SSPC), Peter Davern (CES/SSPC), Beulah McManus (CES) and of course, Peter Childs (CES).

Nearly 80 teachers or student teachers have attended the eight workshops. We frequently give scholarships to final year science education students from UL and other universities around Ireland, who are training science teachers. We hope to run a 9th Science Demonstration Workshop in June of next year (2015), subject to sponsorship being available. Places are limited (~20) - so if you are interested please e-mail either Sarah Hayes (sarah.hayes@ul.ie) or Beulah McManus (Beulah.mcmanus@ul.ie) to reserve a spot. **The dates for the 2015 workshop are 15-19 June in the University of Limerick.**

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A key chemical discovery

"About eight days ago I discovered that sulfur in burning, far from losing weight, on the contrary, gains it; it is the same with phosphorus; this increase of weight arises from a prodigious quantity of air that is fixed during combustion and combines with the vapors. This discovery, which I have established by experiments, that I regard as decisive, has led me to think that what is observed in the combustion of sulfur and phosphorus may well take place in the case of all substances that gain in weight by combustion and calcination; and I am persuaded that the increase in weight of metallic calyxes is due to the same cause... This discovery seems to me one of the most interesting that has been made since Stahl and since it is difficult not to disclose something inadvertently in conversation with friends that could lead to the truth I have thought it necessary to make the present deposit to the Secretary of the Academy to await the time I make my experiments public."

Antoine Lavoisier

Chemlingo: What would ph/fonetic ch/kemistry look like?

Peter E. Childs

"English is the lingua franca of the digital age, yet it has never been spelt phonetically."
TheTimes Leader 14/1/14

Chemistry/kemistry is full of words, often derived from Greek roots, that have redundant letters i.e. letters that are not needed for the correct sound. A common one is ph- (pronounced f-) so that we could have fosforus and fenol, not to mention fenolthalein and thalic (where the p of pthalein and pthalic is silent) and fotosynthesis. The prefix pn- is pronounced n- as is pneumatic and more rarely in pnictogen/pnictide (group 15 elements/compounds). The battle over sulphur and sulfur has been lost and sulphur is now the accepted IUPAC spelling.1

Does this help or hinder students of chemistry? Is the meaning lost in the thicket of difficult spelling? Journalists and authors already get confused between phosphorus (the element) and phosphorous (a compound), which sound the same. Spelling matters in chemistry because a change in one letter can alter the chemical meaning: for example, alkane, alkene and alkyne; phosphorus and phosphorous are not the same.

One of the main reasons for the differences between UK and American English is the simplified spelling introduced by Noah Webster through his influential dictionary: he lost redundant letters so –our became –or (color, odor, flavor etc), ae- became e- as in anesthetic and hemoglobin. It can be confusing to students to read of aluminum in American general chemistry textbooks, although the UK spelling is aluminium; likewise cesium is caesium in UK/Irish books.

The drive to simplify spelling has probably been overtaken by 'textspeak', which is developing into a new language, a dialect of English reduced to its bare minimum. I wonder what would chemistry look like in this language? Here is an example from a *Guardian* competition for text poetry in May 2001[2].

14: a txt msg pom.
his is r bunsn brnr bl%,
his hair lyk fe filings
W/ac/dc going thru.
I sit by him in kemistry,
it splits my @oms
wen he :-)s @ me.
Julia Bird 30, Poetry Book Society

Translation:
14: a text message poem
his eyes are bunsen burner blue,
his hair like iron filings
with ac/dc going through.
I sit by him in chemistry,
it splits my atoms
when he smiles at me

1. http://www.nature.com/nchem/journal/v1/n5/full/nchem.301.html
2. http://www.theguardian.com/technology/2001/may/03/internet.poetry

Obituaries

We don't often print obituaries but in 2014 two giants of UCD chemistry died – Professor David Brown and Mr Peter Start. Both of these were well-known to generations of UCD Chemistry students.

Obituary - David A. Brown

The death has occurred recently (September 27 2014) of David A. Brown, who was Professor of Inorganic Chemistry in UCD for many years, during which time, both in the former College of Science in Merrion Street and in the more recent UCD campus in Belfield, he played a vital role in the development of inorganic chemistry, both in Ireland and internationally. He served the college in many capacities, including the head of the chemistry department, the dean of the science faculty and a member of the governing body.

He joined UCD in 1959 as a lecturer and was appointed in 1964 as the first Professor of Inorganic Chemistry in UCD at a young age, as he was born in 1929 in High Wycombe, England. He was a student at Queen Mary College, now Queen Mary University of London, where he became the president of the student chemical society. Following his studies and research in London he worked as a post-doctoral fellow in Cambridge, where his research focused on theories of chemical bonding, that is on how atoms are held together in molecules. Following these studies in England he worked in Brussels as a European Research Associate, where he became a fluent linguist, and from there he joined the UCD staff.

While an undergraduate in 1949 David Feakins, who joined David in UCD when he became the first Professor of Physical Chemistry, as a first year student remembered David, who was a final year "Olympian" figure, as an outstanding worker. Professor Feakins recalled that David went on to be first in chemistry in the whole university.

Professor Brown was a member of the Royal Irish Academy for 52 years, having been elected in 1962. In 1996 he was awarded the Boyle-Higgins gold medal and lecture awards of the Institute of Chemistry of Ireland, of which he served as President. This is an award for research work carried out in Ireland and is made for an outstanding and internationally recognised research contribution to the advancement of chemistry. He also was a member of the Royal Society of Chemistry for over 60 years.

David, along with Dr Bill Davis of TCD, organized a very successful International Conference on Coordination Chemistry in Dublin in 1974, attended by more than 700 participants. The profit from this conference was used to establish regular inorganic chemistry meetings, initially in Greystones and later in Maynooth. These conferences were attended by chemists from both the Republic and Northern Ireland as well as by prominent international speakers. During his career David also was very successful in obtaining funding both from European and other sources.

As well as his work in UCD administration, David was a very active researcher and teacher. He was a lively and inspiring lecturer and in his lectures to undergraduates he introduced developments that were topical and had practical and academic importance, as for example when he described and clarified for students the structure of a new type of compound, ferrocene, with a special type of bonding, that subsequently led on to a whole new field of science. In his research he had interests in many exciting areas, including the theory of bonding, coordination chemistry, the study of organometallic compounds (that is those with both organic and inorganic parts), bioinorganic and medicinal chemistry. He published extensively and was internationally well known. His Penguin book on *Quantum Chemistry* opened up many insights to non-specialists in a clear, concise way and helped readers to appreciate modern developments. David formally retired in 1994 but continued his active research in retirement and his most recent publication was in 2011.

He jointly worked with many leading chemistry groups, including Professor Kevin Nolan of the Royal College of Surgeons in Ireland, and his standing is shown by the many famous chemists who visited UCD over the years. His students appreciated meeting these in David's house, where he was a hospitable host.

Recently the very successful inaugural David Brown Lecture of the Institute of Chemistry of Ireland and the Institute of Nanotechnology was given by Professor Annie Powell, who received the first David Brown award. Members of the

Brown family attended and this was very much appreciated by the large audience of inorganic chemists in the RCSI where the excellent lecture was given.

He was very encouraging to his students, many of whom blossomed exceptionally under his guidance. If a student had personal difficulties, David helped, discreetly and effectively. This support has been generously acknowledged and appreciated by former students. He worked very conscientiously himself, and his energy, drive and commitment encouraged his students, to whom he was tremendously loyal. As head of department he was exceptionally fair to all groups in sharing often limited resources in difficult times. This generosity helped to maintain a very positive *esprit de corps* in the chemistry department of UCD,

During his time there he established a flourishing nuclear magnetic resonance centre, with substantial industrial funding and also developed excellent micro analytical facilities, which were used by both UCD personnel and others from commercial and academic backgrounds.

David was a true humanitarian and set up UNESCO courses, where students from developing countries came to UCD; this project was supported by UNESCO and was very successful. Through these courses and other opportunities David had many overseas students, whose careers he followed with interest, and his international commitment was shown when he was a visiting professor in Kuwait during 1979. He kept in touch with his former students, and this close contact again illustrated the appreciation that they had for David's interest and support. This acknowledgement is illustrated by the very many sincere condolences received from all around the world.

An indication of his standing in science was illustrated when at an international meeting in Florence a delegate was asked if he seen David and was told, after explaining that as he was so busy with the conference he had not time to visit the Uffizi Gallery, that David Brown was meant.

As well as his tremendous commitment to science and UCD David had other interests, including music, especially opera. Being a student in London he had opportunities to attend operas and he had the pleasure of hearing Maria Callas, and more recently in attending the Verona Opera festival. He enjoyed travel and as well as attending international scientific conferences, he travelled widely all his life and as he had a very sharp memory was able to recall and entertain others with his travelling adventures.

He was also a voracious reader and was very knowledgeable about many areas of history, both military and social, being very aware and concerned about political abuses worldwide.

As well as his interests in UCD, science, music, travel and reading he was a great family person. His dedication to his family was most impressive. He was a devoted husband, a wonderful father and an adoring grandfather, as was acknowledged at his funeral service. He is deeply mourned by Rita and children, Geraldine, Paul, Suzanne, Rory, Elizabeth and Catherine, as well as by his eight grandchildren in Ireland, the UK and the USA.

David had exceptional ability as a scientist, administrator and teacher, but especially he will be remembered as a person of great loyalty, integrity, energy and friendship. His students will always recall his interest in them and his help in their careers and his family will always cherish his love and dedication.

Dr Noel Fitzpatrick
(ex UCD Chemistry)

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Obituary - Peter Allen Smart

We were greatly saddened to learn of the death of Peter Start, retired member of the academic staff of the Department of Chemistry, University College Dublin, on October 16th 2014. Peter was a senior lecturer in Physical and Inorganic Chemistry in the Department and served for 14 years as the University Safety Officer.

When the Chemistry Department moved from what is now Government Buildings to the campus at Belfield in 1964, Peter was charged with the enormous task of organizing the chemistry practical classes for first year students, in the vast new laboratories .With the increase in numbers of the student body, practical sessions in first year became a communications challenge, as it took time to walk from bench to bench talking with only a handful of the class at any one time. Having identified the problem Peter quickly had a solution: “CHEM TV”. CHEM TV was run from a fully-fledged TV studio in the Chemistry Department with TVs installed throughout the laboratories. From the studio Peter and the late Dr J. Gowan would brief and guide all the students through their practical experiments assisted by an army of demonstrators. This method of conducting practical sessions was soon to be used in other Universities. This was a very innovative teaching method at the time, which the students found both entertaining and helpful. The ‘Gowan-Start’ productions along with his memorable lectures are well recalled by many Irish doctors, engineers, agriculturists and veterinarians.

Last January during the 50th BT Young Scientist Exhibition, Peter was delighted to recall the announcement of the First Aer Lingus Young Scientist exhibition which took place at the Intercontinental Hotel, Ballsbridge on the 15th April 1964. He was the last remaining member of the trio who were the scientific advisors to the airline’s air-education team. The other members were the late Fr Tom Burke (physics) and the late Margaret Duhig (zoology). For some twenty years he continued to assist the Exhibition by acting as a chemistry judge. He was popular with the young fledgling scientists and it was not unusual to see him escorted around the Exhibition by those wishing to understand the many exhibits. Peter was a natural teacher. His opinion when sought was carefully listened to and acted upon. He was a gentleman to his fingertips.

Peter had been a loyal member of The Institute of Chemistry of Ireland for well over fifty years, having first been elected Member of the Institute in 1959 and Fellow in January 1964. He was given the distinction of being made an Honorary Fellow of the Institute earlier in the spring of 2014 and attended the award ceremony accompanied by his family at UCD, on the occasion of the annual general meeting of the Institute. Peter commented at the time that for him this was his most cherished award.

Peter was the first Editor of the Institute’s journal, ‘Orbital’ and produced 11 issues in all from 1965 to 1970. He was also for a period of time the Chairman of the Conjoint Chemical Council, which produced a very necessary yearly calendar of events run by the chemical societies in Ireland.

He was also a Fellow of the Royal Society of Chemistry and a Chartered chemist.

In the late eighties Peter played a major part in the development of the University’s Diploma in Safety, Health and Welfare at Work, collaborating with Dr Caroline Hussey, former Registrar and Deputy President, and Tom Walsh, former CEO of the Health and Safety Authority. They set about establishing the National Centre for Safety and Health in Ireland, building up initially a certificate course and then a full Master’s degree programme. He joined the Institution of Occupational Safety and Health (IOSH) and was rapidly elevated to the rank of Fellow. Jointly with RTE he pioneered Ireland’s international tele-education course with students as far away as Chile and South America. Recently this satellite version has been converted into an online blended learning format. In 2012 he was awarded the title” OSH Person of the Year” and it was presented to him by the Lord Mayor of Dublin.

Peter and Marie were made for each other. They were delightful hosts in their home ‘Shaldon Grange’ in Kiltiernan, where many members of the University Chemistry Departments recall the great parties that took place there. On each occasion the development of the grounds was the subject for discussion, such as the diversion of an onsite natural stream to flow beside the house and the laying out of six acres of gardens, waterfalls and lakes. ‘Shaldon Grange’ was his life’s enjoyment and the party highlight for Peter used to be the opening of the reservoir sluice gates that exhibited a spectacular torrent of water.

Peter was able to handle many trades, and besides his design skills he could turn his hand as a brick layer, carpenter, plumber, electrician, and slater to mention but a few. At ‘Sheldon Grange’ he built everything he possibly could himself, and he surrounded himself with his family and machinery of all kinds, his pride and joy being the big yellow JCB. Perhaps what was most endearing was his generosity in giving of any of these skills to help his colleagues and friends. His advice was always being sought and given unstintingly.

Peter will be sadly missed by his friends and colleagues in UCD. He is survived by his wife Marie and his two sons Keith and Nigel.

Professor Dervilla Donnelly
(ex UCD Chemistry)

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Crystal Clear results at the SSPC National Crystal Growing Competition

In November 2014, to celebrate the International Year of Crystallography, the Synthesis and Solid State Pharmaceutical Centre (SSPC) at the University of Limerick launched a National Crystal Growing Competition. The competition was open to primary and post-primary school pupils from across Ireland and coincided with the end of 2014, the International year of Crystallography. Professor Kieran Hodnett, SSPC Scientific Director said:

"Crystals are all around us, and in every aspect of our lives, from chocolate to medicine to paints and plastics. Most of the medicines we take are made up of compacted powders and the individual particles of the powders are in fact tiny crystals. There is even a significant crystalline part to chocolate and the exact type of crystals determines the taste of the chocolate. The SSPC National Crystal Growing Competition will not only enable students to grow their own crystals, but it will increase students' awareness and understanding of the importance of crystals in our lives today."

The SSPC is a world-leading research centre focused upon next generation medicines by developing more environmentally sustainable methods for drug manufacture; increasing the range of medicines available to the public; and reducing drug manufacturing costs. The pharmaceutical industry employs over 25,000 individuals directly and 24,500 indirectly in Ireland, and produces over 50% of all exports, making Ireland the second-largest pharmaceutical exporter in the world. The primary objective of the SSPC is to retain existing jobs and to create new jobs within the pharmaceutical industry in Ireland.

There were entries from across Ireland, from Galway to Cork, to Dublin and across the midlands region. The quality of the entries was exceptional! Jon O'Halloran, SSPC General Manager, said:

"This was an exciting opportunity for young people to engage with the concepts of crystallography and crystallisation and to understand the science behind crystals and to practice growing their own crystals. There is often a poor understanding of the purpose of crystals and how important this branch of science is to our lives. The SSPC Crystal Growing Workshop and the SSPC National Crystal Growing Competition aimed to improve understanding in this area amongst the public and to develop future scientists and crystallographers."

The Synthesis and Solid State Pharmaceutical Centre (SSPC), a Global Hub of Pharmaceutical Process Innovation and Advanced Manufacturing, is funded by Science Foundation Ireland and industry, and is a unique collaboration between 22 industry partners, 9 research performing organisations and 12 international academic collaborators.

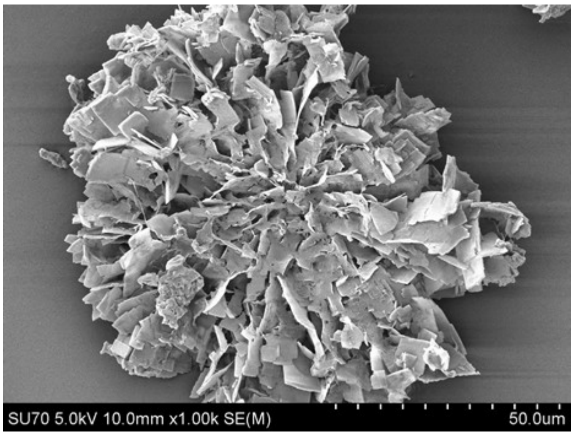


Figure 1: Crystal Bouquet by Teresa Tierney (Irish Research Council funded scholar), SSPC. Description: This flower-shaped crystal cluster of fenofibrate was obtained by Scanning Electron Microscopy and was thought to resemble the popular hydrangea flower. The sample was prepared by precipitating the drug fenofibrate from a polyvinyl alcohol (pva) antisolvent solution and freeze drying the suspension for particle isolation. PVA was used as a suspending agent during precipitation. Fenofibrate is a drug used to reduce cholesterol levels in patients at risk of cardiovascular disease.

Growing a beautiful crystal takes time and an almost daily follow-up. The idea of the competition was for pupils to grow a single crystal, not a bunch of crystals. They first needed to grow a small perfect crystal, a seed crystal, around which they later could grow a large crystal. It was therefore essential to avoid excessive rapid growth, which encourages the formation of multiple crystals instead of a single crystal.

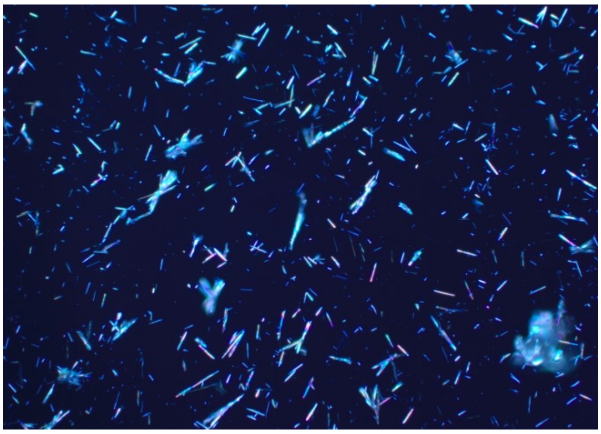


Figure 2: Crystal Galaxy by Dr Luis Padrela, SSPC. Description: This crystal image shows samples of different Carbamazepine polymorphs (needle-shaped particles) with different colours (a polarizer was used during the microscopy analysis). Carbamazepine is a drug used in the treatment of epilepsy

Crystals are an important part of our work here at the SSPC (see Figures 1 and 2), with crystal growth and design being a key research theme. This theme focuses on the science and process engineering underpinning the crystallisation of complex organic molecules with conformational flexibility and a multitude of functional groups. Impurities and solvent selection are central to this strand. Major themes include:

- Study of the underlying molecular interactions in supersaturated solutions and at interfaces
- Understanding the mechanisms that control product crystal properties such as crystal structure, purity, shape and size
- Exploiting these mechanisms to tailor and control crystal properties, to scale up and scale down processes, to develop model based control for improved product quality in traditional batch crystallisations as well as in emerging technologies like continuous processing, cocrystallisation, nanocrystallisation and crystallisation into excipient matrices

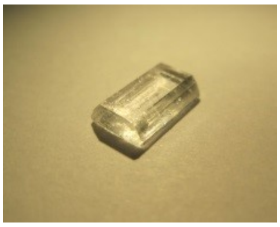
If you would like to try this in your class instructions are available on the SSPC website at the following link: http://www.sspc.ie/crystal_growing

The materials pupils could use to form crystals could be chosen from any of the following:

- Sodium Chloride (Salt): NaCl, Solubility: 35.9 g/100 mL (20°C, water).
- Potassium Aluminium Sulphate (Alum), $KAl(SO_4)_2.12H_2O$, gives transparent octahedral crystals. Solubility: 11.8g/100 mL (20°C, water). Teacher supervision required, see MSDS.
- Copper (II) Sulphate Pentahydrate: $CuSO_4.5H_2O$, gives blue crystals. Solubility: 32 g/100mL (anhydrous, 20°C, water). Teacher supervision required, see MSDS.
- Sucrose (table sugar or known as saccharose), $C_{12}H_{22}O_{11}$: Solubility: 211.5 g/100 mL (20°C, water).
- Ammonium Magnesium Sulfate Hexahydrate, $(NH_4)_2Mg(SO_4)_2.6H_2O$, gives transparent long crystals. Teacher supervision required, see MSDS.
- Magnesium Sulphate (known as Epsom salts), $MgSO_4$/ $MgSO_4.H_2O$, gives clear needle like crystals. Teacher supervision required, see MSDS.
- Copper Acetate Monohydrate $Cu(CH_3COO)_2.H_2O$. The recipe below gives blue-green monoclinic crystals. Solubility: 7.2 g/100mL (20°C, water). Teacher supervision required, see MSDS.
- Potassium Sodium Tartrate (Rochelle Salt) of $KNaC_4H_4O_6.4H_2O$, gives transparent long crystals. Solubility: 63 g/100mL (anhydrous, 20°C, water). Teacher supervision required, see MSDS.

The competition winners and their classmates were all invited down to SSPC in the University of Limerick to an awards ceremony. A series of SSPC researchers spoke to the teachers, parents and pupils about their own lives and career paths and how crystals have played a part. Professor Kieran Hodnett welcomed all the pupils, and spoke to them about the importance of crystals in our everyday lives. Finally Professor Michael Zaworotko, UL Bernal Chair of Crystal Engineering, and one of the world's top 20 chemists, gave a brief talk about his love of crystals and then it was time for him to present the prizes! The awards ceremony followed on from these talks and then it was photographs and lunch.

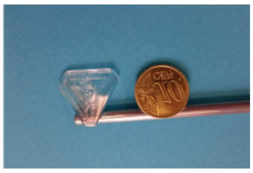
The winners of the competition were:
In joint first place:



Youbeel Hagi, from Galway Community College. Youbeel is 17 years old and grew a potassium sodium tartrate crystal (commonly known as Rochelle salt).

Jason Folan, from Coláiste Bhaile Chlair (Claregalway secondary school). Jason is 13 years old and grew an excellent alum crystal (Potassium Aluminium Sulphate).

Finalists were so close that the judging panel had great difficulty in deciding on the winners, and the runners-up are:



Oisín Tobin, from Coláiste Bhaile Chlair (Claregalway Secondary School). Oisín is 13 and in 1st year. Oisín grew an alum crystal (Potassium Aluminium Sulphate)

Clare McKernan, from St Aloysius' Secondary School in Cork. Clare is 17 years old, and grew a copper sulphate crystal, which is very difficult to grow as a full single crystal.

Figure 3: Professor Michael Zaworotko, with competition winners and runners up, Jason Folan, Oisín Tobin, Youbeel Hagi and Clare McKernan, at SSPC, UL.

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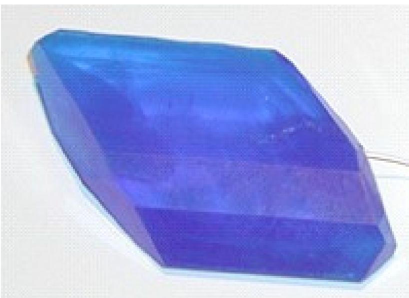
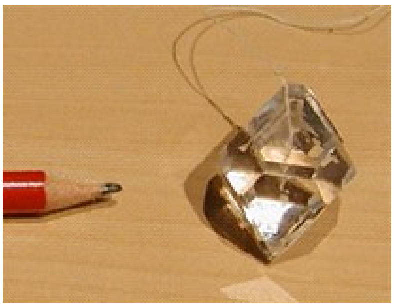
Some examples of single crystals:



Copper Sulphate crystal, credit: picture by Luc Van Meervelt



Alum crystal, credit: picture by Luc Van Meervelt

Ammonium Magnesium Sulfate Hexahydrate Crystal, Credit: picture by Luc Van Meervelt

Medicines in my life

Sarah Hayes
Education and Outreach officer, SSPC, University of Limerick, Limerick

The Synthesis and Solid State Pharmaceutical Centre (SSPC) has begun an exciting new project, with the support of SFI Discover. The project is entitled ‘Medicines in my Life’.

The aim of the project is to use formal (at school) and informal (at a museum/public space or festival) teaching and learning to familiarise pupils and the wider public with science. The goal of this project is to take STEMM education beyond the confines of the classroom and school into the wider community. SSPC has developed a Transition Year (TY) module entitled 'Innovation in Medicines'. It is envisaged that pupils taking the module in their Transition Year will take the knowledge learned through the module and translate this into an exhibit for a science centre/museum/art gallery/library or public space. This will be supported by teacher training, development of materials and a visit from an SSPC scientist. The exhibit should shed light on the relationship between scientific research and society. The idea is that a coherent set of exhibits will be produced, exhibited, judged and the best will combine into a travelling exhibition, which can be displayed throughout Ireland. The exhibitions should be interactive and should approach different aspects of 'Medicines in our lives', and the development of medicine through advances in scientific research and in industry. The best exhibits from the project will have the opportunity to be presented to the European public through the FP7 project ‘IRRESISTIBLE’.
The broad overall vision for ‘Medicine in my Life’ is to promote learning about contextualised real world cutting-edge science for school pupils, the wider community and general public. ‘Medicine in my Life’ is an exciting and novel way in which to engage pupils in formal education, while bringing this interesting topic to a wider audience through pop-up exhibits in a variety of public spaces across Ireland.

There are many barriers which prevent schools, communities and the wider general public accessing the work carried out by large scientific research centres. Yet community action is frequently considered a major aspect of scientific literacy (Hodson, 1998; Roth, 2003). This project offers a platform through which to translate the research and engage across formal and informal learning environments, bringing science into the community. Each exhibit developed by Transition Year groups will be unique as it will be their interpretation of the research. In addition they may exhibit on any topic area within the module, from bioavailability, to process control, to the future of medicines, or some broader topic in a related area. Students devising and presenting an exhibition is a means of transforming science from product to process (Hawkey 2001). During these exhibits’ preparation, learners will ask questions, use logic and evidence in formulating and revising scientific explanations, recognizing and analysing alternative explanations, and communicate scientific arguments.

Please contact: Dr Sarah Hayes, SSPC Education and Outreach Officer, E-mail: sarah.hayes@ul.ie ,
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