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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.

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Cover photo: **ESERA 2015 in Helsinki, Finland – many ways to reach the sky.** (Photo: P.E. Childs)

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Editorial #106

The new JCSA Science course

The new junior science course had been due to start in 2015 and was postponed to 2016 because of the dispute with the teachers' unions. The ASTI members have now rejected the agreement for implementing the new Junior Cycle and the TUI have accepted it. This means that TUI teachers and schools will cooperate in rolling out the new courses, attending CPD sessions etc. and ASTI teachers schools will not, never mind the problem in mixed schools. The ASTI decision was based on a low turnout (38%), compared to 60% for the TUI poll, and it represents a failure of democracy among the rank and file ASTI members. The revised agreement, which gave teachers almost everything they wanted, was signed off by both unions but the ASTI put it to their members without a recommendation. We now see the result of this and the low turn-out – the second-level education system is in a state of uncertainty and turmoil and everyone will suffer. The TUI is also taking industrial action in 2016 but over different issues.

Still no sign of STEM Report

I know that this report, first due in 2014, has been submitted to the Minister of Education and Skills in 2015, for her approval, so what is holding it up? Delaying reports usually means that the government doesn't want to act or make a decision about the recommendations. If STEM education is as important to the country as everyone says it is (see below), then surely the Minister, Jan O'Sullivan, should publish this report and act on its findings? However, since an election is due in Feb. 2016 it is unlikely that the report will be published before then and with a possible new government, there is a danger of it being forgotten.

Elementary chemistry

A number of items in this issue look at the chemical elements, including an article (p. 18) on the naming of the chemical elements and also the announcement that the discovery/synthesis of 4 new elements has been confirmed by IUPAC, allowing them to be named. Watch this space! There is also the latest in our Periodic Table of Limericks from Peter Davern.

Practical work

Practical work in schools is a topic of interest to chemistry teachers and this issue (p. 37) contains a reprint of a recent chapter on Practical Work in relation to the training of chemistry teachers. I think it contains a lot of useful ideas for practising teachers. The 2016 Dortmund Symposium will focus on 'Science education research and practical work', and will be held at the TU Dortmund University, 26-28 May. Registration at this biannual meeting is free but participants have to pay their own travel and accommodation expenses.

Bonding matters

Bonding has been left out of the new JCSA Science course although it is an essential idea in chemistry and one of the key ideas that should be covered in introductory chemistry. An article in this issue (p. 27) looks at how to introduce the basic ideas of bonding as part of scientific literacy and as a foundation for future science courses. Biology cannot be understood properly without a good chemical foundation, nor can the properties of materials covered in engineering courses. We need a campaign to 'Bring Bonding Back' into Junior Science.

Hon. Editor

Peter E. Childs

The importance of STEM for Ireland

"Science and technology play an increasingly important role in addressing the economic, social and environmental problems faced by the world today. That role needs the support and active engagement of the public who fund the work and are the ultimate beneficiaries of it. An engaged public is one that understands the role of science, can judge between competing priorities and arguments, encourages young people to take science, technology, engineering and maths (STEM) subjects, and feels that is has the appropriate level of engagement with, and influence upon, the researchers. SFI, as the primary investor in scientific research in this country, must form a strong relationship with the Irish people, built on trust."

Science Foundation Ireland Strategic Plan Agenda 2020

Education News and Views

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

Mary Mulvihill: champion of Irish science

In 11th June 2015 we were saddened to hear of the death at the early age of 55 of Mary Mulvihill, science journalist and author, and an advocate for the history of Irish science and technology and the role of women in science. She wrote or edited a number of books: *Ingenious Ireland* (also a website http://ingeniousireland.ie/) and *Ingenious Dublin*, and two volumes on Irish women in STEM - *Stars, Shells and Bluebells: Women Scientists and Pioneers*, and *Lab Coats and Lace: The Lives and Legacies of Inspiring Irish Women Scientists and Pioneers*. Mary also had a regular column in the *Irish Times* and she set up a company, Ingenious Ireland, which produced podcasts and ran science-focused tours. She was a founding member and first chairperson of Women in Technology and Science (WITS), and she had numerous popular science series on RTÉ radio, including *The Quantum Leap*, *The Goldilocks World* and *Left Brain, Right Brain.*

Karen Lillington wrote an excellent appreciation of Mary in the *Irish Times* for 18/6/15 (http://www.irishtimes.com/business/technology/farewell-mary-mulvihill-great-champion-of-irish-science-1.2253421). In it she wrote: *"Alongside her engaging ability to bring science, especially the history of Irish science, to life as a broadcaster and writer, Mary pretty much singlehandedly ensured that generations of notable Irish women of science and technology were not entirely forgotten, or left as mere footnotes to (men's) history."*

Minister of State at the Departments of Education and Skills and Jobs and Enterprise and Innovation, Damien English, said that Mary Mulvihill's *'infectious enthusiasm for science and her gift for communication, both as a writer and broadcaster, has greatly enhanced our appreciation of the excitement and importance of science'.*

"Her magnus opus, Ingenious Ireland is a rich compendium of Ireland's scientific and engineering heritage. It highlights on a county-by-county basis an under-appreciated part of our cultural inheritance.

Mary continually highlighted the important contributions and legacy of Irish women in science, particularly through the two books she edited on the topic. As a co-founder of Women in Technology and Science, Mary did much to support women in science today and to help them achieve their full potential.

Mary's own personal legacy to Irish science will endure well beyond her premature passing and will not be forgotten."

Minister Damien English TD

Her books and articles. chronicling the history of Irish science and the role of women, will be lasting legacy of Mary's life and work.

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Powering economic growth: attracting more young women in into science and technology

https://www.accenture.com/ie-en/~/media/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Industries_14/Accenture-STEM-Powering-Economic-Growth.pdf

This survey of the opinions of 500 girls and young women on their attitudes to STEM subjects was published in 2014. 48% said they thought science and maths were too difficult and 48% said they were more suitable for male careers. Biology (43%) was their favourite subject, followed by maths (39%).

The report identified several barriers to young women taking up STEM subjects and STEM careers:

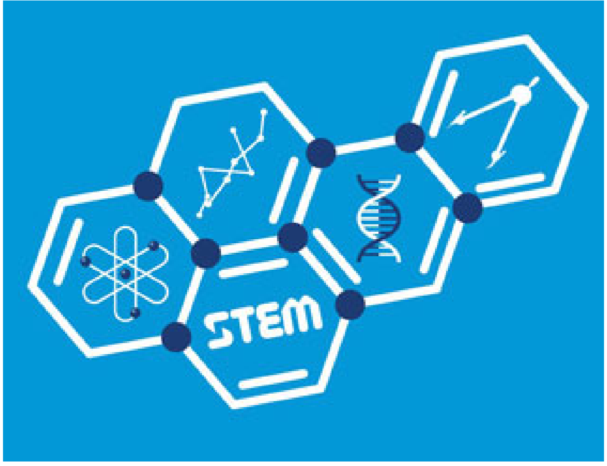
Key barriers include:

- *Negative stereotypes persist that STEM is more suitable for boys, and perceptions exist that STEM subjects are overly difficult.*
- *Parents lack information on STEM career options, yet parents are the main influencers when it comes to advising their daughters on how to define educational and career paths.*
- *There is fragmented information available about STEM careers, making it difficult for students and their parents to evaluate options.*
- *A disconnect exists between industry's skill needs and students' subject choices for their Leaving Certificate Examinations.*

The report made a number of recommendations:

1. *Maximise the impact of existing Government and Industry funded programmes by creating a more joined up approach between the relevant stakeholders.*
2. *Making STEM career information real, tangible and meaningful for parents.*
3. *A new STEM branding and communications approach for female students.*
4. *Industry continuing to design practical career programmes with school children.*
5. *Better support for Teachers and Guidance Counsellors in relation to up to date information on the range of careers available in science and technology.*

This is a report that all science teachers and parents should read. Girls make up over 50% of the LC cohort but the % doing STEM courses has dropped to 40% in 2013, compared to 47% in 2003, and only 25% of science and technology jobs are done by women. This is a very leaky pipeline and the campaign to encourage more girls to take STEM subjects and consider careers in STEM is clearly still not over.



An updated, 2.0 version of the report was published in 2015.
https://www.accenture.com/t20150730T220312__w__/ie-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_12/Accenture-Stem-Report-Final.pdf

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ASTI rejects Junior Cycle Reform

In a ballot of ASTI members in September 2015 members voted to reject the document entitled "Junior Cycle Reform - Joint Statement on Principles and Implementation (including the appendix)" by 55% to 45%. Members also voted to continue industrial action up to and including strike action by 70% to 30%. The turnout was only 38%. In contrast the TUI ballot result was 69% in favour of the reforms, 31% against, turnout was 60%.

"ASTI president Máire G. Ní Chiarba said that, while the latest proposals addressed a number of significant issues, in an era of education cuts, diminished resources for students and increased teacher workload, teachers did not have faith in the Government. "Second-level schools and teachers are delivering much more with far less. In this context teachers do not trust the Government to adequately resource and support schools as they implement the significant changes required by the Junior Cycle proposals." Ms Ní Chiarba also said ASTI members had expressed concern about the lack of clarity in the latest proposals.

"Teachers needed far more clarity and detail about how the process will operate in reality. "ASTI members are committed to educationally sound reform of the Junior Cycle. We have participated in a robust campaign including two days of strike action which led to significant advances in negotiations. The ASTI will now engage with its members in order to consider how best to pursue the outstanding concerns of teachers," she said."

Irish Independent 24/9/15
http://www.independent.ie/irish-news/education/asti-members-reject-proposals-on-new-junior-cert-31554853.html

Brian Mooney (an ASTI member) commented in his column in the *Irish Times* (19/10/15):

"We now have a ludicrous situation in schools regarding both TUI and ASTI members: second-year English students are taught the department-approved curriculum by a TUI teacher, who has had comprehensive in-service training, while in the classroom next door an ASTI member muddles through, not knowing what he/she should be teaching, and unable to attend in-service training as a result of the no vote."

Are we going to have the situation like when the new Junior Certificate course was introduced, also after industrial action, of the old and new courses being taught and examined in an overlap period? The roll-out of CPD courses and the publication of new textbooks will be affected by this uncertainty, and will do nobody any good.

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Honorary doctorate from UCC for Sr. Mercedes Desmond

On Nov. 2nd 2015 Sr Mercedes Desmond was awarded an honorary doctorate by UCC. She is a long-time member and supporter of the ISTA and nearly always made an appearance at the annual conferences, long after she retired from teaching.

Sr Mercedes Desmond**,** now 93, seen above with Aine Hyland, Declan Kennedy and Mary Mullaghy, has championed science education in Ireland for over 60 years.

Born in Donoughmore, Co. Cork, Sr Mercedes was professed as a Sister of Mercy in 1944 and despite having never studied science at secondary school, she enrolled to study Physics at UCC in 1945. In addition, she studied astronomy, which spurred a lifelong interest in the subject. She also studied chemistry and, due to the daytime rationing of gas during World War II, carried out practical work in Chemistry at night in the old science building (now Civil Engineering) in UCC.

After graduating with a B.Sc. in Physics and Chemistry, and later a HDip in Education, Sr Mercedes was assigned to St. Aloysius School in Cork city in 1949, where she taught Physics, Chemistry and Maths, as well as Physiology until the introduction of biology as a subject on the curriculum. After her appointment as principal of the school in 1978, enrolment rose to 1200 students, becoming the largest all-girls secondary school in Ireland.

In 1962 Sr Mercedes, along with a small group of others, founded the Irish Science Teachers' Association (ISTA). Sr Mercedes immersed herself in science education at local and national level, organising courses for science teachers, from glass-blowing and electronics to ecology and astronomy. She will be conferred with a Degree of Doctor of Education.

Widely esteemed for her humility, Sr Mercedes' commitment to science education has made a massive impact on standards across Ireland and beyond.
(Evening Echo article)

See also:
https://www.ucc.ie/en/about/uccnews/fullstory-609055-en.html

RDS STEM Learning Programme

The RDS STEM Learning Programme is an innovative and interactive professional development programme aimed at developing primary school teachers' pedagogical and conceptual knowledge of science and mathematics.

RDS STEM Learning was developed and piloted from 2012 – 2014 by the RDS, St Patrick's College of Education and CASTeL, SPD/DCU, and following a successful external evaluation of the project, it is now being scaled-up in partnership with SFI Discover.

Following completion of the pilot, the RDS commissioned an external evaluation which has established that *'the pilot project has delivered significant measurable impact in the areas of teacher confidence and ability, and student engagement. The pilot programme showed* *evidence of creating a community of practitioners, enhancing teachers' scientific inquiry skills and the breadth of methodologies used, increasing child-led learning, enhancing pupils' numeracy and literacy skills and ensuring the cross-curricula integration of science'*

A professional development programme with a difference - developed by teachers, for teachers - RDS STEM Learning challenges teachers to embrace children's natural curiosity and to focus on how they think, not what they know. It is also a community for shared learning amongst teachers, providing know-how and confidence in science and maths teaching. The classroom benefits of RDS STEM Learning are many: literacy and numeracy improvements; better problem solving; oral language development and integration of inquiry skills across the curriculum.

A national conference for primary school teachers on 'Creativity in Science Education', Teachers, was held on Nov. 14th 2015 in the RDS.

The RDS and SFI Discover offer a range of continuous professional development opportunities in science and maths education to primary school teachers through the **Discover Primary Science and Maths/ESERO Programme** and **RDS STEM Learning**.

In 2016 the RDS will be running two Primary Science Fairs – one in Dublin and one in Limerick.

For further information, please contact:
Ms Karen Sheeran
Science & Technology,
RDS, Foundation Department,
Ballsbridge, Dublin 4
Email: science@rds.ie

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SFI supports science outreach

Science Foundation Ireland (SFI) in Jan. 2015 announced €1.6 million in funding for science, technology, engineering and maths (STEM) educational and public engagement projects in Ireland.

Supported by the Department of Jobs, Enterprise, and Innovation (DJEI) and delivered through SFI's education and outreach programme, SFI Discover The funding will support 39 initiatives designed to encourage people of all ages to develop an active and informed interest and involvement in STEM. It is estimated that over 4.5 million people will engage with the various projects over the course of 2015.

Some of the SFI Discover funded projects include: Brain Freeze 2, a science-based animated series developed with RTE and CBBC; MakerDojo, a hardware or 'hacker' style club delivered by Tyndall National Institute, Biomaker Fórma and DesignerDojo, where the public can get hands-on with science and technology; DART of Physics, a project which encourages thousands of commuters to think about physics in a different way through a poster campaign on the DART; and a a range of family-friendly space-related experiments at Blackrock Castle Observatory, complemented by a new video exhibition focused on Irish space scientists and STEM careers.

SFI Discover's strategic partners include SciFest, The Festival of Curiosity and National Maths Week, which have also received funding.

Dr Ruth Freeman, director of strategy and communications, SFI added: "The fields of science, engineering, technology and mathematics are interlinked with the future prosperity of our economy and society. SFI is committed to stimulating interest in, excitement and debate about STEM among the general public through SFI Discover. The projects to receive funding were assessed by international experts and selected based on their potential to promote awareness and understanding of the importance and relevance of STEM to everyday life and to reach new audiences not normally engaged with STEM, as well as continuing to target existing audiences."

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New book series on chemical education:

RSC Advances in Chemistry Education

Books in this Series will review developments in areas of chemistry education internationally or report on a single educational context where the work has clear international significance; cover formal education, informal education, teacher education/development or public understanding of chemistry; and cover innovations in chemical education practice where suitable evidence of research-based evaluation is included. The Series provides volumes of high quality and significance in the field of chemistry education research for researchers and postgraduates. Topics covered will include approaches to teaching chemistry and chemistry topics; the use of technology in chemistry teaching and learning; assessment of learning in chemistry education; chemistry in the curriculum; chemistry teacher preparation and development; initiatives to improve public understanding of chemistry; and developments in research methodology as applied in chemistry education.

Print ISSN: 2056-9335
Series ISSN: 2056-9335

Keith Taber
University of Cambridge, UK
Editor-in-Chief

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Primary Science takes off

For the last 7 years there has been a Primary Science fair running alongside the Young Scientists Exhibition in the RDS in Dublin. This year (2016) 120 schools took part in Dublin and a second Primary Science Fair was held in Limerick 15-16th January. This was hosted by Mary Immaculate College and involved 60 primary schools. In the two venues over 5,000 children took part. It is intended to repeat the double venue next year and extend it to other centres in subsequent years, as some schools had to be turned down.

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Concern over high drop-out rates

A report from the HEA highlights the problem of student dropout after one year in science/technology/ICT courses in Universities but more worryingly in the IoTs, at certificate and pass degree level. A particular focus of concern is poor performance in maths and the problems students face in adjusting to third level courses. The bonus points for higher maths and the introduction of Project Maths, with less emphasis on some traditional topics, may be contributing to this fall-out. The concern was also expressed that students are getting less careers advice and are not always aware of and prepared for taking science and maths courses at third level. As more and more students stay on at school and go on to third-level courses, the intake must inevitably cover a wider range of ability. Whatever the causes, the high dropout rate represents an unacceptable result for the students concerned, their parents and the colleges. It is something that needs addressing urgently.

http://www.irishtimes.com/news/education/concern-over-drop-out-rates-in-computer-science-courses-1.2491751

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Dortmund Symposium

The 2016 Dortmund Symposium will focus on ‘Science education research and practical work’, and will be held at the TU Dortmund University, 26-28 May. Registration at this biannual meeting is free but participants have to pay their own travel and accommodation expenses.
For more information:
http://www.idn.uni-bremen.de/chemiedidaktik/symp2016/Flyer%20SS%202016.pdf

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New book for training chemistry teachers

A new book, *A Guidebook of Good Practice for the Pre-Service Training of Chemistry Teachers,* is now available free-of-charge online for those involved in training chemistry teachers or for chemistry teachers who would like a refresher. One of the chapters, on practical work, is included in this issue (pp 37-50).
The chapter titles are:

- ***Chapter 1:*** *Educational Theories and How Students Learn Chemistry; Practice what you Preach.*
- ***Chapter 2:*** *Taxonomies of Learning.*
- ***Chapter 3:*** *Understanding and Using Chemistry Curricula for Effective Teaching.*
- ***Chapter 4:*** *Planning a good chemistry lesson.*
- ***Chapter 5:*** *Practical work in chemistry and its goals and effects.*
- ***Chapter 6:*** *Design of Learning and Assessment Tasks.*
- ***Chapter 7:*** *The Use of Pedagogical Content Knowledge in Teacher Education.*
- ***Chapter 8:*** *Students’ alternative conceptions and ways to overcome them.*
- ***Chapter 9:*** *Chemistry and context.*
- ***Chapter 10:*** *Designing Courses on Nature of Science and History of Science.*
- ***Chapter 11:*** *Inquiry Based Chemistry Instruction.*
- ***Chapter 12:*** *Continuous Professional Development.*

It is available for download at:
http://www.ec2e2n.net/publication/msct2

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ISTA Conference comes to Limerick

The 2016 ISTA Conference will be held in the Limerick Institute of Technology, Limerick from 8-10 April. This is an excellent venue and the organising committee, chaired by Maria Sheehan, have devised an interesting programme. For more details see:
http://www.istaconference.com/

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In memoriam:

At the end of 2015 the education and scientific communities in Ireland were shocked by two early and unexpected deaths.

Professor Peadar Cremin, former President of Mary Immaculate College, Limerick died on 1st December. Peadar originally taught science/science education in MIC and in the 1980s worked with staff from Thomond College on the Primary School Science project (PSSP), one of Ireland's first attempts to bring science back into primary schools. He was the first male and the first lay President of MIC and was responsible for its major expansion.

On the 4th December the sudden death of Dr Paraic James, DCU was announced. Paraic was a good friend to science education and was involved in the organisation of the Science Olympiads and often mentored and travelled with the teams. He was a well-known organic chemist worked in the Chemistry Department at DCU and was a former President of the Institute of Chemistry of Ireland. His sudden death was a shock to his colleagues and friends and a major loss to DCU and to the chemical community in Ireland.

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"As Ireland continues to meet its aspirations to be a world-leading centre for the industries of tomorrow in technology, science and engineering, one challenge that is cited again and again by enterprises large and small is that of acquiring and producing the best talent in these crucial industries. That this talent gap in the knowledge industries is a global one is well documented, but it is also now widely recognised that women are vastly under-represented in the science and technology-based careers that will drive the industries of tomorrow and shape all our futures."
Accenture Report, 2014

STEM job areas

http://www.qualifax.ie/index.php?option=com_content&view=article&id=623&Itemid=261
STEM workers are driving Ireland's innovation and competitiveness by generating new ideas, new companies, new industries and attracting multinational investment. This is also part of a global trend. According to the European Commission, demand for STEM professionals and associate professionals is expected to grow by around 8% between now and 2025, much higher than the average 3% growth forecast for all occupations. Employment in STEM-related sectors is also expected to rise by around 6.5% between now and 2025. Research shows that there is clear need to do more to inspire young people to study STEM subjects in order to take advantage of job opportunities in these fields. The future success of the Ireland's economy will require increased numbers of skilled workers with Science, Technology, Engineering and Mathematics (STEM) qualifications.
A few years ago Government asked the Research Prioritisation Group to identify a number of priority areas around which future investment in publicly performed research should be based.
This provides a useful map to where the STEM-related jobs of the future should be:

* Future Networks & Communications
* Food for Health
* Sustainable Food Production and Processing
* Data Analytics Management, Security & Privacy
* Digital Platforms, Content & Applications
* Marine Renewable Energy
* Connected Health & Independent Living
* Smart Grids & Smart Cities
* Medical Devices
* Manufacturing Competitiveness
* Diagnostics
* Processing Technologies and Novel Materials
* Therapeutics - synthesis formulation, processing and drug delivery
* Innovation in Services and Business Processes □

Micro and Macro Pedagogy for Science Education

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Introduction

Policy makers nationally and internationally have recognised the influential role of science and its capacity to promote economic growth (DETI, 2009; European Commission, 2007; Osborne and Dillon, 2008). As such, the decline in numbers of students opting for science, in particular the physical sciences, in Ireland has become a concern. Although curricular change and teacher education have been the traditional methods of targeting improved scientific capacity amongst students (Bell et al., 2009), as key stakeholders, universities have responded with a surge of science outreach strategies and interventions (Davison *et al.,* 2008; DETI, 2009; Regan, 2009) to support Irish teachers. We argue that teachers and teacher educators could play an active role in science outreach by considering micro and macro pedagogical innovations. The proposed micro pedagogy involves the application of effective lesson hooks, and macro pedagogy involves embedding outreach strategies into science lessons, as a part of recognizing that the daily work of science teachers is conscious science promotion. This article will highlight the significant potential of teachers and teacher educators in promoting science and science careers.

Science Outreach Review

In response to the concern about the declining student interest and academic achievement in the sciences, the authors of this article have been working together in the area of science outreach for almost a decade. As teacher educators, we wanted to play a role in researching outreach and designing innovative approaches that would acknowledge the context of science teaching in Ireland. While we knew that there were diverse science outreach initiatives across the island of Ireland, there was little communication or coordination between these stakeholders, and little information about the work they do. In response to this, we organized (in conjunction with other colleagues: Marketing, NUI Galway, and Forfás, Engineers Ireland) the first all-island conference in STEM Outreach in 2007 which ignited national dialogue between outreach providers, practitioners, policy makers, teachers, teacher educators, and scientists, regarding science outreach, best practice and evaluation opportunities.

A key outcome from the first conference was the publication of a report (Davison *et al.,* 2008) that mapped the diverse nature of STEM outreach initiatives, the majority of which (54%) were educational providers in third level institutions. Data also revealed the challenges in terms of greater integration of multiple partners, a more comprehensive evaluation of activities and in particular the need for a shift away from simply providing information about science or activities in science, and instead advancing a strategic approach that attempts to influence social behaviour towards science engagement. Conferences over the four following years introduced examples of science outreach from internationally recognised practitioners, teachers and researchers, including theories of social marketing aimed at voluntary behavioural change.

While we believe that the series of national science outreach conferences broadened knowledge of both theory and practice in the science outreach community, we felt that teachers and teacher educators were not considered key stakeholders. More often than not we regularly encountered research (Aikenhead, 2006; McCoy *et al.*, 2012, Osborne and Dillon, 2010) and outreach practitioners questioning the way science is taught in the classroom. As stated by Zachary, et al., (2000, p.1), “The way science and math are taught critically affects their [student] interest and later participation in science and engineering. If this is the case, then the responsibility falls primarily on the teaching profession”. In response, outreach strategies are often designed to address a deficiency, which can position teachers as passive, silent partners in science outreach

(Gomes, 2015).

It is easy to understand how one might trace a path from unenthusiastic, underperforming science students to similar kinds of teachers. We concur with the argument that many primary teachers often do not have a background in science and therefore may be less prepared to teach foundational elements of science (Eivers and Clerkin, 2013), and that there are likely to be some poor teachers in the system. However, we think that it is much too simplistic and reductionist to blame science teaching when all qualified teachers have been taught pedagogical theory, and have the opportunity to attend regular professional development. As professional educators, primary and secondary teachers in Ireland are committed to quality teaching and learning, and as such, can play a significant role in promoting science.

Science outreach providers are less constrained by curricular and institutional structures and are therefore in a unique position to craft inspiring and unexpected science lessons which can supplement primary and secondary science education. These initiatives are highly valued by teachers, and unarguably function to promote science interest in students. However, if science teachers and science teacher educators are to play a greater role in the promotion of science, there is a need to consider approaches that do not function as additional curricular content, but rather are designed as innovations at the level of pedagogy. We are proposing the possibility of micro injections of pedagogy in the form of strategic and effective lesson hooks, as well as macro pedagogy which involve rethinking science teaching as inherently an outreach practice.

Micro Pedagogy: Lesson Hook Research

Lemov (2010) defines a *hook* as a short, introductory, pedagogical moment that captures what is interesting and engaging about the material to be covered. As teacher educators, we regularly tell our pre-service teachers about the benefits of lesson hooks, but we frequently found that, if hooks were used at all, the quality was often quite poor. In response to this, we worked with some of our pre-service teachers to research and collaboratively design effective lesson hooks for Junior Certificate-level science teaching (McCauley *et al.*, 2016). This research offered us a greater understanding of the degree of detail and consideration required in the design of truly effective lesson hooks (McHugh and McCauley, 2016). Actively engaging students from the outset of a lesson has the potential to trigger and re-trigger student interest and may result in a more persistent, intrinsic personal interest in the topic.

The Interest Theory that drives this discussion is based on Hidi and Renninger's (2006) Four Phase Model of Interest Development (see Figure 1 below), which illustrates a process of moving learners from where their interest is triggered, Situational Interest (SI), toward an intrinsically-generated Personal Interest (PI). *Situational Interest* refers to 'focused attention and the affective reaction that is triggered in the moment by environmental stimuli' (Hidi and Renninger, 2006, 113). SI plays a vital role in *triggering student interest*, whereas to *maintain attention*, PI is pivotal (Schraw *et al.*, 2001). The model represents situational and individual interests in terms of cognitive and affective processes. Personal Interest is characterised by an intrinsic desire to understand and re-engage with a particular topic that persists over time (Hidi and Renninger, 2006; Hidi, 1990). SI is a necessary precursor for PI (Bergin, 1999).

Figure 1: The Four Phase Model of Interest Development (Hidi and Renninger, 2006)

The pre-service teachers discovered that adding a video clip to the beginning of a lesson has a limited capacity to engage students after the clip has ended. Understanding Interest Theory was a key component in the development of effective and engaging science hooks. The hooks which the pre-service teachers collaboratively designed, were made into Chemistry, Physics, and Biology iBooks (also *as Gaeilge*) to serve as resources for science teachers nationally and internationally (www.sciencehooks.scoilnet.ie). A short series of science hooks, Kitchen Chemistry, for primary science will be launched in Spring 2016.

Our experience of collaboratively designing science lesson hooks played a significant role in raising our pre-service teachers' awareness about what is involved in capturing the attention and interest of science students and how they might be able to move students to see that it is in their interest to engage in science.

We are not proposing lesson hooks as a panacea to transform the science classroom. However, we strongly believe that designing and using strategic and effective lesson hooks is a part of a teacher's routine pedagogical practice that considers knowledge, skill and affect to arouse student interest, not only in the lesson that is to unfold, but also in science more broadly. Recognising the value and potential of a well-designed lesson hook is the first step science teachers can take in applying sound pedagogical principles in the service of promoting science.

Macro Pedagogy: Hybrid Outreach Relationships

We would argue that outreach is inherently a part of science teachers' work, not an additional burden. However, teacher education rarely makes explicit reference to the fact that the very way teachers teach, their application of sound pedagogy and their explicit enthusiasm for their subject, are tools to promote interest in science, and in science careers. Focusing on teaching the curricular content in the limited time available, and ensuring students are well prepared for exams, often make it difficult for teachers to regularly demonstrate their enthusiasm for science. However, through our regular collaborations with science teachers, in the classroom, school corridors, staffrooms, continuous professional development (CPD) events, the zest for science and teaching science is evident.

While it may seem like a daunting task for teachers both to teach and provide outreach, it may be comforting to know that they have allies in the outreach community. Consciously weaving outreach theories into teaching science may be facilitated by building on the extant network of science outreach providers and practitioners, whose mandate is to support teachers and inspire students. Gomes and McCauley (2013) have argued for the growth of hybrid conversations and collaborations between teachers and outreach practitioners to open up a 'third space', where both parties can work together toward a common goal of engaging students in science in society. This is in line with the NCCA's (2013, p. 18) vision of science students developing an appreciation of the Nature of Science, within the Proposed New Junior Science specification. This hybrid relationship, where teachers and outreach practitioners collaborate on outreach strategies, may have a greater chance of moving students toward personal interest in science, while at the same time making the promotion of science an ordinary part of the way science is taught.

Conclusion

Science teachers and science teacher educators have a lot to contribute to the promotion of science but are currently on the margins of the diverse outreach initiatives. However, subtle micro and macro pedagogical shifts may be a viable way to foster wide-spread personal interest in science without significant demands on the teacher. Science teacher educators may impart these pedagogical approaches to the next generation of science teachers through a focus on lesson hook design and science outreach theory as pedagogical practice. We hope our future research will introduce these approaches to science teachers in Ireland. Lesson hooks and conscious outreach teaching approaches facilitated by new hybrid relationships between teachers and outreach practitioners are small steps toward a common goal of the advancement of science and Irish society.

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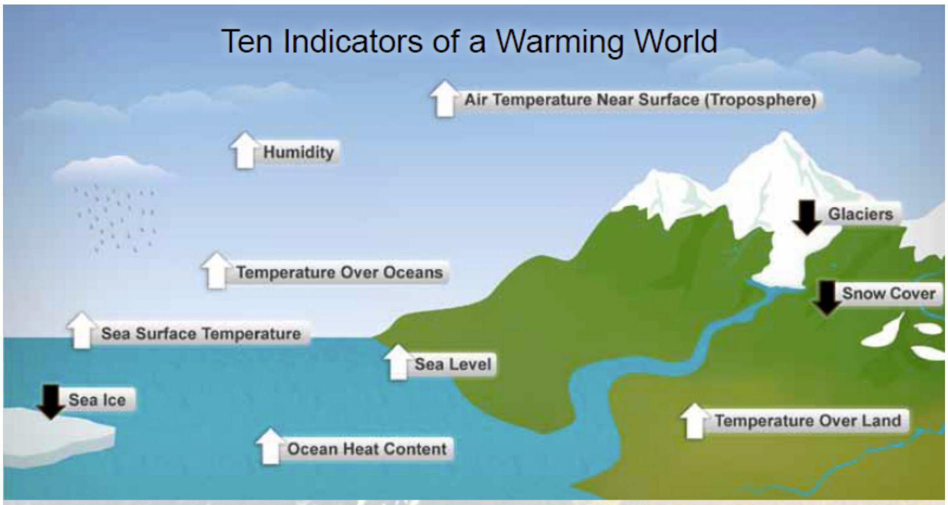


Seven of these indicators would be expected to increase in a warming world and observations show that they are, in fact, increasing. Three would be expected to decrease and they are, in fact, decreasing.

ChemData: focus on climate change statistics and data

Coal-fired power stations

The Times 2/12/15

The results of a recent survey of coal-fired power plants showed that worldwide 2,440 new plants are planned, emitting 6.5 billion t of CO_2 per year, which would raise CO_2 emissions by 5 times the level consistent with a 2°C temperature rise. In other words, if all these were built there would be no hope of controlling the rise in global temperature.

Location	Existing	Planned	Total
EU28	468	27	495
Turkey	56	93	149
S. Africa	79	24	103
India	589	446	1,035
China	2,363	1,171	3,534
Japan	90	45	135
Philippines	19	60	79
S. Korea	58	26	84
Total analysed		2,011	
World total		2,440	

Top 10 CO_2 producers (2013)

Country	Production/Mt CO_2
1 China	10.330
2 USA	5,300
3 EU average	3,740
4 India	2,070
5 Russia	1,800
6 Japan	1,360
7 Germany	840
8 Canada	550
9 =UK	480
9= Brazil	480

What would happen in China and India, the world's most populous countries were to catch up the USA in per capita emissions? China already produces twice as much CO_2 as the USA in total but less than half per capita.

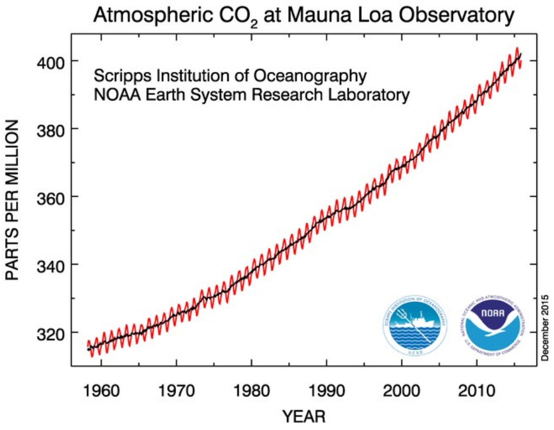
Top 10 per capita CO_2 producers (2013)

Country	Production/ tpc
1 Australia	16.9
2= USA	16.6
2= Brazil	16.6
3 Canada	15.7
4 Russia	12.6
5 Japan	10.7
6 Germany	10.2
7 UK	7.5
8 China	7.4
9 EU average	7.3
10 India	1.7

Atmospheric CO2 levels at Mauna Loa, Hawaii

Source:
http://www.esrl.noaa.gov/gmd/ccgg/trends/
Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/).

In Nov. 2015 the CO_2 levels had reached 400 ppm and since 1960 have increased over 25% (see graph below).



Climate change: the evidence

There is a debate about whether or not climate change is happening and whether or not it is due to human activity or is a natural phenomenon. There is a strong lobby by sceptics but the majority of scientists accept that the evidence we have supports global warming and thus climate change, even though we cannot say unequivocably that it is due to human activity there is a high probability that it is. A useful website which refutes the sceptics' claim by reviewing the scientific evidence is http://www.skepticalscience.com/. What is does is to take the skeptics' claims in turn and answers them. An example is given below.

It's not happening
"...these global warming studies that now we're seeing (are) a bunch of snake oil science." (Sarah Palin)

The 2009 State of the Climate report of the US National Oceanic and Atmospheric Administration (NOAA), released in mid-2010, brings together many different series of data "from the top of the atmosphere to the depths of the ocean". The conclusion? All of these independent lines of evidence tell us unequivocally that the Earth is warming. (The 2014 edition of this report is at https://www.ncdc.noaa.gov/news/state-of-the-climate-2014) Since 2009 the evidence has got stronger not weaker.

The very accessible 10-page summary (http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/2009/bams-sotc-2009-brochure-lo-rez.pdf) examines the trends for 10 key climate indicators using a total of 47 different sets of data. All of the indicators expected to increase in a warming world, are in fact increasing, and all that are expected to decrease, are decreasing:

The 10 indicators (see diagram on p.12) are:

1. **Land surface air temperature** as measured by weather stations. You know all those skeptic arguments about how the temperature record is biased by the urban heat island effect, badly-sited weather stations, dropped stations, and so on? This is the only indicator which suffers from all those problems. So if you're arguing with somebody who tries to frame the discussion as being about land surface air temperature, just remind them about the other nine indicators.
2. **Sea surface temperature.** As with land temperatures, the longest record goes back to 1850 and the last decade is warmest.
3. **Air temperature over the oceans.**
4. **Lower troposphere temperature** as measured by satellites for around 50 years. By any of these measures, the 2000s was the warmest decade and each of the last three decades has been much warmer than the previous one.
5. **Ocean heat content,** for which records go back over half a century. More than 90% of the extra heat from global warming is going into the oceans – contributing to a rise in…
6. **Sea level.** Tide gauge records go back to 1870, and sea level has risen at an accelerating rate.
7. **Specific humidity,** which has risen in tandem with temperatures.
8. **Glaciers.** 2009 was the 19th consecutive year in which there was a net loss of ice from glaciers worldwide.
9. **Northern Hemisphere snow cover**, which has also decreased in recent decades.
10. Perhaps the most dramatic change of all has been in **Arctic sea ice.** Satellite measurements are available back to 1979 and reliable shipping records back to 1953. September sea ice extent has shrunk by 35% since 1979.

Science isn't like a house of cards, in that removing one line of evidence (e.g. land surface air temperature) wouldn't cause the whole edifice of anthropogenic global warming to collapse. Rather, "land surface warming" is one of more than ten bricks supporting "global warming"; and with global warming established, there is a whole other set of bricks supporting "anthropogenic global warming". To undermine these conclusions, you'd need to remove most or all of the bricks supporting them – but as the evidence continues to pile up, that is becoming less and less likely.

Basic rebuttal written by James Wight

If you go to the original article (link below) then you can click on links to access the evidence.
http://www.skepticalscience.com/evidence-for-global-warming-basic.htm

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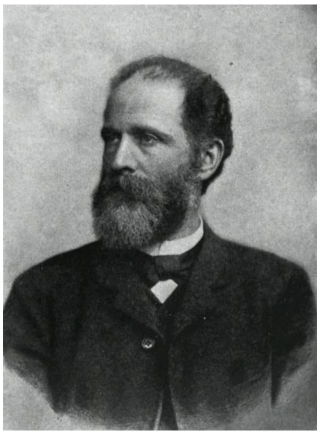
The Instrument Makers No. 9:

Victor Meyer 8/Sept/1848 – 8/Aug/1897

Adrian Ryder tutorajr@gmail.com



Victor Meyer

Victor, or sometimes spelt Viktor, Meyer was born in Berlin on the eighth of September 1848 to a Jewish couple, Jacques Meyer (b. 7/Sept/1816 – d. 5/June/1892), a well-to-do trader and cotton printer, and his wife Bertha (neé Meyer but no relation) (b. 10/Jan/1822 – d. 27/Oct/1896), who had married in 1845. The couple had four children: Richard, Victor, Otto and Clara. Not being strictly raised in the Jewish faith, Victor married Hedwig Davidson, a Christian, on 2/Mar/1873 and had their five children, all girls, raised in that faith. The girls' names were Ella, Gretel, Lotte, Lilly and Irmgardt.

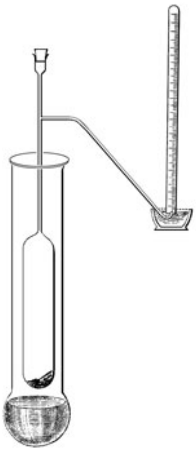
At the age of ten Victor began his schooling and was entered in the same class as his older brother, by two years, Richard. In 1865, influenced by Richard's chemistry studies in Heidelberg University, Victor began his studies in that subject at Berlin University under the direction of August Wilhelm von Hofmann (8/Apr/1818 – 5/May/1892). After just one semester Victor moved to Heidelberg and studied under the direction of Robert Wilhelm Eberhard Bunsen (30/Mar/1811 – 16/Aug/1899), taking organic chemistry lectures from Emil Erlenmeyer (28/Jun/1825 – 22/Jan/1909). Bunsen did not require research work and Victor, who had topped his class in all the courses, when only aged eighteen, was conferred with a Ph.D. (Summa cum Laude) in 1867, which opened doors for him in the chemical establishments of the time. On the 13/May/1867 Victor sent a three word telegram to his parents. The words were "Summa cum Laude" and was signed "Victor Dr. phil."

Victor remained with Bunsen in Heidelberg for a year engaged on the analysis of various spring waters and teaching some Ph.D. students, many of whom were older than himself. Returning to Berlin, Victor joined the research group headed by Adolf Baeyer from 1868 to early 1871 and did, among other work, an investigation into the composition of camphor ($C_{10}H_{14}O$) and of the chloral hydrates.

The Franco-Prussian conflict broke out on July 19th 1870 and although Victor was of age to be conscripted, he did not want to enlist as he was eager to pursue his scientific researches. However, he spent sessions at the Lazarett Hospital at St. Thomas's Church, often three times a day, helping his father care for the war wounded. The war brought an unexpected benefit to him when Wilhelm Sklarek, the editor of the '*Naturalist*' was called to arms. Sklarek asked Victor to take over the running of the magazine and the control of the young researchers who wrote for it. The fact that Victor had no experience of the fields involved, Botany, Zoology, Geology etc., did not hinder him at all but gave him great experience of dealing with researchers, which was to stand him in good stead with his own students in the years to come.

At the end of 1870 Baeyer got a request from Hermann von Fehling (9/6/1812 – 1/7/1885), the director of the chemical laboratory at Stuttgart Polytechnic, to recommend a young chemist as associate professor, whose job was to lecture on organic chemistry and to guide those studying for higher degrees. Victor was just 23 years of age on his appointment. The rise in his fortunes continued rapidly, and the following year saw him move to the Zurich Polytechnikum in Switzerland as Professor ordinarius.

Victor remained in Zurich for thirteen years and it was during 1878 that he developed his famous apparatus for the determination of vapour density. He also did much work on the halogens. In 1871 he discovered that the molecules of iodine and bromine dissociated into their individual atoms at high temperatures. In 1872 he devised what is known as the Victor Meyer test to distinguish between primary, secondary and tertiary alcohols by the formation of nitroalkanes from alkyl iodates and silver nitrate. In the same year he was the first to identify the aliphatic nitro compounds and he coined the term stereochemistry. Later, in 1878 he discovered the oximes (compounds containing the C=NOH group) and studied the isomerism associated with these compounds. In 1882, while lecturing and demonstrating on benzene derivatives, a failure in an experiment led him to investigate the reason why and he thereby discovered thiophen (C_4H_4S) in the impure sample of benzene being used. In 1885 he was appointed Professor of Chemistry at Göttingen University, Germany and on the retirement of Bunsen in1889 was appointed to the Chair of Chemistry in Heidelberg.



Victor Meyer's apparatus

Victor's famous apparatus is shown above. A small stoppered bottle (known as a Hofmann bottle), containing a measured amount of volatile liquid, is dropped into the unit on the left which has sand on the bottom to break the fall. The unit is now tightly stoppered. The water in the outside vessel has been heated and this causes the liquid in the stoppered bottle to evaporate, displacing the stopper and further displacing liquid filling the container on the right, so as to give the volume of the evaporated liquid. On correcting for temperature and pressure the vapour density is calculated from the displaced liquid.

Victor is credited with the discovery of an effective method for the production of the infamous sulphur mustard (mustard gas), $(Cl\text{-}CH_2.CH_2)_2S$, in 1886, which was used by the Germans in 1917 with horrific effect on allied forces in WWI and by various other countries up to the 1960's. Meyer did not intend to produce a war gas and he had no role in its later use.

Between 1884 and 1893 he produced six very well-received books on chemistry. He enjoyed travelling abroad nearly every year, and also wrote a travel guide to Tenerife and Las Palmas. Apart from these books, he published more than three hundred scientific papers. In recognition of his experimental prowess, the Royal Society presented Victor Meyer with the Davy Medal in 1891.

A complete workaholic throughout his career, Victor suffered a series of illnesses, including diphtheria in October 1888, and nervous breakdowns in the last years of his life, probably due to inhaling the fumes arising from his high temperature studies of Iodine and Bromine. He had to take drugs to sleep which exacerbated his condition and finally in a fit of depression on the night of the 7/8 of August 1897,Victor committed suicide by the ingestion of cyanide, leaving a note of apology to his family. Victor Meyer was buried in the Bergfriedhof of Heidelberg.

Victor Meyer's tomb in Heidelberg

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https://archive.org/stream/victormeyerleben00meyeuoft#page/n7/mode/2up

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Elementary Chemistry

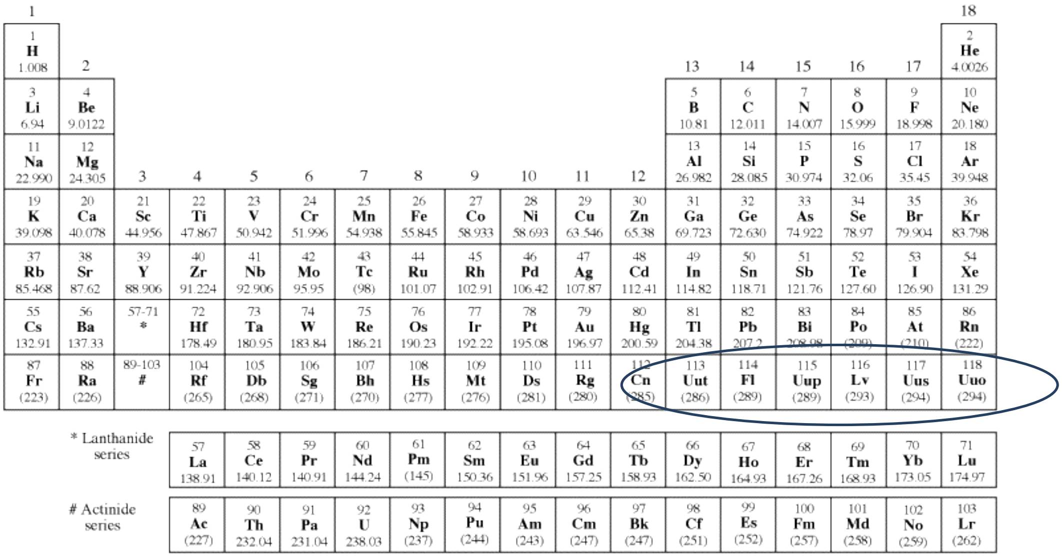
On 30th Dec. 2015 the IUPAC Committee approved the recognition of elements 113, 115, 117 and 118, thus officially completing period 7 of the Periodic Table. The existence of these new elements, all of which are synthetic, has been known for years but the evidence for their existence has only just been verified. 113 was made in Japan and the other 3 jointly by labs in Germany and the USA. The scientists who made the new elements now get the privilege of suggesting new names. Their suggestions are submitted to the International Union of Pure and Applied Chemistry (IUPAC), who will approve or reject the suggestions. The new names are then put out for public consultation for 5 months, approved by the IUPAC Council and finally announced to the public, together with their new symbols. The 7th row will then be complete. New elements can be named after people (who must be dead), places, or from mythology.

For the moment, the elements are named after their number (see Periodic Table below): element 113 is called ununtrium (which means 113-ium), and has the symbol Uut. Element 115 is referred to as ununpentium or Uup; 117 is called ununseptium or Uus; and 118 is called ununoctium or Uuo. These will be the heaviest members of groups 13, 15, 17 and 18. Elements 114 and 116 were approved by IUPAC in 2011 and named flerovium, Fl and livermorium, Lv.

Some good candidates for new names: John Dalton (daltonium), Michael Faraday (faradayium), Ada Lovelace (lovelacium)…. Any ideas? No element starts with the letter J.

After the 4 new elements were announced there was a campaign to call one of them Lemmium after the heavy metal rock star. Another proposal was to name one in honour of Terry Pratchett http://www.independent.co.uk/news/people/petition-launched-to-name-new-element-octarine-in-honour-of-terry-pratchett-a6803866.html).

"That's what should make the four new elements so exciting. They help us to look at the universe with awe. Their discovery completes the seventh row of the periodic table. Okay, so we don't think about the periodic table too often. Maybe we remember it as a bizarrely coloured wall chart we had to memorize in the 8th grade, or as a set of columns and rows whose mysteries we briefly unlocked to pass undergraduate chemistry, or even as the cleverly deployed inspiration for the opening credits in "Breaking Bad."
But the periodic table is more than that. It's a near-perfect index to the various properties of the elements, and in that sense a window into creation. When the Russian chemist Dmitri Mendeleev organized his early version in the 1860s, he was ridiculed by his fellow scientists for believing such a chart could predict the properties of elements yet undiscovered. But he was right.
And the periodic table continues to predict. The newly approved elements fit in exactly as they're supposed to. That's exciting."
Stephen L. Carter
http://www.bloombergview.com/articles/2016-01-08/in-celebration-of-4-new-elements



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																	2 **He** 4.0026
3 **Li** 6.94	4 **Be** 9.0122											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.085	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.723	32 **Ge** 72.630	33 **As** 74.922	34 **Se** 78.97	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.95	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57-71 *	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89-103 #	104 **Rf** (265)	105 **Db** (268)	106 **Sg** (271)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (276)	110 **Ds** (281)	111 **Rg** (280)	112 **Cn** (285)	113 **Uut** (286)	114 **Fl** (289)	115 **Uup** (289)	116 **Lv** (293)	117 **Uus** (294)	118 **Uuo** (294)
	* Lanthanide series		57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
	# Actinide series		89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

Symbols of the elements

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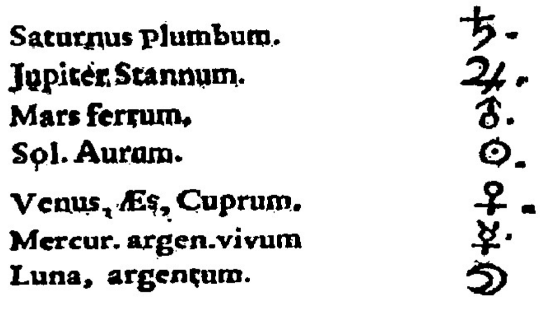
Four systems of notation have become so universal that they now surpass most linguistic barriers. These are (1) mathematical signs and symbols, (2) the International System of Units, (3) the traditional musical notation, and (4) the symbols for chemical elements [1]. Imagine the world with a different symbol for the plus sign in various languages, or a different symbol for hydrogen. Although chemists worldwide now enjoy the peace of universally accepted symbols for all elements, which are not subject to translation, it took a long time for such a convention to root.

The dawn of element symbols

Symbols for various chemical substances are older than the discipline of chemistry. The ancient symbol for water, the upside-down triangle, □, is among the most recognizable examples of this practice. Even though the modern concept of the chemical element emerged only in the late 18th century with Lavoisier, substances which we now recognize as proper chemical elements have had standard symbols for a long time. The seven metals upon which modern civilization was founded were traditionally linked to the seven 'planets'. Consequently, the astrological symbols of the 'planets' were used also for these metals. Gold was depicted alchemists as an empty circle with a dot in the middle (representing Sun), silver as the crescent moon, iron as a spear and shield (representing Mars), and so on. (Figure 1)



Saturnus plumbum. ♄.
Jupiter Stannum. ♃.
Mars ferrum, ♂.
Sol. Aurum. ☉.
Venus, Æs, Cuprum. ♀.
Mercur. argen.vivum ☿.
Luna, argentum. ☽

Figure 1. The seven 'planets' and their symbols traditionally has been associated with the seven known metals (1652) [2]

These symbols, however, were not reserved only to medieval alchemists. Swedish chemist Torbern Bergman (1735-1784), one of the most esteemed chemists of his time, used these symbols in his work (Figure 2), and so did Antoine Lavoisier.

Figure 2. Bergman's symbols of the chemical elements (1785) [3] Although the symbols are unaltered from the cited source, their layout has been modified

Not long after Bergman, the English chemist John Dalton (1766-1844) introduced a new set of symbols for elements in *A New System of Chemical Philosophy* (1808-1810). In a reference to spherical atoms, Dalton writes:

> *"the elements [...] are denoted by a small circle, with some distinctive mark"* [4].

Phosphorus was represented with a symbol now better known as the Mercedes hood ornament, and the alchemist's symbol for gold – that circle with a dot in the middle - was to became the symbol for hydrogen. Dalton also combined the element symbols to create composite formulas for chemical substances, something which was almost never done before. Not everyone liked his pictorial symbols (see Figure 3) and Dalton's system soon entered obscurity. Some forty years later, Michael Faraday noted that these symbols had not the slightest use in chemistry. Nevertheless, they had provided an important stepping stone which soon revolutionized the chemical nomenclature.

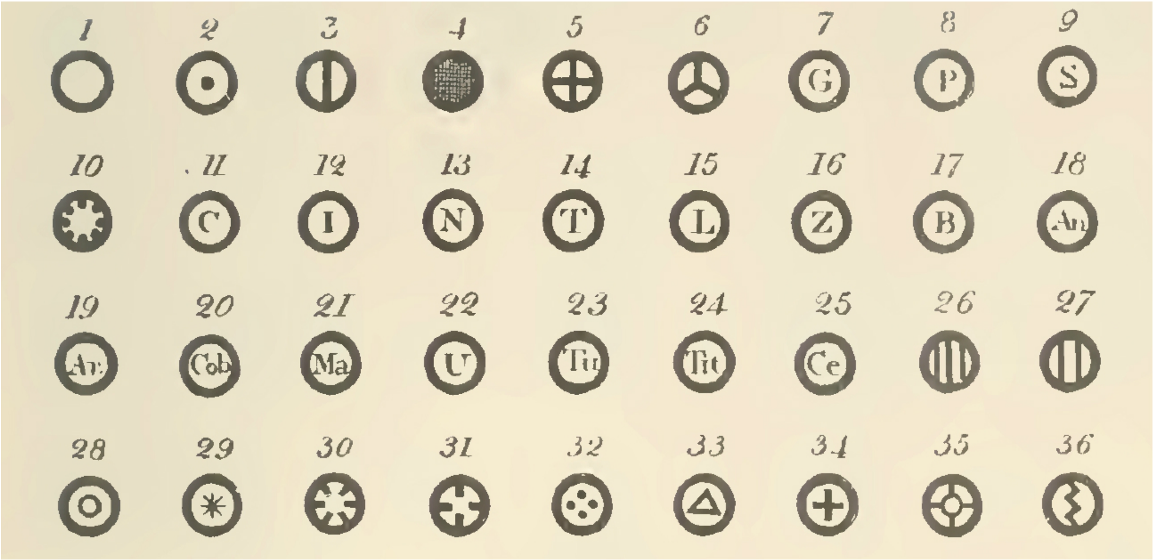


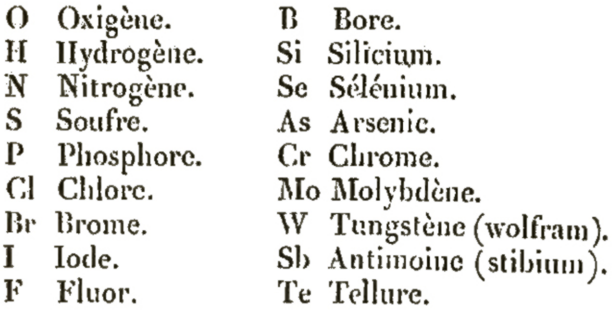
Figure 3. Dalton's symbols of the chemical elements (1810) [5]

The Gutenberg of chemistry

In 1813-1814, the noted Swedish chemist Jacob Berzelius (1779-1848), published a series of articles suggesting that *"the chemical signs ought to be letters, for the greater facility of writing, and not to disfigure a printed book"* [6]. This simple notion is regarded as one of Berzelius' most important contributions to the develop-ment of chemistry, at least by his biographer Söderbaum.

> *"I shall take, therefore, for the chemical sign, the initial letter of the Latin name of each elementary substance : but as several have the same initial letter, I shall distinguish them in the following man-ner :–*
> *1. In the class which I call metalloids, I shall employ the initial letter only, even when this letter is common to the metalloid and to some metal.*
> *2. In the class of metals, I shall distinguish those that have the same initials with another metal, or a metalloid, by writing the first two letters of the word.*
> *3. If the first two letters be common to two metals, I shall, in that case, add to the initial letter the first consonant which they have not in common : for example, S = sulphur, Si = silicium, St = stibium (antimony), Sn = stannum (tin), C = carbonicum, Co = cobaltum (cobalt), Cu = cuprum (copper), O = oxygen, Os = osmium, &c."* [6]

Berzelius' nomenclature (Fugure 4) had the advantage that it was founded on a logical set of rules in contrast to Dalton's arbitrary choice of pattern-filled circles. Consequently, Berzelius' system could be codified and then applied for any future element. Like many things of this world, however, Berzelius' system is not without its flaws. For example, how do we decide on the symbols for stibium and stannum? Which element gets "St"? Another problem lies in the chosen language for the symbols. Since Latin is an ancient language, the 'Latin names' for newly discovered elements, such as the hydrogen, needed to be invented.



O	Oxigène.	B	Bore.
H	Hydrogène.	Si	Silicium.
N	Nitrogène.	Se	Sélénium.
S	Soufre.	As	Arsenic.
P	Phosphore.	Cr	Chrome.
Cl	Chlore.	Mo	Molybdène.
Br	Brome.	W	Tungstène (wolfram).
I	Iode.	Sb	Antimoine (stibium).
F	Fluor.	Te	Tellure.

Figure 4. Berzelius' typographical symbols of the chemical elements (1831) [7]
Although the symbols are unaltered from the cited source, their layout has been modified.

The use of typographic symbols was not new with Berzelius. In fact, half of Dalton's symbols for elements were encircled initials and abbreviations of their English names. In this way, Dalton's nomenclature was positioned exactly in the middle between the pictorial systems of the past and the typographic systems of the future. Concurrently with Berzelius, Thomas Thompson

(1773-1852) also attempted to introduce typographic symbols of elements. His series of six articles appeared alongside with Berzelius' in the same journal. Thompson wrote:

> *"I presume the method of denoting the number of atoms combined will be intelligible to every reader. It is denoted by figures prefixed to the initial letters of the substances uniting together"* [8].

Thompson used slanted lower-case letters to denote elements, yet it was impossible to deduce the element from his symbols. Thompson used "m" for manganese, molybdenum, mercury, and magnesium, "c" for carbon, cobalt, and so on. Even his sporadic use of two-letter symbols did not solve the problem: "si" was used for both silver and silicon.

Although, as we have seen, Berzelius was not the first to employ typographic symbols, this time a typographical revolution of sorts did have a lasting impact on chemistry. To further simplify his already concise chemical formulas, in 1818 Berzelius introduced a special symbol for oxygen: a typographic dot [10]. This re-finement was later extended to sulphur (the comma), his discovered selenium (the dash), and also tellurium (the plus sign). In this most-unique notation, the reaction of tellurium with oxygen could be shown as "+ + .. = +:". This modification clearly did not outlast its time. Nevertheless, despite Dalton's own characterization of Berzelius' symbols as 'horrifying' and 'abominable', they are used in chemistry to this day [11].

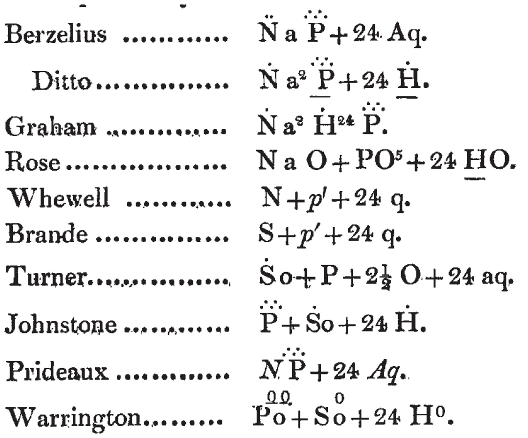
Typographical symbols of chemical elements were established in the early 19th century and they soon spread throughout the textbooks of chemistry. This spread, however, was not an exemplary adoption of international standards. Rather, a garden variety of individual notations soon emerged. This is a brief story of their eradication.

What's in a symbol

One of the most salient features of Berzelius' nomenclature included the combining of symbols in the fashion AnBm. This notation appeared unacceptable to many 19th century chemists who advocated an algebraic interpretation of chemical symbols. Thus, contrary to the mathematical notation, the exponent in the chemical formulae indicated the total number of atoms and not raising powers. Likewise, juxtaposition of symbols in chemical formulae indicated addition and not multiplication. The 1830s Britain witnessed fierce quarrels over these issues and many chemists, Dalton and Faraday included, supported the Reverend William Whewell's algebraic notation (nA + mB) over the Berzelian AnBm or AnBm.[12] Whewell was an influential Victorian thinker, and was soon to become the Master of Trinity College, Cambridge. We know that history has not favoured the opponents of Berzelian notation as their arguments were rather subjective. John Prideaux of Plymouth aptly noted in 1831, that we have no fear of understanding the number 534 as 5×3×4, nor has there ever been any confusion among chemists over 'square of hydrogen' in H_2O.[13] In addition, the quest to interpret chemical language using mathematics is somewhat arbitrary. The 'chemical equations', for example, do not resemble mathematical equations. After all, two molecules of hydrogen and a molecule of oxygen does not equal two molecules of water. Yet, chemistry textbooks often place the equality sign between the two as in $2H_2 + O_2 = 2H_2O$ without fear of confusion.

Lost in tranlsation

During the most part of the 19th century, scientific conventions often stopped at the national borders. The French would use the symbol Az for nitrogen (from the word azote), whereas the English would not give up the symbol N. As several historians have aptly noted, chemistry textbooks of this period teach us more about the psychology of the 19th century chemists than about the chemistry itself. Even more troubling than the nationalistic nomenclatures is the fact that scientists were often inconsistent with the use of the chemical symbols. It is not hard to find examples where different symbols are used for the same element in various pages of the same publication. In his seminal 1813 multi-part publication ,Berzelius indiscriminately uses both Cb and Cl for columbium (niobium), Sb and St for antimony, just to name two examples. Ironically, it was this publication that championed the standard symbols for elements. Likewise, Berzelius adopted Po in 1813 for potassium, whereas both Ps and K are used in his 1838 textbook. Overall, the nomenclature of the chemical symbols was far from uniform, to say the least. One French textbook would use O, B and F for gold, barium, and iron, whereas another would use these symbols for oxygen, boron, and fluorine. Likewise, Z stood for zirconium, zinc, and nitrogen interchangeably across many British textbooks of the 1830s. In 1833 editor of the *Philosophical Magazine*, Richard Phillips, commented on the use of the chemical symbols and summarized a "specimen of confusion" with no less than ten systems of notation (Figure 5).[14] One wonders if physics or mathematics were also once plagued by such nomenclature wars.



Berzelius	$\ddot{N}a\overset{\cdot\cdot\cdot\cdot\cdot}{P}+24\,Aq.$
Ditto..............	$\dot{N}a^2\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{P}}+24\,\underline{\dot{H}}.$
Graham	$\dot{N}a^2\dot{H}^{24}\overset{\cdot\cdot\cdot\cdot\cdot}{P}.$
Rose..................	$NaO+PO^5+24\,\underline{H}O.$
Whewell	$N+p'+24\,q.$
Brande	$S+p'+24\,q.$
Turner.................	$\dot{S}o+P+2\tfrac{1}{2}\,O+24\,aq.$
Johnstone	$\overset{\cdot\cdot\cdot\cdot\cdot}{P}+\dot{S}o+24\,\dot{H}.$
Prideaux	$\mathit{N}\overset{\cdot\cdot\cdot\cdot\cdot}{P}+24\,\mathit{Aq}.$
Warrington.........	$P\overset{00}{o}+S\overset{0}{o}+24\,H^0.$

Figure 5. Ten systems of chemical symbols circulating in the early 19th Europe. This "specimen of confusion" shows the constitution of the common sodium phosphate.[14]

Although IUPAC did much to standardize the chemical nomenclature, the symbols of elements remained subject to translation until well into the 20th century. In the early 20th century, the annual reports of the International Atomic Weights Commission served as a reference list not only for the atomic weights of all elements, but also for their international symbols. The 1947 IUPAC Atomic Weights Table, for example, lists different symbols between the French and English tables for four elements – beryllium (Gl and Be), niobium (Cb and Nb), hafnium (Ct and Hf) and tungsten (Tu and W).[15] Compared to the situation a century earlier, this is an immense improvement towards uniform symbols.

The christening

IUPAC is not in the business of naming chemical elements, the discoverers are. However, a discovery, or now more commonly – the synthesis - of chemical elements is rarely an event with a clear victor and therefore a formal mechanism is crucial in order to "assign" the priority of discovery. This duty has traditionally been carried by IUPAC and since 1987 by a joint working party formed by IUPAC and IUPAP. Since its inception, the joint group has conferred the coveted 'elemental status' to many elements, most recently to elements 114 and 116. Once the discovery is confirmed, the assigned discoverers are then formally asked to suggest a suitable name and a symbol, which are then reviewed by IUPAC. There are a few official guidelines for suitable names of new chemical elements [16], but none for symbols other than being made of two letters and, obviously, unique.

Today all symbols of elements are coined from their English names, yet the current Periodic Table features plenty of historical exceptions, much to the frustration of high-school students worldwide. In fact, there are eleven historical misfits – sodium, potassium, iron, copper, silver, tin, antimony, tungsten, gold, mercury, and lead. The symbols of these elements are derived from their Latin, Greek, or German names.

Unlike the proposed name of an element, the proposed symbol is often subjected to additional scrutiny and even rejection. Thus, Margueritte Perey's suggested symbol for francium, Fa, was rejected by IUPAC in 1947, E was rejected for einsteinium in 1955, and Lw was rejected for lawrencium in 1963 (although it is not hard to find books that still use "Lw"). Most recently, the proposed symbol for copernicium, Cp, was rejected by IUPAC in 2009.

Although the nationalism among chemists in the 19th century is not a flattering aspect of science, history repeated itself at the height of the cold war. For decades after the 1960s the element 104 was known as kurchatovium (Ku) in the USSR and as rutherfordium (Rf) in the USA. Elements 105 and 106 had also a difficult path in securing a unique name. As a result, a system of formal temporary names was introduced by the IUPAC in 1979 to facilitate the scientific discourse of as yet unnamed elements.[17] This, however, did not eradicate the controversies in naming new elements. In fact, the naming controversy grew even bigger and reached a peak in the period 1994-1997, when no international agreements could be reached for the names and symbols of elements 104-109. Indeed, it is hard to imagine a blow to the chemical nomenclature that is harder than a renaming of an element. The great trans-fermium element impasse of 1994-97 notwithstanding, the last time this happened was in 1949 when columbium was renamed niobium, in order to put an end to a century-old dispute of the naming practice of the element 41. (For example see Figure 6.)

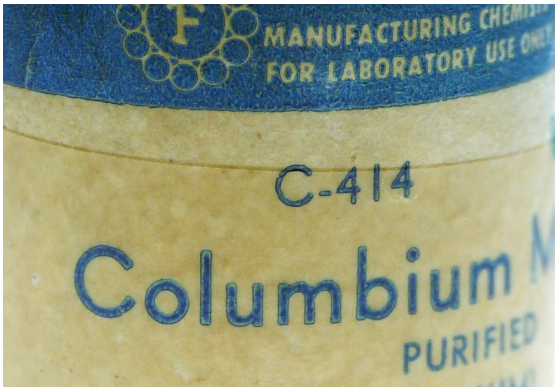


Figure 6. This bottle of columbium metal is a vivid reminder that nothing can avoid change – not even a well-established name and symbol of an element.

It is interesting to note that today isotopes are numbered, whereas elements are named. We have carbon-12, carbon-13, and carbon-14. This was not always the case. In the early 20th century, when the isotopes were not yet fully understood, they too were named. In 1923, for example, IUPAC endorsed the names radon (symbol Rn), thoron (Tn), and actinon (An) for isotopes 222, 220, and 219 of the element 86, respectively [18]. Decades later, radon became the name for this element. Today, the special names deuterium (D) and tritium (T) remain as historical vestiges of this tradition.

During the twentieth century the IUPAC symbols for all known chemical elements gradually became the international standard. With the house all in order, the proposed symbols for all newly discovered elements were now scrutinized more than ever, and the nomenclature was set for elements which have not even been yet discovered. This is the story of the 20th century.

The forbidden symbols

Most aspects of our culture undergo change. Newspapers change their design, corporations change their logos, and countries even change their flags. Symbols of chemical elements are no exception to this rule of life. The inaugural 1903 International Atomic Weights Report, for example, contains quite a few symbols that are no longer in use. There is A for argon, Rd for radium, Yt for yttrium, Gl for glucinum (beryllium), and Cb for columbium (niobium). In addition, other elements have had their symbols changed over the years. By the late 1950s, argon officially become “Ar” and element symbols became finally standardized.

It has been long accepted that the names of elements should be unique and should not recycle some older names that have fallen out of vogue long ago. Arguably, the same logic should also apply to symbols of elements.[19] This kind of convention, however, cannot extend too deep into the past because far too many letter combinations were indiscriminately used during the 19th century textbooks. While it is indeed impractical to restrict our choice of new symbols by lingering too deep into the recycle bin of history, it seems fair that any overlap between the International Atomic Weight Tables dating from 1902 and the subsequent IUPAC recommendations is off-limits. Table 1 lists the symbols of elements once used in the International Atomic Weight Tables, which are no longer used by IUPAC and therefore are unlikely to enter the Periodic Table ever again.

Table 1. Symbols of elements that are no longer used by IUPAC.

Symbol	Previous use	Example reference*
A	argon	CIAAW 1902-1955
An	radon-219 (actinon)	CIAAW 1923
Cb	niobium (columbium)	CIAW 1903-1947
Cp	lutetium (cassiopeium)	used by many for lutetium in the past
Ct	hafnium (celtium)	CR 1947
Gl	beryllium (glucinium)	CIAAW 1903-1925
Ha	hassium (hahnium)	IUPAC 1994
Io	thorium-230 (ionium)	CIAAW 1923
J	iodine	CIAAW 1925,

		CIAAW 1902
Jl	dubnium (joliotium)	IUPAC 1994
Mv	mendelevium	CR 1955
Nt	radon (niton)	CIAAW 1912-1922
Rd	radium	CIAAW 1903, 1906-1907
Sa	samarium	CIAAW 1906-1922
Tn	radon-220 (thoron)	CIAAW 1923
Tu	tungsten, thulium	CR 1947, CIAAW 1902
X	xenon	CIAAW 1902
Yt	yttrium	CIAAW 1903-1907, 1910-1922

* CIAAW: International Atomic Weight Tables, CR: Comptes Rendus IUPAC. CIAAW-1902 refers to the 1902 German edition of the first CIAAW table preceding the 1903 Inaugural CIAAW report.

Interestingly enough, because all symbols of chemical elements are now formed from the letters in their English names, and because all symbols have to be unique, this may result in a situation when the inability to form a proper symbol does pre-empt the choice of a suitable name of an element. For example, it would be impossible to name a future element after the Estonian capital Tallin (tallinium) because no unique two-letter symbol starting with "T" can be formed. This is because all letter combinations – Ta, Tl, Ti, Tn, Tu, and Tm – are either currently used by IUPAC or have been used in the past, as in the case of Tu which was used for thulium by IUPAC in the 1940s, and Tn which was used for an isotope of radon in the roaring twenties. Although this obscure roadblock is not likely to be encountered in naming of some future element, it nevertheless shows the intricate kinship between the symbols and the names of elements.

Brave new elements

It is in our human nature to seek behind what is known in order to discover new treasure, new worlds, or new chemical elements. The question is – how do we talk about the elements yet to be discovered? What name and symbol shall be given to elements that do not yet exist? Mendeleev had an idea back in the 19th century.

> *"So as to avoid introducing new names for the unknown elements into science, I shall designate them by the name of the nearest lower analog of the odd or even elements in the same group, and place in front of this name a Sanskrit numeral (eka, dvi, tri, tschatour, etc.). The unknown elements of the first group will be called eka-cesium (Ec = 75), dvi-cesium (Dc = 220), etc. If niobium, for example, were not known, we would call it eka-vanadium."*[20]

Although Mendeleev's nomenclature was good for Sanskrit lovers, and is still used informally, it relies on the Periodic Table. If elements are rearranged in the Periodic Table, their temporary names change thus avoiding unnecessary confusion. A case in point is rhenium which was dubbed tri-manganese by Mendeleev but now appears only two places below manganese. Also, protactinium used to be eka-tantalum before it was properly placed among the actinides.

In 1979, IUPAC adopted a naming system of all future elements which relies on their atomic numbers [21]. In this system, the name of a newly discovered (or undiscovered) element is formed by stringing prefixes of Greek and Latin words of the numerals which form the atomic number of the element (see Table 2). The portmanteau name is always followed by the suffix "-ium". The symbol of an element is formed by stringing together the first letters of the corresponding prefixes. The systematic nomenclature is straightforward. For example, until a proper name will be adopted (if ever), the element with atomic number 2176 is officially called biunsepthexium (symbol Bush), which literally means "the 2176th" in the made-up hybrid list of scientific Latin and Greek.

Table 2. IUPAC systematic nomenclature for naming newly discovered or not yet discovered elements

Numeral	Prefix[a]	Symbol
0	nil	n
1	un	u
2	b(i)	b
3	tr(i)	t
4	quad	q
5	pen(t)	p
6	hex	h
7	sep(t)	s
8	oc(t)	o
9	en(n)	e

a. Letters in parenthesis are omitted if they are followed by a repeating letter (eleison rule). For example, the element with atomic number 902, or simply the element 902, is named ennilbium, and not ennnilbiium.

One would never guess, but chemical nomenclature can indeed be amusing. As the previous example hinted, there is plenty of room for play with the IUPAC nomenclature.[22] Does the roman pontiff have his personal chemical element (yes, the element 5859)? Which elementary particle is also a symbol of an element (Photon)? We will end the series on element symbols on this note.

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This article originally appeared in three parts in Chemistry International and are repirnted by permission of IUPAC and the author. The original references to the articles are:

J. Meija. Symbols of the elements. *Chem. Intl.* 2014, 36(1), 20-21 (doi: 10.1515/ci.2014.36.1.20)

J. Meija. Symbols of the elements (part II). *Chem. Intl.* 2014, 36(3), 18-20 (doi: 10.1515/ci.2014.36.3.18)

J. Meija. Symbols of the elements (part III, concluded). *Chem. Intl.* 2014, 36(4), 25-26 (doi: 10.1515/ci.2014.36.4.25)

□

A Limerick Periodic Table

Created by Peter Davern
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Carbon, C

From CO_2 to CHOs and back to CO_2,
And so this ‘vital force’ of life transfers from me to you.
Its PET scan pinpoints cancers,
While its Dating undoes ‘chancers’.
Bond-friendly with its neighbours so, each day brings compounds new.

To carbon our world’s fate is bound, through oil and gas and coal,
Organic to our way of life, our true synthetic soul.
With nanotubes and fullerene,
And diamonds, graphite, thin graphene,
This humble rhyme, too short by far its virtues all extol.

From $\overset{\text{‘see oh too’}}{CO_2}$ to $\overset{\text{‘see aytch ohs’}}{\text{CHOs}}$ and back to $\overset{\text{‘see oh too’}}{CO_2}$,
And so this ‘vital force’ of life transfers from me to you.

The “Carbon Cycle”: During photosynthesis within the leaves of plants, sunlight provides the energy that drives the reaction of atmospheric carbon dioxide gas (CO_2) and water (H_2O) to form carbohydrates – organic sugars made up of carbon, hydrogen and oxygen. As a fuel, these “CHOs” represent our primary source of energy. So when this fuel is “burnt” within our bodies’ cells, it produces CO_2 (and water vapour) which returns to the atmosphere as we exhale - ready to begin the cycle all over again.

When German chemist, Friedrich Wöhler, successfully synthesised urea (NH_2CONH_2) in his laboratory in 1828, it was the first time that an otherwise naturally occurring (or 'organic') chemical had been prepared without the involvement of living organisms – urea is a by-product of protein metabolism in the body and ends up being excreted in urine. Up until then, the so-called Vital Force Theory had held that such 'organic' chemicals could only be produced by living organisms with the aid of some mysterious 'vital force' within them. The synthesis of urea sounded the death knell for the Vital Force Theory and heralded the birth of Organic Chemistry…the chemistry of carbon.

Its PET scan pinpoints cancers,

Positron Emission Tomography (PET): A nuclear magnetic imaging method that uses carbon (or other elements, like nitrogen or fluorine) to identify the location of cancerous cells in our bodies.

While its Dating undoes 'chancers'.

Carbon dating has been used extensively to authenticate or refute the provenance claims of so-called "ancient" artefacts.
[chancer: noun (slang) *a con man or rogue]*

Bond-friendly with its neighbours so, each day brings compounds new.

Its position on The Periodic Table makes carbon a particularly versatile element, not only capable of forming bonds with other carbon atoms, but also with atoms of many other elements.

To carbon our world's fate is bound, through oil and gas and coal,
Organic to our way of life, our true synthetic soul.

From plastics to medicines (not to mention fuels and energy), today's world relies heavily on the synthetic organic chemistry of carbon – a reliance destined to be challenged in the years ahead as the planet's finite reserves of carbon-based fossil fuels become ever scarcer.

With nanotubes and fullerene,
And diamonds, graphite, thin graphene,

Just some of the different physical forms (a.k.a. "allotropes") of carbon.

This humble rhyme, too short by far its virtues all extol.

I guess this line speaks for itself!

Chemists love making bonds

Peter E. Childs
Chemistry Education Research Group, Dept. Of Chemical and Environmental Sciences, University of Limerick, Limerick
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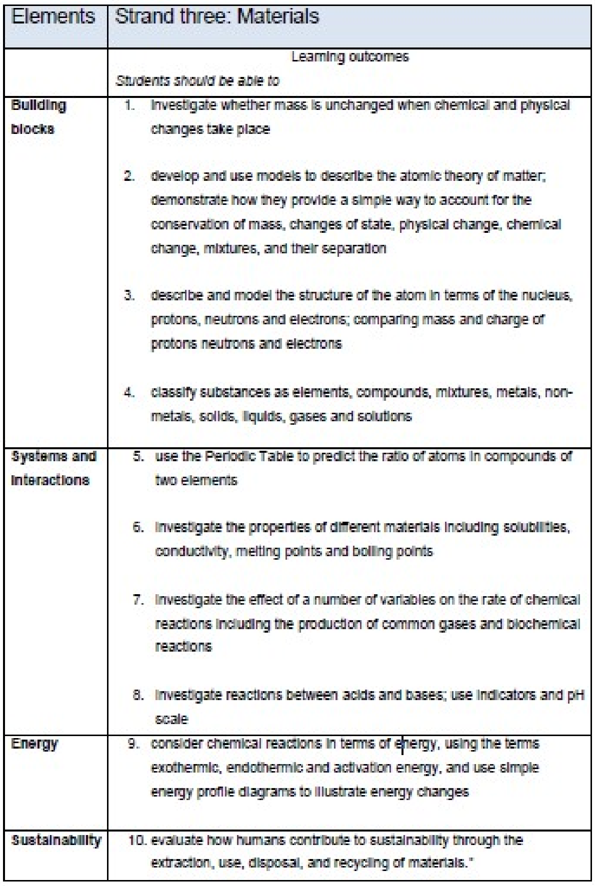
You cannot live without it!

Bonding is a core chemical idea and you can't think about Chemistry for long without bringing in bonding. (See the article in *CinA!,* #104, p. 6-12, Winter 2014 on 'The Big Ideas of Chemistry.') Is it possible to have an introductory Chemistry course which does not include some coverage of bonding as one of the key chemical ideas? To leave it out is to omit a key building block, even perhaps a foundation stone of the subject. Table 1 shows the current learning outcomes for the proposed syllabus.

Table 1: Learning outcomes for strand three The Chemical World (formerly Materials)



Elements	Strand three: Materials
	Learning outcomes *Students should be able to*
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. investigate the properties of different materials including solubilities, conductivity, melting points and boiling points 7. investigate the effect of a number of variables on the rate of chemical reactions including the production of common gases and biochemical reactions 8. investigate reactions between acids and bases; use indicators and pH scale
Energy	9. 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	10. evaluate how humans contribute to sustainability through the extraction, use, disposal, and recycling of materials."

Bonding has been left out of the Junior Cycle Student Award (JCSA) draft science specification and I think this is a mistake. It was omitted, I think, based on the mistaken belief that chemical bonding is too complicated for beginners. I want to show that we can teach bonding in a simple but not a simplistic way.

Bonding and the link between structure and bonding and properties (chemical and physical) is central to Chemistry. From the previous article on 'The big ideas in Chemistry' (*CinA!,* issue 104, p. 6-12, Winter 2014) it is clear that bonding is a central and foundational concept in Chemistry. How can we explain the difference between the physical and chemical properties of sodium, salt, sugar and sand without bringing in bonding? These examples are representative of four types of solid defined by the type of bonding holding them together (Table 2).

(Note: In an earlier set of articles in *Chemistry in Action!* I looked at the interplay between bonding and the properties of materials.
Chemical bonding and the structure and properties of solids: Part 1. *Chemistry in Action!,**10**,23-28 1983*
Chemical bonding and the structure and properties of solids: Part 2. *Chemistry in Action!,***12**, 18-25, 1984
Chemical bonding and the structure and properties of materials: The properties of engineering materials: Part 3, *Chemistry in Action!,* **34**, 3-11, 1991)

Table 2: Four types of bonds – four types of solids

Type of solid	Metal	Ionic salt	Molecular solid	Covalent solid
Examples	Sodium, copper	Sodium chloride, magnesium bromide	Sugar, urea	Sand (silicon dioxide),zinc sulfide
Bond holding solid together	Metallic bonds	Ionic bonds	Molecular	Covalent
Other bonds	-		Covalent within molecules	

Each of these types of solid has specific and typical properties determined by their bonding. Metals (and alloys) form metallic solids. Non-metals form either molecular or covalent network solids. Ionic bonding is found in compounds of metals and non-metals. Covalent compounds (between two non-metals) may either form molecular or covalent network solids but the vast majority form molecular solids. Molecules are held together by strong covalent bonds, which are unaffected by melting or boiling – the molecules stay intact. The molecules themselves are bonded to each other in the solid (or liquid) state by molecular (van der Waals) bonds. These are weak and easily broken, so that molecular substances generally have low melting points and boiling points. Covalent solids, however, consist of atoms bonded by strong covalent bonds (e.g. diamond or silicon dioxide) and can be elements or compounds.

Bonding makes all the difference between the different types of materials.

In the past bonding was presented and taught in Junior Science as an abstract and theoretical way, with over-simplification (e.g. ionic bonding involving only a pair of ions) and simplified ideas were taught as definitive (e.g. the octet rule). Not surprising then that bonding was poorly understood and the misunderstandings and misconceptions persisted into LC Chemistry and on into university Chemistry. Having taught bonding at university for many years, I always found it hard to remove the deeply-entrenched ideas carried over from school and very effectively drummed into students by teachers. The importance of chemical bonding for understanding the structure of matter and the properties of substances should surely be introduced in their first Chemistry course (as part of Junior Science), if only at a simple and elementary level. A deeper treatment should be left to LC Chemistry and an even deeper one for university. There should be a spiral approach to bonding, whereby it is introduced at a simple level and then progressively made more complex, without having to contradict the simple ideas, but rather to build on them.

As most LC students (~85%) do not study LC Chemistry, the only place they will meet the basic ideas of Chemistry, including bonding, is in the Junior Science course. Bonding is also needed to understand parts of LC Biology and students who take Biology must depend on what they have studied in Junior Science, unless they also take LC Chemistry. I often say there is more and more difficult Chemistry in LC Biology than in LC Chemistry e.g. in the Kreb's cycle. The majority of students who do not take further Chemistry courses are dependent on what they studied in Junior Science for their future scientific literacy in Chemistry. They may find to their horror that they have to take Chemistry courses at third level, for which they are badly underprepared. Many science, health-related and technology courses require Chemistry at least in first year. Also many primary teachers' only exposure to chemical ideas was in Junior Science, as few of them have done LC Chemistry.

The proposed draft Science specification for the JCSA does **not** mention bonding. I believe we need to include a 5th outcome under the Building Blocks of the Materials strand. [To be fair and consistent the 'Materials' strand should be renamed 'The Chemical World', to match 'The Biological World' and 'The Physical World', so as to clearly identify the strand as Chemistry, and following the consultation this has now been done.]

I suggest the following outcome: *'To describe the nature and role of chemical bonding in determining the physical properties of elements and compounds and materials.'*

Bonding and the properties of materials

A simple approach to materials through the four main types of solids - metallic, ionic, molecular and covalent – would introduce JCSA students to the four main types of chemical bond and their effect on the properties of substances.

Melting point is determined by the strength of bonding holding the constituent particles together in a solid. Weak bonds result in low melting points and strong bonds in high melting points.

Metals like copper or sodium (or metal alloys) conduct electricity because of the nature of the bonding in the solid (and when melted in the liquid), which involves mobile or free electrons which can conduct electricity.

Ionic salts like sodium chloride conduct electricity when melted or when dissolved in water because they are made of positive and negative ions, which can move around in the liquid state or in solution and conduct electricity.

A molecular substance like water, sugar or urea does not conduct electricity in the solid or liquid states, or in solution, because they contain no ions or free electrons, and all the electrons are locked up in strong bonds in neutral molecules. The same is true of covalent solids like diamond or sand, where the electrons are locked up in strong covalent bonds between atoms.

Thus the basic properties like melting point, electrical conductivity and hardness are determined by the nature and strength of the chemical bonding between the constituent particles.

I would suggest that rather than adding the complication and over-simplification of electron dot diagrams to explain electron sharing (covalent bonding) and electron transfer (ionic bonding), as in the current JC Science syllabus, that bonding be left at the introductory level of identifying different types of substance and their bonding and relating this to their characteristic bonding. A more detailed but still simplified treatment could then be left to LC Chemistry.

The idea that melting or boiling molecular solids like water (ice → water → steam) does **not** break the strong covalent bonds that hold the atoms in a molecule together, but only the weak molecular bonds between molecules, is an important idea. It undermines the common misconception, which persists in many students to degree level, that when water boils it breaks up into hydrogen and oxygen atoms. Figure 2 illustrates what happens when water changes state. Such diagrams should be used to undermine the alternative conceptions and reinforce the correct conceptions.

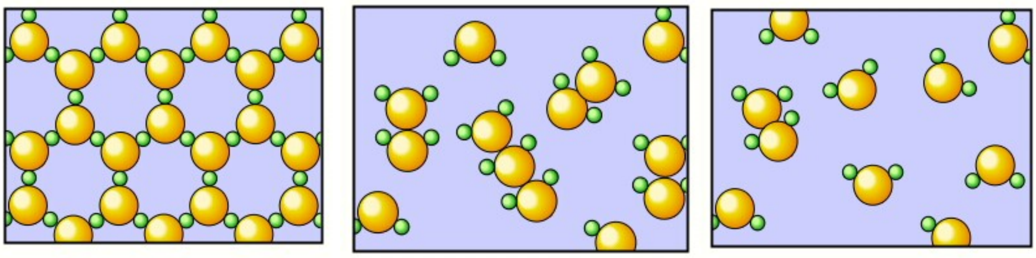
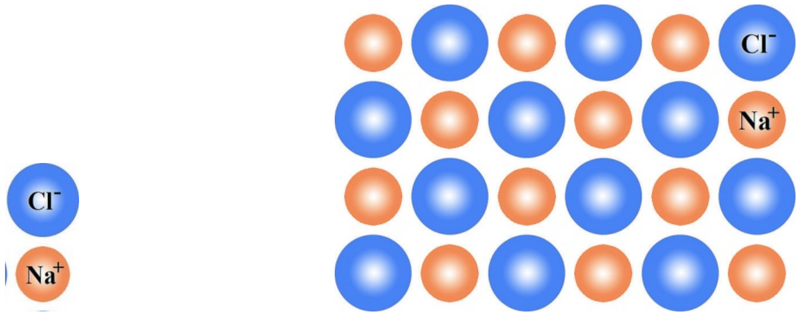

(a) Ice – solid water **b) Water – liquid water** **c) Steam – gaseous water**

Figure 1 Water: the states of matter (http://www.physicalgeography.net/fundamentals/8a.html)

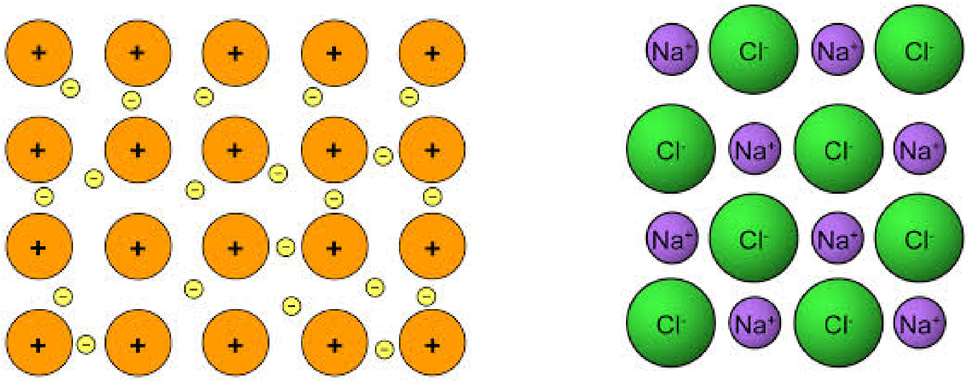
Likewise, many students are convinced, because of the treatment in JC science and textbooks, that sodium chloride exists as an ionic molecule, Na^+Cl^-, which it doesn't. (Figure 2)



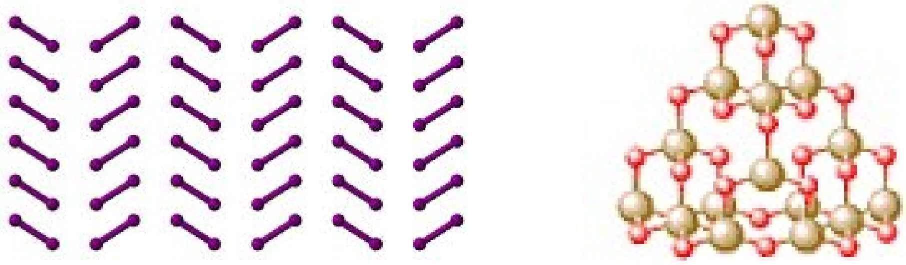
a) A common, wrong view **b) A better view (but should be 3D)**

Figure 2: The ionic structure of sodium chloride (Source: https://commons.wikimedia.org/wiki/File:NaCl_crystal_structure_D2.jpg)

Simple diagrams (see Figure 3) can be used to illustrate and distinguish between the different types of bonding in solids, without going into detail about the different bonds, and relating them to their properties. The teacher should identify where the valence (outer) electrons are located in the diagrams and what sort of bond holds the particles (atom, ions or molecules together).



a) Metallic bond in metallic solids **b) Ionic bonds in ionic solids**



c) Molecular bonds in molecular solids (and covalent bonds within the molecules) **d) Covalent bonds in covalent solids**

Figure 1: Four different types of chemical bond in solids

Understanding the different types of bonds will help students to understand why reactions involving ions (e.g. acid and base, precipitation) are fast, as they only involve existing ions combining with each other and no strong bonds have to be broken. Whereas reactions involving molecules are slow and need heat because we have to break strong covalent bonds first in the molecules, before we can make new bonds to form new molecules. (Cooking is a good example of such reactions.) Similarly most metals do not react with oxygen in air unless heated because we have to break strong bonds in the metal and in the oxygen molecules before they can combine to form ionic bonds, forming the metal oxide.

Breaking bonds requires energy and the stronger the bond the more energy is required; making bonds releases energy and the stronger the bond the more energy is released. Thus bonds do not store energy, contrary to what biologists are taught, and when energy is released in a reaction as heat e.g. in burning fuel, it is because there is an excess of heat produced (by bond making) over that consumed (in bond breaking) during the chemical reaction. These are basic ideas which should be covered in a first Chemistry course.

What is a chemical bond? How do atoms bond together?

The nature of chemical bonding is more difficult to explain simply but worth trying to do. An atom is held together by the attraction of the positive charge on the nucleus (due to protons) and the negative charge on the electrons (forming an electron cloud around the nucleus and arranged in shells or energy levels). The structure of the atom has already been covered. The outermost electrons (valence electrons) of atoms are the ones most easily removed and used and thus are the ones involved in forming chemical bonds. At the simplest level all bonding is electrostatic in origin – the attraction of opposite charges. Students are familiar with magnets – where two like poles (N or S) repel each other and two different poles (N and S) attract each other. This is a model (not the same thing) of electrostatic attraction, but gives a good picture of bonding.

Demonstration of attraction and repulsion

We can demonstrate electrostatic attraction and repulsion (usually part of the Physics course). Suspend a plastic straw from a paperclip using a thread, so that it can rotate freely. Charge the straw by rubbing it on dry hair. Charge a second straw in the same way and bring ti close to the first straw. It should rotate away as like charges repel. Recharge the first straw again and charge a glass rod. When this is brought up to the straw the straw is attracted not repelled. Like charges repel and unlike charges attract.

Another way of doing it uses plastic straws, a cocktail stick and a lump of plasticine/marla (or a clothes peg, as shown below). Stick a cocktail stick through the centre of a plastic straw, and support a second straw vertically in a lump of plasticine or a clothes peg. Insert the cocktail stick into the vertical straw so the first straw can rotate freely. Bring a third straw up against the rotatable straw. Nothing happens. Now rub the rotor straw and the third straw with paper to charge it electrostatically. When you bring one straw close to the rotor it is repelled and rotates. **Like charges repel.** Now rub a wine glass or glass rod with a cloth. When this is brought near the rotor it is attracted not repelled and now moves in the opposite direction. The charges are now opposite and attract each other. **Unlike charges attract.**

You can easily find videos on You Tube showing this effect.
https://www.youtube.com/watch?v=jcGoK270ibA
https://www.youtube.com/watch?v=57s7e9Dl2wQ

Ionic bonding

In the ionic bond the metal loses valence electrons to the non-metal, creating a positive cation (from the metal) and a negative anion (from the non-metal). These then attract each other to form an ionic or electrostatic bond. This does not occur just in pairs because each ion creates an electric field around it in all directions which attracts ions of the opposite charge. Thus in NaCl each sodium ion (Na^+) and each chloride ion (Cl^-) is surrounded by and bonded to six oppositely charged ions, keeping the 1:1 stoichiometry of the compound. There is no ionic sodium chloride molecule (Na^+Cl^-), contrary to the impression in many JC science books. Ionic bonds are formed between a metal and a non-metal, which are elemental opposites. A metal has few electrons in its outer shell and tends to lose them; a non-metal has a half-full or an almost full outer shell and tends to either gain electrons from a metal or share them with a non-metal. In ionic solids there are no mobile electrons and the ions cannot move so the solid does not conduct electricity. When melted to form an ionic liquid, the ions are free to move and can conduct electricity. When dissolved in water the ions are hydrated by water molecules (which form bonds to the ions), and this pulls the ions away from the solid and they separate from each other and can now move and conduct electricity. This type of conduction is ionic or electrolytic conduction.

Covalent bonding

A covalent bond is formed between two non-metals, which prefer to share electrons with each other due to their similarity. The outer electrons are strongly held so it is easier to gain or share electrons than to lose them. When a covalent bond forms, the valence (outer) electrons of one non-metal atom start to interact with those of another non-metal atom, so that each electron is attracted to the other nucleus, as well as its own. Thus the electrons (negative) hold both nuclei (positive) together. For this to work the electrons, one from each atom, have to occupy the same orbital and energy level and are said to be paired or form an electron pair. *(They have opposite spins and thus are allowed to occupy the same molecular orbital). When a covalent bond is formed, the atomic orbitals combine to form new molecular orbitals, which are occupied by paired electrons.* The number of covalent bonds an atom can form is determined by the number of valence electrons and the number of outer orbitals. Any electrons which cannot form electron pairs (bonds) stay as lone or non-bonding pairs. Thus carbon has 4 valence electrons and 4 orbitals and so it can form 4 covalent bonds. Nitrogen has 4 orbitals and 5 electrons so it can only form 3 covalent bonds and one lone pair. The octet rule (each atom tries to get 8 electrons in its outer shell) only applies to elements with only 4 valence orbitals (first short period). If more orbitals are available then more covalent bonds can be formed.

The shape of the resultant molecule is determined by the number of bonding and non-bonding electron pairs. They arrange themselves in space to minimise repulsion between the electron pairs, so that in methane, CH_4, the molecule has 4 bonds and is tetrahedral. (This is covered in LC Chemistry under valence shell electron pair repulsion theory.) Covalent bonds are thus directional in nature (unlike ionic bonds) and determine the structure of molecules and covalent solids. The electrons are trapped in the electron pairs and cannot move so that covalent solids and molecules/molecular solids do not conduct electricity.

Metallic bonding

The metallic bond is found in metals and alloys (which are solutions of one metal in another and usually have variable composition). Metals are similar to each other in that they few electrons in the outer shell and prefer to lose rather than to gain or share electrons with other atoms. The outer electrons are weakly held. When metal atoms come together their outer electron shells start to interact and electrons on one atom are attracted to the nucleus on another atom as well as their own. This interaction is not directional but is the same in all directions. As the metal atoms get closer to each other they lose their outer electrons to each other, which form an electron cloud (gas) together with electrons from other atoms. These electrons are not tied to any one atom but are free to move throughout the solid. The negative electrons (electron cloud) move between the positive nuclei and bond them together by electrostatic attraction. It is sometimes described as an electron ‘glue’ (see Figure 1(a).) The metallic bonding is the same in all directions and so the atoms pack as close as possible to get as many atoms as possible around each one (usually 12 or 8). The electrons are not tied to a particular atom/nucleus and are free to move, so that metals (and alloys) conduct electricity easily. This type of conduction is electronic conduction.

Molecular bonding

The molecular bond is the bond between molecules (not within molecules) and is the hardest to understand. There are different types of molecular bond, of which the hydrogen bond is the strongest. Molecular bonding is weak and it is the bond that determines the melting point and boiling point of molecular substances. When such a substance is melted or boiled only weak molecular bonds have to be broken and the strong, covalent bonds holding the atoms together in the molecules are unbroken. Consider a molecule like hydrogen (H_2).It has a shared electron cloud holding the two hydrogen nuclei together by a single covalent bond. The electron cloud is negatively charged and is not static. It fluctuates in density and it can attract weakly the positive nuclear charge of another molecule to form a weak bond. A covalent bond can be formed by two very different atoms like H and Cl to form HCl. This has a single covalent bond but the electron cloud is not symmetrical as in H_2. One end of the molecule (Cl) is slightly negative and the other (H) s slightly positive. We say that the bond and molecule is polar. The positive charge on one molecule can attract the negative charges on other molecules and this is an additional molecular bond, stronger than the first. The hydrogen bond (formed when hydrogen is bonded to O, N or F in a molecule) is a stronger form of this type of bond. These molecular bonds have no direction and operate equally in all directions. Thus molecules try to pack together to get the maximum number of neighbours (usually 12). Molecular bonds are usually weak and easily broken, with the exception of hydrogen bonds, which are ~10 times stronger. This is why water, with a molecular mass of 18, has such a high melting point and boiling point compared to heavier molecules like H_2S (mass 34) or SO_2 (mass 64).

We can see from this simple treatment, that all chemical bonds are due to the interaction of negative charge (from the electrons) and positive charge (from the nucleus) in various ways. Each type of bond gives rise to particular properties and often also determines the 3D structure of a solid.

Understanding this is a key part of scientific literacy and something that every student leaving school should know.

Bonding misconceptions

A simple view of bonding is necessarily simplified but what we should **not** be doing is either reinforcing or creating wrong ideas (known as misconceptions or alternative conceptions) for our students, which may cause them problems later on. Chemical bonding is an area where misconceptions are common and persist into third level.

The RSC Learn Chemistry website has a useful resource on bonding misconceptions this available at:
http://www.rsc.org/learn-chemistry/resource/res00001140/chemical-bonding

At the end of this excellent treatment is the advice:
"Teachers who wish to encourage their students to develop their ideas about chemical bonding should:
emphasise the nature of bonds as electrical interactions;
avoid using anthropomorphic language, but rather explain bonding in terms of forces;
and avoid talking about electron transfer (ion formation) when considering ionic bonding."

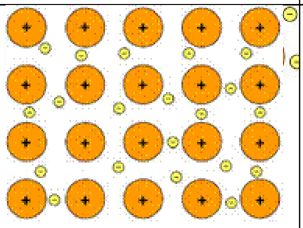
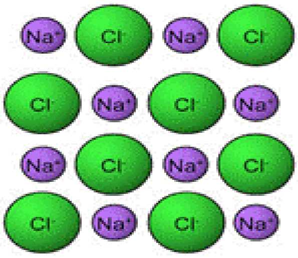
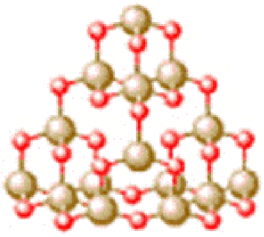
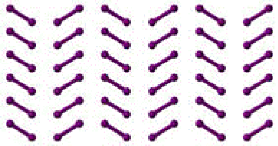
The article by H. Ozmen (*J. Science Education and Technology*, May 2004, **13**(2) 147-159) is a useful summary of common misconceptions related to chemical bonding.
Some general misconceptions about bonding:

- *Chemical bonds form in order to produce filled shells rather than filled shells being the consequence of the formation of many covalent bonds.*
- *Atoms need filled shells.*
- *A covalent bond holds atoms together because the bond is sharing electrons.*
- *Molecules form from isolated atoms.*
- *There are only two kinds of bonds: covalent bonds and ionic bonds. Anything else is just a force, "not a proper bond."*
- *Ionic bonds are the transfer of electrons, rather than the attractions of the ions that result from the transfer of electrons. The reason electrons are transferred is to achieve a full shell.*
- *An ionic bond only occurs between the atoms involved in the electron transfer. Thus, sodium ion forms one ionic bond to a chloride ion in solid sodium chloride and is involved in five forces with the other adjacent chloride ions.*
- *Na+ and other ions are stable because they have a filled outer shell*

It is important for the teacher that you are aware of common bonding misconceptions and that you know how to avoid them and how to address them and deal with them in your teaching. Laying a good foundation in the junior cycle will benefit students' scientific literacy, whether or not they study chemistry further and will also provide a stable launching pad for LC chemistry.

□

Chemical bonding and the properties of solids

	Metallic solids	**Ionic solids**	**Covalent solids**	**Molecular solids**
Structure				
Bonding	Metallic bonding Metal cations in a sea of delocalised electrons	Ionic (electrostatic) bonding Alternating positive and negative ions	Covalent boding Atoms held together by covalent bonds	Molecular bonding between molecules (intermolecular bonds); covalent bonding within molecules (intramolecular bonds)
Electrons	Bonding electrons delocalised throughout the solid	Electrons localised on each ion	Electrons localised in shared orbitals between atoms	Electrons localised in shared orbitals between atoms in molecules
Electrical conduction	Conducts electricity	Insulator in the solid – conducts when molten or in solution	Insulator (non-conductor) or semiconductor	Insulator (non-conductor)
Hardness	Soft (e.g. sodium) or hard (e.g. tungsten) depending on strength of metallic bond Usually malleable	Hard and brittle	Hard and brittle	Soft
Melting points	Range from low to high depending on the strength of the metallic bond	Moderate to high depending on the strength of the ionic bond	High	Usually low – depends on molecular size and polarity
Examples	Sodium, calcium, iron, tungsten gold	Sodium chloride, calcium carbonate, iron(II) sulphate, magnesium oxide	Diamond, silicon, silicon dioxide	Iodine, sulphur, benzoic acid, aspirin
Location in relation to Periodic Table	Metals found at the left-hand side and lower down	Compounds of metals and non-metals	Non-metals or compounds of non-metals (right-hand side)	Non-metals or compounds of non-metals

Everyday Chemistry:
How fattening are alcoholic drinks?

There is legitimate concern about over-consumption of alcoholic drinks in Ireland, as in other countries. But drinkers don't usually think about the effect of drinking on their weight and waistline. Ethanol is a fuel and a food and the body 'burns' ethanol for energy, as well as its intoxicating effects on the brain. How fattening are alcoholic drinks? Remember that the recommended daily 'calorie' intake of men is 2,500 and for women is 2,000 – these are actually kcal and there are 4.2 cal/J. You can set this as an exercise to do after doing heats of combustion as a practical example.

How can we calculate the calories in drinks?

Q. What information do we need?
Ethanol is a fuel and so the calculation is about working out the energy released when a known amount of ethanol is burnt, as with any other food. We need to know how much ethanol there is in a glass or bottle (in cm^3 or g), we need to know its heat of combustion (kJ/mol) and its molar mass **(GMM).**

The data:
The GMM of ethanol is 46 g/mol.
The heat of combustion of ethanol is 1,368 kJ/mol or 1,368/46 = 29.7 kJ/g = 7.08 kcal/g.
The density of ethanol =0.80 g/ cm^3
This means that every g of ethanol consumed can contribute 7.08 'calories' to our diet.

A glass of beer
Beer typically contains 4.5% of ethanol by volume i.e. 4.5 cm^3 per 100 cm^3 or 22.5 cm^3 per 500 cm^3 can or glass.
The density of ethanol is 0.80 g/ cm^3 so 22.5 cm^3 of ethanol weighs 18.0 g and thus contains 18.0 x 7.08 = 127.4 kcal. Knock back 8 cans of beer and you will be taking in 1,019.5 kcal, half the daily recommended intake for a woman, 40% of that for a man.

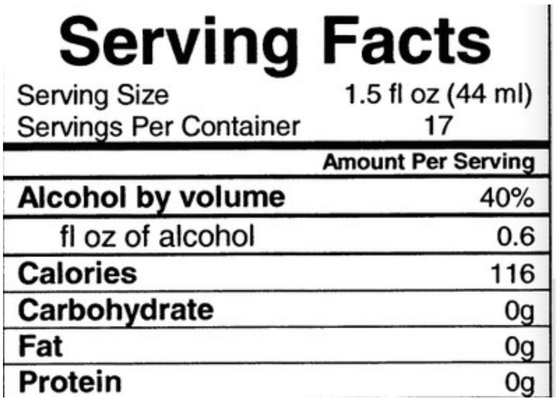
A glass of wine
Wine typically contains 12% ethanol by volume so a bottle of wine (750 cm^3) will contain 750 x 12/100 = 90.0 cm^3 ethanol or 72.0 g. Drinking a bottle of wine will thus mean ingesting 509.8 kcal. A small glass of wine, typically 125 cm^3 (1/5th of a bottle) will be 102 kcal.

Units of alcohol
A unit of alcohol is 10 cm^3 of ethanol. The diagram below shows what this means.

The U.K. government advises that people should not regularly drink more than 3-4 units of alcohol a day for men (equivalent to a pint and a half of 4% beer) and 2-3 units for women (equivalent to a 175 ml glass of wine). 'Regularly' means drinking alcohol every day or most days of the week. This means a limit of 21-28 units a week for men and 14-21 units for women.

20 units a week means 20 x 10 = 200 cm^3 ethanol = 160 g = 1,133 ‘calories’. This is excluding the crisps, peanuts, snacks, burgers, chips etc. that often accompany having a drink. No wonder that regular over-consumption of beer leads to the classic beer belly. When there is alcohol in the system the body will burn it in preference to fat, meaning that more fat will build up, which otherwise might be burnt up by the body.

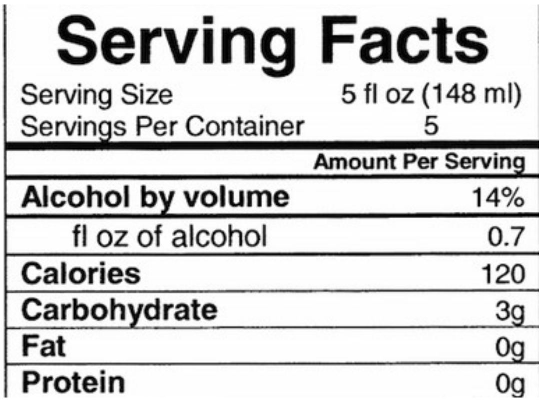
There is a move to put more information on alcoholic drinks, including their energy content, as the sample labels below show.



Serving Facts

Serving Size 1.5 fl oz (44 ml)
Servings Per Container 17

	Amount Per Serving
Alcohol by volume	40%
fl oz of alcohol	0.6
Calories	116
Carbohydrate	0g
Fat	0g
Protein	0g



Serving Facts

Serving Size 5 fl oz (148 ml)
Servings Per Container 5

	Amount Per Serving
Alcohol by volume	14%
fl oz of alcohol	0.7
Calories	120
Carbohydrate	3g
Fat	0g
Protein	0g

☐

Diary

2016

ASE Meeting
6-9 January University of Birmingham, Birmingham, UK
http://www.ase.org.uk/conferences/annual-conference/

5th NPSE
17-18 March
Florence, Italy
conference.**pixel-online.net/**NPSE/

ISTA Conference
8-10 April
Limerick Institute of Technology, Limerick
www.ista.ie

Primary Science Conference
9-11 June
Waterfront Hall, Belfast
www.primaryscienceconference.org

7th SMEC
16-17 June
Dublin City University, Dublin
http://www.dcu.ie/smec/index.shtml

BCCE 2016
University of Northern Colorado, Greeley, USA
31 July – 1 August
http://www.unco.edu/bcce2016/

24th ICCE
15- 20 August
http://www.icce2016.org.my/
Kuching, Sarawak, Malaysia

13th ECRICE
7-10 September
Barcelona, Spain
http://ecrice2016.com/

ChemEd-Ireland
15 October
Dublin City University, Dublin
Odilla.finlayson@dcu.ie

ICASE World Science and Technology Education
Conference
1-5 November
Antalya, Turkey
http://www.icase2016.org/

2017

ASE Meeting
4-7 January
University of reading, Reading, UK
http://www.ase.org.uk/conferences/annual-conference/

ESERA
21-25 August
Dublin City University, Dublin
www.esera2017**.org/**

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

Practical work in chemistry and its goals and effects

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The importance of practical work in chemistry in pre-service teacher education

Practical work has had a central and distinct role in chemistry education (from school to university) for more than a century. One of the features of chemistry as a subject in school or university is that it involves practical work in the laboratory. It is not difficult to see why. The aim of chemistry is to increase our understanding of the composition, properties and change of matter. Claims and explanations in chemistry should be supported by observational data (Hofstein & Lunetta, 2004; Millar, 2010).

What does the phrase 'practical work' mean? Based on science education literature practical work "refers to *any* type of science teaching and learning activity in which students, working either individually or in small groups, are involved in manipulating and/or observing real objects and materials […] as opposed to virtual objects and materials as those obtained from a DVD, a computer simulation, or even from a text-based account" (Abrahams & Reiss, 2012, p. 1036). In this chapter, the emphasis will be on two types of practical work: different types of laboratory experiments carried out by school students and teacher demonstrations.

Practical work has a prominent position in chemistry curricula. The Norwegian curriculum in chemistry includes these statements about practical work in the introductory paragraph about the purpose of the subject (Udir, 2006):

- The development of the science of chemistry is the result of an interaction between experiment and theory. This interaction is reflected in the programme subject Chemistry, in which the planning and implementation of experiments play a key role.
- Training in chemistry shall link theory with practical laboratory work.

Many of the competence aims in the curriculum deal with practical work. It is stated explicitly that practical work has to be done. Here are some examples (Udir, 2006):

The aims of the studies are to enable school students to:

- plan and carry out experiments and evaluate risk, sources of error and results;
- plan and carry out acid-base titrations; justify choice of indicator and interpret titration curves and
- carry out colorimetric analyses and interpret simple mass spectra and 1H-NMR spectra.

Practical work is an essential aspect of everyday practice in the chemistry classroom. Why has practical work such a strong position in chemistry? Among other things it should be mentioned that in chemistry, almost exclusively, one could 'engage' all five senses of a school student (Petruševski & Najdoski, 2000, p. 8):

1. The results of an experiment can basically be *seen* (as in most of the other practical educational activities used in the sciences or other disciplines).

2. Often they can be *heard* in the form of bangs, pops, etc.

3. On many occasions the result could be *smelled* (during generation of ammonia, iodine, hydrogen sulphide, samples of various alcohols etc.).

4. The system (a beaker or a flask where a chemical reaction occurs) can quite often be *touched*, to witness that it is hot, warmer, colder or freezing cold when compared with the temperature of the environment.

5. Under special circumstances (when talking about different carbohydrates, presenting samples of glucose, fructose, sucrose, … or during neutralization of

> sodium hydroxide, with a slight excess of hydrochloric acid, and evaporation till solid NaCl is obtained) it might be permissible to carefully *taste* the samples/product, under the supervision of the instructor.

Indeed, teachers (and others interested in chemistry education) assume many benefits as a consequence of school students engaging in laboratory activities and other practical work. Practical activities are claimed to increase the interest for chemistry and to support learning (Millar, 2010). In addition they contribute to a student-directed and inquiry-based learning environment in contrast to more teacher-directed learning (Hofstein & Lunetta, 2004).

Researchers have questioned the role of laboratory work; particularly its effectiveness has been a research focus. In an often cited review (Hofstein & Lunetta, 1982, p. 212) it is concluded: “The research has failed to show simplistic relationships between experiences in the laboratory and student learning.” (Abrahams, 2011, p. 12) concluded from several reviews related to practical work: “When outcomes are measured using pen and paper tests, […] the use of practical work offers no significant advantage in the development of school students’ scientific conceptual understanding”. Also Hodson (1990) was very critical about the effect of laboratory work as it is carried out in many cases. It appears as unproductive and confusing. He questions what the school students actually do and for what purpose. Tobin (1990, p. 405) on the other hand was far more positive towards laboratory work: “Laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science”. He placed emphasis on the possibility of achieving meaningful learning through inquiry-based activities in the lab.

Pre-service (and many in-service) teachers are very surprised to learn that there is no straightforward positive correlation between practical work and learning. Therefore it is important that practical work and particularly reflections on the goals and effects of practical work have a prominent position in pre-service teacher (PSTs) training.

Theoretical framework

Types of experiments

There is no unique way for the classification of chemistry experiments. The very classification often depends on the ‘taste’ of the experimenter/instructor. Still, many chemists would agree that experiments as a tool of the chemical educator could conveniently be classified into three groups:

1. Teacher demonstrations
2. Cookbook/recipe experiments
3. Open-ended/inquiry experiments

One type, open-ended experiments, has received a lot of positive attention in recent years. Different terms like open-ended, inquiry-based or open-inquiry experiments are used in the literature. They all refer to experiments where school students cannot follow a given procedure. The experiments can be more or less open-ended in different ways: data may be given or incomplete, methods can be familiar or unfamiliar and outcomes/goals given or open (Wood, 2006).

Most laboratory work in school and higher education is of “cook-book” or recipe style. This traditional way to do practical work has been criticized for several reasons (Berry, Gunstone, Loughran, & Mulhall, 2001; Hart, Mulhall, Berry, Loughran, & Gunstone, 2000; Hofstein, Shore, & Kipnis, 2004) as follows:

- Cook-book experiments are an ineffective way to learn science concepts and might provide a wrong picture of how knowledge is developed in science;
- Such experiments do not challenge the school students to think about the purpose of the experiment or the sequence of steps involved and
- Both the practical work and the following written report are often of a ritualized or formulaic nature. The school students’ focus is on following the given step-by-step procedure and finishing the task (getting the “right” results).

Important general goals in secondary education are creativity, problem-solving skills, and critical and independent thinking. Many science educators (Abd-El-Khalick et al., 2004; Hart et al., 2000; Hofstein et al., 2004; Lunetta, 1998) have called for more open-ended experiments to address these general goals. Other more specific benefits of open-ended experiments are well documented in the literature (e.g. Barnea, Dori, & Hofstein, 2010; Berg, Christina, Bergendahl, & Lundberg, 2003; Deters, 2004; Hofstein & Lunetta, 2004; Hofstein et al., 2004; Lunetta, 1998) as follows:

- Learning of content knowledge (CK);
- Scientific process skills;
- Attitudes towards chemistry;
- Motivation to learn chemistry;
- Understanding of the nature of science and
- Communication skills.

As a consequence of reforms in chemistry education, more inquiry-based laboratory work was introduced in high schools in Israel. Barnea et al. (2010) investigated the effects of these changes. They reported an increased interest in chemistry, and both inquiry skills and scientific understanding improved significantly. Similar results were found in a Swedish study (Berg et al., 2003). Students in their first year of chemistry studies at university level showed better learning outcomes and more positive attitudes when doing open-inquiry experiments.

Comparing inquiry and confirmatory experiments, Katchevich, Hofstein and Mamlok-Naaman (2013) found that discourses were rich in arguments during inquiry-type experiments. The construction of arguments was encouraged especially when students discussed possible hypotheses, analysed their results and worked on conclusions.

Challenges associated with implementing inquiry-based laboratory work include: a lack of time, shortage of instructional materials and class sizes (Chueng, 2007). The implementation is specially demanding for novice teachers, who are inexperienced in domains like pedagogical content knowledge (PCK), and knowledge of teaching, school students and classrooms (Crawford, 1999). During open-ended experiments the following undesirable behaviour might be observed (Berry, Mulhall, Gunstone, & Loughran, 1999):

- After school students have worked out a procedure, they follow it cook-book style;
- School students can work out and stick to an inadequate procedure leading to meaningless results and
- Still, school students' main goal can be to finish the task and get the expected results.

It is therefore particularly important to monitor the work of school students while they are carrying out open-ended experiments. As mentioned before, one of the features of chemistry as a subject in school is that it involves experiments. At least some of these experiments should be open-ended.

Main goals for practical work

What are the main goals for practical work based on the research literature? Different researchers have presented overviews of the main goals for practical work (Hodson, 1990; Hofstein & Lunetta, 2004; Lazarowitz & Tamir, 1994). Hofstein and Lunetta (2004) suggest that the principal aims of practical work are to enhance students':

- understanding of scientific concepts;
- interest and motivation;
- scientific practical skills and problem solving abilities;
- scientific habits of mind and
- understanding the basics of the nature of science.

Based mainly on Hodson (1990) and Hofstein & Lunetta (2004) we chose to focus on the following four goals for practical work in chemistry in this chapter:

- enhancing school students' interest and motivation;
- learning practical skills;
- learning of scientific knowledge and
- giving insight into the nature of science.

It is important to realize that all these goals are not likely to be achieved in any experiment at the same time.

Enhancing school students' interest and motivation

Research from many countries confirms that chemistry experiments are popular. Experiments are also what Norwegian and Macedonian school students like best about chemistry. This is a good starting point for learning, when school students enjoy the activities offered in lessons.

What are the consequences of this positive attitude? It is useful to start with a closer look at the use of terminology. The terms *motivation* and *interest* are often not differentiated. According to Bandura (1986, p. 243) "there is a major difference between a motive, which is an inner drive to action, and an interest, which is a fascination with something." Interest might mean *personal interest* or *situational interest*. Personal interest is about dispositional preferences or enduring preferences for certain activities. Personal interest in activities in chemistry lessons is likely to influence school students' engagement with the subject, their efforts and the learning of content knowledge (CK). Situational interest is stimulated by a certain situation or in a specific environment (Bergin, 1999).

In many cases school students only have situational interest in practical work in chemistry. This is illustrated quite clearly in the following example from an interview (Abrahams & Sharp, 2010, p. 113):

> Student (aged 15): *I really like practical work, it's good fun.*
> Researcher: *Oh, so are you going to study a science after your GCSEs?*
> Student: *You must be bloody joking sir.*

It is difficult to find a correlation between doing practical work and the motivation to go on with chemistry (Abrahams, 2009). There are also many other factors influencing school students' choice to continue with chemistry post compulsory schooling (typically at 16 years). Doing a considerable amount of practical work is unlikely to have any negative influence on this choice. On the contrary, chemistry education without any, or only very few, practical activities would certainly not contribute to higher enrolment into chemistry courses at any level.

School students' declared positive attitude towards practical work might have other reasons than those the teachers would prefer. Some school students like practical work because it provides "welcome relief from listening to teachers and from writing, a task which many school students report as being something they particularly dislike about science lessons" (Bennett, 2003, p. 86).
School students, mainly boys, may have wrong expectations as to what chemistry is about: "*Teacher, can we blow up something today?*" Surely, not all practical work is expected to be spectacular. Pure entertainment is a legitimate goal for a chemistry show, for example, in the last lesson before Christmas, but for the rest of the year the goals typically should be those listed earlier. Motivation beyond situational interest might arise from learning in exciting learning environments, which include inquiry-based activities, chemistry in a context or more broad authentic learning environments (Hofstein & Lunetta, 2004; Parchmann, Gräsel, Baer, & Nentwig, 2006; Schumacher & Reiners, 2013).

Learning practical skills

In general, chemistry courses have the focus both on CK in chemistry and practical skills. In the laboratory the PSTs learn how to use practical chemistry equipment (from glassware to sophisticated instruments). Not surprisingly, research studies show consistently that the best way to learn practical skills is the "hands-on" approach (Millar, 2010). The PSTs have to acquire a number of practical skills to be able to follow more advanced courses in chemistry. At the same time it is essential for laboratory safety that future chemistry teachers learn how to use equipment and handle chemicals properly. PSTs have to learn about safety and waste management in the laboratory, in accordance with the new CLP-regulations (ECHA, 2009). No PSTs are allowed to work in a chemistry laboratory on their own without having completed a compulsory safety course (which could be a part of the chemistry course).

More details about teaching of different practical skills will be presented later as good practice examples.

Enhancing the learning of scientific knowledge

As presented in the introduction, there is no clear evidence supporting the idea that practical work gives a higher learning effect of CK than other methods, like teacher demonstrations or non-practical teaching methods (Millar, 2010). The science laboratory settings can be a very good learning environment; the social environment is usually less formal than a classroom, the school students collaborate in small groups, the student-teacher ratio is usually lower than in a classroom and most school students have positive attitudes towards laboratory activities. Unfortunately, research has shown that during laboratory activities much of the time is spent on reading recipes, following instructions and interacting with equipment (Hodson, 1990). But if the practical work is well organized, then the school student can learn CK, as illustrated by this quote (Lunetta, Hofstein, & Clough, 2007, p. 405):

> *"When well planned and effectively implemented, science education laboratory and simulation experiences situate students learning in varying levels of inquiry requiring students to be both mentally and physically engaged in ways that are not possible in other science education experiences"*

An important question is how teachers can enhance the learning of CK through practical work. The literature describes several important factors which promote learning from practical work:

- the activity should interact with the prior knowledge of the student;
- the activity should have a clear goal;
- time for reflections and discussion and
- the teachers' role.

Information about the school students' prior knowledge is essential to ensure learning in general, also in the laboratory (Lunetta et al., 2007). If the prior knowledge is insufficient then the school students are not able to derive meaning from their results (Berry et al., 1999) and the learning of CK will be poor. Thus, the timing of the experiment is important (Southam et al., 2013), since the school students need to have the necessary CK for the practical work to be effective.

During a laboratory session, school students often have to process a lot of information in addition to carrying out the practical work. The school students are reading the laboratory description, interacting with peers, activating their prior knowledge, getting messages from the teacher, interacting with the equipment and doing the experiment. In such settings school students can get a cognitive overload, with too much information at the same time (Johnstone & Wham, 1982). A study from several European countries has identified that embracing too many objectives in one laboratory session will give a poor learning result (Sere, 2002). Ways to avoid this can be to give school students small qualitative laboratory tasks (Gunstone & Champagne, 1990), activities with a clear goal and to clarify the pedagogical purpose of the activity for the school students (Hart et al., 2000). An important part of most learning processes is that the learner needs time to reflect, and to embed the new knowledge into the existing cognitive networks. This is also true for the learning of CK from laboratory activities. Findings from a study in England stated that teachers need to be more realistic in terms of what they want school students to do and learn in the laboratory session (Abrahams & Reiss, 2012). If there is a shortage of time, the school students still have to finish the practical task, but the time for reflection and discussion is reduced. This will result in a poor learning outcome. Short but high quality activities, in which there is time for reflection and discussion, will enhance learning (Gunstone & Champagne, 1990). In some cases, time-consuming laboratory activities could be replaced with time-efficient alternatives, like teacher demonstrations or simulations (Lunetta et al., 2007). The school students will then have more time to discuss and reflect about the results of the experiments.

The teacher's input is essential to achieve the desired learning outcome from practical work. In addition to the more obvious aspects of the teacher's role (like deciding the practical task, how time is spent, etc.) the student-teacher interactions during practical work have been shown to be especially important (Hogstrom, Ottander, & Benckert, 2010; Lunetta et al., 2007). School students need help to develop the abilities of observation during experiments. Quality discussions between the teacher and school students are effective in enhancing the learning outcome from practical work (Millar, 2010). Laboratory activities including "scaffolding" have also been shown to enhance learning (Abrahams & Reiss, 2012).

Giving insight into the nature of science

The construct of the nature of science (NoS) is complex and different definitions can be found in the literature (Lederman, 2007). An introduction to the construct and why it is important is given in another chapter. We also refer to that other chapter for good practice examples about teaching NoS. In this chapter we look briefly at contributions from practical work to a better understanding of NoS.

Misconceptions about different elements of NoS should be addressed in teacher training, in the context of practical work and/or in seminars. It is important that future chemistry teachers have a sound understanding of key concepts like theory, law and hypothesis and the relations between them. McComas (1998) presents different myths concerning these key concepts, as follows:

- hypotheses become theories that in turn become laws,
- scientific laws and other such ideas are absolute,
- a hypothesis is an educated guess.

The performance of investigative or inquiry-based experiments helps school students to get a better understanding of scientific methods. According to Trefil (2003) and McComas (1998) the existence of a general and universal scientific method is a myth:

> *"The notion that a common series of steps is followed by all research scientists must be among the most pervasive myths of science given the appearance of such a list in the introductory chapters of many precollege science texts"* (McComas, 1998, p. 57).

Instructional approaches which are mainly implicit (with learning about NoS as some kind of by-product) are not sufficient. Lederman & Abd-el-Khalick (1998, p. 83) argue that school students would not get enough understanding of a complex concept like NoS *"solely through learning about the content of science or its processes [...] a concerted effort on the part of science educators and teachers to explicitly guide learners in their attempts to develop proper understanding of the scientific enterprise is essential."*

PSTs must be provided with an adequate understanding of NoS. Explicit instructions about NoS aspects and active discussions about the practice of science with regard to important aspects of NoS are essential.

Analytical framework

It does not make sense to look at the effectiveness of practical work in general. There is a broad variety of different activities with different aims and objectives. It is more useful to consider the effectiveness of a specific experiment with a specific goal. To develop an analytical framework Abrahams and Millar (2008, p. 1947) started with a model based on earlier work from Millar et al. (1999). The model (Figure 1) distinguishes between two levels of effectiveness.

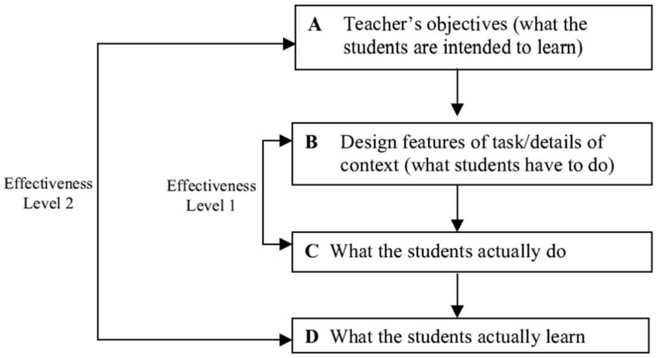

Figure 1: Model of the process of design and evaluation of a practical task (Abrahams & Millar, 2008, p. 1947)

Box A indicates the teacher's learning objectives from a specific activity. The objective might be the learning of a certain piece of CK in chemistry or a certain aspect about the nature of science. Box B describes the activities that school students are supposed to carry out in order to achieve the learning objectives from box A. Box C shows what the school students actually do. This may, or may not, differ to some extent from the intention. Box D then deals with the learning outcome of the activity. The effectiveness at Level 1 relates to the relationship between boxes B and C, and whether the school students did what they were expected to do. The effectiveness at Level 2 is concerned with the relationship between boxes A and D: the actual learning outcome compared to the intended learning outcome.

Practical work can be characterised "as trying to help school students make links between two 'domains' of knowledge: the domain of objects and observables (o) and the domain of ideas (i)" (Abrahams & Millar, 2008).

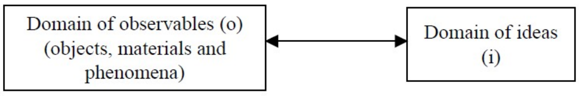

Figure 2: Practical work: linking two domains of knowledge (Abrahams & Millar, 2008, p. 1948).

Abrahams and Millar (2008) combined the two-level model of effectiveness (figure 1) and the model of two domains (figure 2) to produce an analytical framework. This analytical framework (table 1) can help PSTs to analyse their practical work at the university and in their school practice.

Table 1: Analytical framework for considering the effectiveness of a practical task (Abrahams & Millar, 2008, p. 1949).

Effectiveness	Domain of observables	Domain of ideas
A practical task is effective at Level 1 (the 'doing' level) if …	… the students do with the objects and materials provided what the teacher intended them to do, and generate the kind of data the teacher intended.	… whilst carrying out the task, the students think about their actions and observations using the ideas that the teacher intended them to use.
A practical task is effective at Level 2 (the 'learning' level) if …	… the students can later recall things they did with objects or materials, or observed when carrying out the task, and key features of the data they collected.	… the students can later show understanding of the ideas the task was designed to help them learn.

Good practice examples

Practical work is a substantial part of the teaching a chemistry teacher does during a day. Thus, it is important that teacher educators focus on this part in the teacher education courses. In this sub-chapter we will present good examples of how practical work is included in the education of PSTs for secondary school.

Practical work – the importance of school practice

PSTs gain knowledge about how to do practical work both at the university and during practice at schools. The PSTs will experience considerable differences between the University chemistry laboratories and the laboratory facilities at schools, especially in lower secondary schools. Some of the challenges are:

- less (or no) support by technicians;
- other (usually much less sophisticated) equipment;
- lack of important/necessary equipment and chemicals and
- responsibility for experiments, safety, storage of chemicals and waste management.

When it comes to practical work there has to be a different focus in teacher education courses compared to University chemistry courses. The PSTs must be prepared to meet the reality in school. This has to be addressed in the lectures and followed up during school practice. PSTs spend a significant amount of time in schools (100 – 110 days in Norway). Out in school they have the opportunity to test different types of practical work and get feedback right away, both from school students and the tutor. The tutor is crucial for the PSTs' learning outcomes. Our experience is that PSTs find it difficult in the beginning to conduct experiments in their school practice. There are a lot of things to consider in addition to the challenges mentioned above: how to organize the experiment, clarify the goals, getting familiar with the laboratory, guide the class, covering Environmental, Health and Safety (EHS) considerations etc. Thus, it can be overwhelming for the PSTs to do laboratory activities with a large group of school students. However school practice is an important arena for giving PSTs experience with experiments in a classroom setting. We believe that our qualified PSTs will be well suited to organize practical work in a way which arouses excitement and promotes learning for their future school students. We try to achieve this by giving the PSTs the chance to try out different types of practical work, both at the university and during school practice, combined with high quality reflections.

Laboratory safety

One of the goals when doing practical work is to learn laboratory safety. To be skilled in this field one needs to have worked for a substantial amount of time in the laboratory. Then one gets to know how to handle chemicals, learns important laboratory techniques and safety rules. Environmental, Health and Safety (EHS) has increasing attention in education in recent years. This is due to the new EU-regulation CLP (the **c**lassification, **l**abeling and **p**acking of substances and mixtures) (ECHA, 2009). Closely related are the CLIPs (**c**hemical **l**aboratory **i**nformation **p**rofiles) of various substances (Young, 2001) that are used in the laboratory (the latter are extensively in use in USA and could be easily found on the Internet). In addition some countries have in recent years implemented regulations which demand risk assessment of all laboratory experiments in school and in higher education.

Both in lower and upper secondary teacher education in Norway there is an increased focus on laboratory safety. One of the challenges was that the EHS regulations are not very easily accessible for PSTs. But lately the University of Oslo (UiO) has developed an online resource for teachers, which gives an introduction to the CLP regulations, safety concerns in school laboratories and risk assessments (Skaugrud & Hannisdal, 2014). These resources are written in a language and a style that is well suited to be used by teachers in secondary schools and PSTs. At the Arctic University of Norway (UiT) we use these resources in the EHS part of the teacher education courses. The PSTs get a theoretical background about safety issues concerning laboratory experiments at an appropriate level. The PSTs have to apply this knowledge to work out risk assessments before they perform a selection of experiments. The EHS is part of the curriculum and the PSTs know that they can be tested in this area in the final exam, which contributes to more emphasis on EHS. We believe that laboratory safety is best learned in context. By using appropriate teaching materials, trying out some potentially risky experiments and discussing laboratory safety, we believe the PSTs will become chemistry teachers who know the regulations and have good insight into potential risks in the chemistry laboratory. In Macedonia, unfortunately, there isn't any systematic approach to this important issue, but some authors use somewhat arbitrary estimates of the overall risks for a given demonstration, using signs to indicate the degree of risk: 1 – being the lowest and indicating virtually no risk at all, and 5 – being the highest risk, in which case the demonstration should be performed only by highly experienced and skilled instructors (Najdoski & Petruševski, 2002; Petruševski & Najdoski, 2000).

Low-cost experiments

Experiments in science are associated with different challenges (SALIS, 2012):

- They cost money and the budgets for this kind of expenses are decreasing (no matter how rich the country is).
- New regulations about safety in connection with chemicals (CLP) are introduced in the EU.
- In many schools (especially lower secondary schools) experiments have to take place in traditional classrooms.

As a consequence school students' activities are reduced to a minimum in many cases. Low-cost experiments provide several distinct advantages:

- Schools save money (less need of chemicals, cheaper materials from everyday life or medical supply);
- Less room for storage is needed;
- Experiments take (much) shorter time;
- They offer higher mobility (transport without special needs);
- Fewer EHS concerns (less chemicals, easier disposal) and
- They can be done in an ordinary classroom.

Microscale experiments

Microscale chemistry is an environmentally-friendly, pollution-prevention approach accomplished by using miniature glassware and significantly reduced amounts of chemicals. Many schools (and teacher education institutions) use microscale-kits. It is not necessary to buy all the equipment. Low-cost experimental kits can be developed in the classroom as part of the experiments.

Learning outcomes associated with microscale experiments are likely to differ from LOs using equipment of usual size.

Equipment from medicine

Syringes (with or without cannula) in different sizes and with different seals can replace much more expensive burettes and gas syringes.

One example is a low-cost Hofmann apparatus (SALIS, 2012):

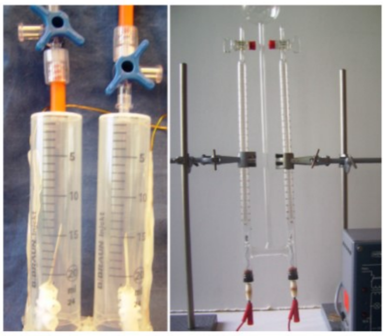

Figure 3: Low-cost Hofmann apparatus (illustration from the SALiS project)

Another example is the production of hydrogen (SALIS, 2012):

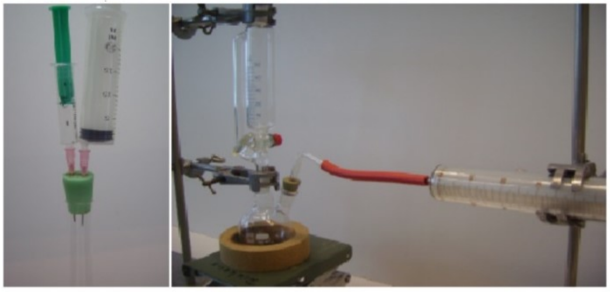

Figure 4: Low-cost apparatus for hydrogen production (illustration from the SALiS project)

In addition it's possible to recycle waste (e.g. cans, glasses, pill packaging, film containers) and to use chemicals from everyday life.

This paragraph gives just a very brief introduction to low-cost-experiments. A lot of resources for low-cost-experiments are available in different languages from the web-page of the SALiS project (Student Active Learning in Science) (SALIS, 2012):

- A lab-guide for low-cost-experiments
- A large collection of low-cost-experiments
- Experiments on video
- More ideas for low-cost-experiments from the web.

Open-ended experiments

At UiT the experiments in the compulsory chemistry courses for PSTs (upper secondary school) are almost exclusively of cook-book style. We address open-ended experiments in our science education courses. We carry out examples of open-ended experiments adapted for both lower and upper secondary chemistry:

- Electrochemistry: The laboratory exercise is organized as a competition: set up a good galvanic cell (battery) from equipment available in the laboratory. This task includes reflections on what a "good battery" means. And PSTs are asked to elaborate criteria for the ranking of the galvanic cells produced by different groups.

- Solubility: How does the solubility of a certain salt change with temperature? The PSTs have to elaborate hypotheses about the relationship between temperature and solubility and to suggest procedures for testing their hypotheses. PSTs (and school students) usually come up with many different hypotheses: solubility might increase, decrease or not change at all; the correlation might be linear, exponential or vary in another way. A suitable salt is potassium nitrate: its solubility increases exponentially with rising temperature.

- Qualitative analyses: A very easy example with kitchen chemicals: what is what from a selection of white solid substances, like citric acid, baking soda, baking ammonia (NH_4HCO_3), sugar, table salt, flour? In addition to basic glass equipment, school students may only use water, vinegar, pH strips and matches.

The PSTs need experience to carry out these kinds of experiments. In connection with the laboratory experiment we spend time to discuss different types of experiments, what the intended outcomes could be and challenges the school students are likely to meet. These discussions are based on the experiments, research literature and the PSTs' experience from earlier school practice. We want to give our PSTs ideas and a certain repertoire of open-ended (and other) experiments. During school practice (at least in four of the five years of the master's programme) they are encouraged to try out their ideas.

Developing abilities to successfully present experiments

Occasionally the main goal for a teacher demonstration may be pure entertainment (e.g. in chemistry shows). Usually other goals mentioned earlier are prevalent. A teacher demonstration can be chosen in preference to experiments done by school students for several reasons: safety aspects, costs, difficult experiments or to save time. The following suggestions can be useful for performing and presenting the demonstration successfully (Petruševski & Najdoski, 2000, p. 12):

- The experimental set-up should be prepared in advance and often it is necessary to try it out before the lesson (certainly, if the teacher is unfamiliar with the experiment).
- The teacher is not supposed to talk in advance about the results of the experiment!
- While performing the experiment it is good practice that school students pay attention to every change in the system (e.g. smoke, flame, light, sound, odour, bubbling, glow, colour change etc.) as a basis for discussions and interpretations. It is advisable that the teacher turns their attention to such events.
- It is never recommended to carry out too many experiments at the same time to prevent school students from being confused and distracted.
- When working with older and more experienced students it is advisable to stimulate students to ask questions regarding the experiments and to encourage them to predict the outcome of such experiments. Each of these reinforcements represents a challenge for the student and each successful prediction increase their motivation and self-confidence.
- Secondary-school teachers usually work alone (without an assistant) so, at some point, they can ask school students to assist.
- Real chemistry is very far away from acting, magic or show business. Still, experiments should be as spectacular as possible. In that way they can evoke discussion among school students and increase their interest in the subject. Usually loud explosions, glimmering, spontaneous appearance of flame or light and sharp changes of colour leave strong impressions on school students, engrave on their minds and make school students fond of chemistry.

These are some of the advice that can help PSTs to get started with successful demonstrations. They have to practice and modifications are inevitable. For example, it is not always easy to cover all the time with suitable remarks, questions or comments. Moreover, the more complex the experiment the less likely it is that an inexperienced teacher will successfully activate the school students. Often he/she will be worried about the successful outcome of the experiment. This is mainly a matter of routine in experimenting and teaching experience.

Preparing lectures for fellow university students

At the UiT PSTs in chemistry (and biology and physics) have to follow a compulsory module of 10 ECTS in science education in the fifth year of their master's programme.

As one of the course work requirements during the module, each PST has to prepare a lecture for PSTs in the third year. The PSTs responsible for the lecture have to provide in advance a written documentation for that lecture. The lecture has practical work as a starting point.
The main focus is on reflections about different aspects of practical work:

- How could this, or similar, practical work be done in school?
- How is the practical work linked to theory?
- What are the goals of this practical work?
- How can we reach those goals?

The PSTs get feedback both from their fellow PSTs and from the tutors. Lectures organized like this provide a rich learning environment for all PSTs involved. The PSTs from the third year get a well-prepared lecture, they are challenged to discuss important aspects of science education and they practice peer assessment. The PSTs in the fifth year practice planning of demanding lectures, initiate and lead discussions and get immediate and constructive feedback.

Out-of-school lab days

This good practice example is from the Institute for Chemistry Education at the University of Cologne, Germany. The out-of school lab days (*Schülerexperimentiertage – SETs*) have existed for about 10 years. The focus of the SETs is on

inquiry. The activities include much experimental work, but also discussions on selected items (Schumacher & Reiners, 2013).
The SETs address three major fields:

- Chemistry classroom: Classes are invited to spend a whole day in the laboratories and work on motivating, interesting topics
- Pre-service teacher education: the SETs can be integrated in chemistry education courses and/or exam papers for PSTs
- Research in chemistry education: the SETs are used in different research projects

Table 2: An overview of the activities offered by SETs at the moment

SET	Year	Method
Laboratory equipment & safety	6/7	Station learning
Indicators	6/7/8	Experiment orientated group jigsaw
Sport drinks	8/9/10	Experiment orientated group jigsaw
Soap & detergents	9/10	Classic group jigsaw
Fragrance	11/12	Classic group jigsaw

PSTs get the opportunity to meet chemistry classes and their teachers. The PSTs get useful experience with the preparation and organising of lab-days. They guide groups of school students and get feedback from a supervisor.

Practice at the Science Centre of Northern Norway

Science centres are suitable arenas for PSTs' practice (as a supplement to practice in schools). The Science Centre of Northern Norway is located on the University campus at UiT. One of the objectives for the Science Centre is to cooperate with the University both for outreach activities and teacher training. The Science Centre wants to be a meeting point where children and adults can explore Mathematics, Science and Technology through "learning by doing".

A popular Science club for children 10 – 14 years is arranged every year during school vacations, both in summer and winter. PSTs are strongly involved in the one week Science club in winter time. As part of their school practice, up to five PSTs run the club together with staff from the Centre. Each day one of the PSTs is the leader, and the others are assistants. Each assistant follows up a group of six children.

The PSTs get experience in planning and preparing laboratory activities for children. The PSTs have to be creative and find suitable activities. Then they must try out the activities, develop the teaching materials and work out risk assessments.

The Science club concentrates on the fun sides of science, where the children don't have to worry about stuff like writing, homework or assessment. The PSTs have close contact with small groups of children over a whole week. They have the time to talk to each child, to explain the activities and to follow up all kind of questions. During this week the PSTs get insight into how young school students think about science, which is a very useful experience.

Chemistry shows

In Macedonia there is a semiformal group of enthusiasts called by themselves 'The Happy Chemists Group' (THCG). The group comprises PhD students and a few professors and teaching assistants. The mission of the group is to spread 'the chemistry virus' into the population of youngsters (high-school or secondary school students). Each year, the members set up at least two chemistry shows at the Chemistry Department of Ss. Cyril & Methodius University in Skopje, for curious and interested youngsters, hoping to increase school students' motivation to the point where they decide to devote themselves to the study of chemistry. The group has existed for several years, but the last three years their activities have intensified. It seems likely that their activity could be related to the change in the trend of the decreasing number of chemistry students at Ss. Cyril & Methodius University in Skopje (the number of chemistry students in 2013 is somewhat bigger than that in 2012).

Recommendations/implementations for teacher education/conclusions

This chapter is about the goals and effects of practical work in chemistry. The effectiveness and role of practical work in science education has been focused upon, and questioned, by researchers for over 40 years (Hofstein & Lunetta, 2004). After all, a lot of time, money and effort is spent on practical work. Therefore it is important to study the goals and effects of this practical work.

It is important to identify goals for the chemistry lessons, and to isolate and define goals where practical work makes a unique and significant contribution in reaching these goals. In some cases other activities than laboratory experiments might be a better option.

A clear message to PSTs in chemistry should be: "Do a substantial amount of practical work in chemistry with your future school students". Therefore, different aspects of practical work must have a prominent position in PSTs training:

- Reflections on the goals and effects of practical work;
- Getting familiar with an analytical framework;
- Reflections on the role of the teacher before, during and after practical work;
- Getting experience with a variety of experiments (and other practical activities) both at the university and in school practice;
- The importance of prior knowledge (CK) and
- Laboratory safety and EHS regulations.

Chemistry experiments can be supplemented, but not replaced, by computer animations and simulations. There have to be hands-on activities in school chemistry; there have to be sensations of smell, sound and smoke.

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This chapter appeared in the book, *A Guidebook of Good Practice for the Pre-Service Training of Chemistry Teachers*, produced by a group of teacher educators under the auspices of EC2E2N, a European chemistry thematic network. The contents of the book are available on fee access at: http://www.ec2e2n.net/publication/msct2

Although aimed at chemistry teacher educators for use with trainee chemistry teachers, much of this article, and the book , will be a useful reference and resource for practicing chemistry teachers.

Chemlingoaceous: a likely story

Peter E. Childs

If you frequent garden centres, or are a keen gardener, then you will be familiar with the word *ericaceous* applied to plants. But you may not know what it means or where the word comes from. Ericaceous is used to describe plants that like acid soils or to describe such soils. The suffix -*aceous* means like something or belonging to. The first part of the name comes from the *Ericaceae* plant family, which like acid, heathy soils. And so this became a description of the soil type on which they thrive. But once you start looking you find other interesting words ending in -*aceous*, particularly in agriculture. If the farmer or gardener has *argillaceous* soils then they are heavy and clayey. The word comes from the Greek *argillos* (Latin *argilla*) for white clay, from the word *argos* = white. Hence argil means clay, and alumina, which is also a white solid, used to be called argil. Not surprising perhaps as aluminium oxide is a major constituent of clays, which are collectively known as aluminosilicates.

Calcareous soils are those containing calcium carbonate (lime), from the old word *calc* (calx) for lime, and from which we get the word calcium. *Carbonaceous* means carbon-containing. Sandy soils are referred to as *arenaceous*, which derives from the Latin *harēnāceus* = sandy, from *harēna*= sand, from which we get the word arena, a place strewn with sand (in classical times used for absorbing blood!)

What do you think *rudaceous* might refer to? My first thought was something red, but in fact it comes from the Latin *rudis* = coarse, rough and refers to coarse-grained soil. The opposite of rudaceous would be *lutaceous*, which means fine-grained or mud-like, from the Latin *lutum* for mud.

Micaceous refers to a rock, which is like mica in that it breaks into thin sheets. *Lardaceous* means lard-like or fatty, similar to the word *sebaceous*, or oil-like (Latin *sebum* = tallow). *Saponaceous* means like soap or soapy. *Nacreous* means pearl-like, or nacre-like, referring to the iridescence of pearl. Nacre is an old name for mother of pearl, and it is also used for a type of cloud, which appear pearly. Most of the -*aceous* words are found in biology and refer to classes of plants, as in herbaceous.

□

Places to Visit: Arigna Mining Experience, Arigna, Co. Roscommon

www.arignaminingexperience.ie/
http://www.showcaves.com/english/ie/mines/Arigna.html

View over L. Allen from in front of the Arigna Mining Experience

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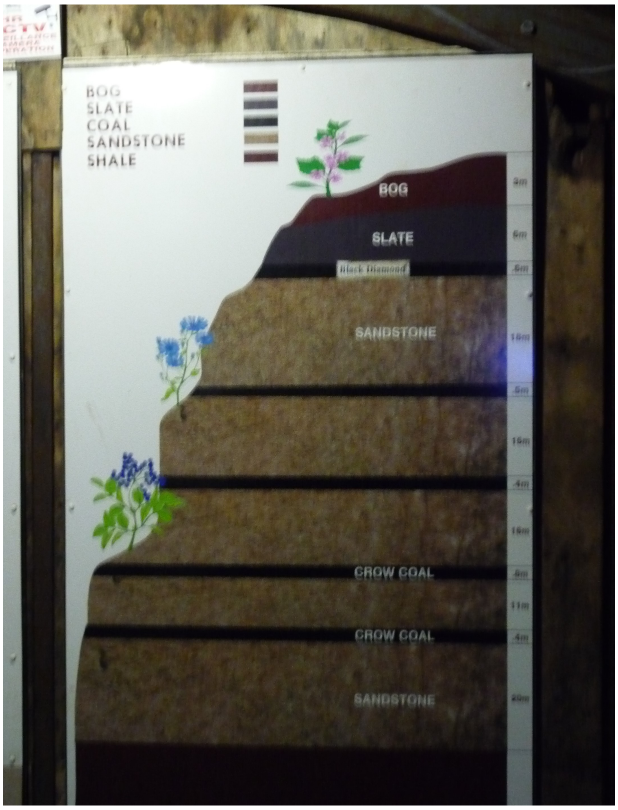
Mining in the Arigna area goes back over 400 years and both coal and iron have been mined there. The last coal mine closed in 1990 and a local campaign to open a visitor attraction based on the mines started in 2003. There is now a visitor centre, a small informative exhibition and video, and underground tours. The tours are conducted by former coal miners and last about 45 minutes. They give an interesting insight into the hard life of the miners even in the late 20th century. The coal seams at Arigna were high up the mountain and were quite narrow. This meant they could only be worked manually in most cases and eventually the mines became uneconomic. There is still a large amount of coal underground, of various grades, and it will remain there until there is a major fuel crisis. The Connaught coal field also sits on top of shales, which also contain large amounts of gas and could be tapped by fracking. There were also ironstone mines in the area and a local iron industry at the end of the 18th century, fuelled by local coal. In the 19th century and early 20th century this area of Ireland was quite prosperous because of the coal.

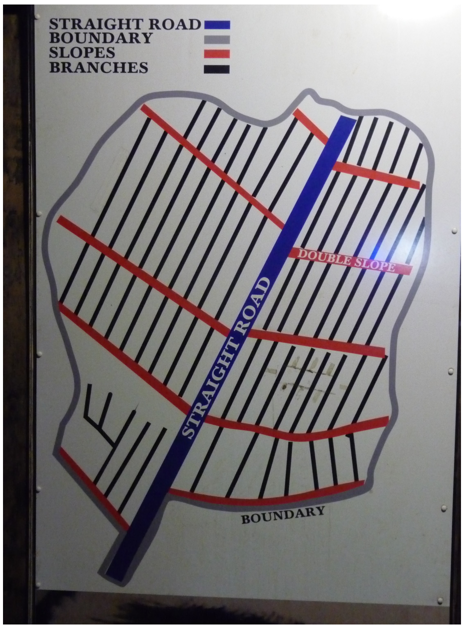
The Arigna Mining Experience buildings, built over and around the old mine entrance.

The Arigna Mining Experience is located at one of the old mines, located on the hill above the village of Arigna and looking out over Lough Allen. There is a superb view over Lough Allen from the mine. There is also a circular 39 km Miner's Trail that runs over the mountains and connects various mines and villages.
The coal is found in 5 narrow, ~horizontal beds at different levels in the mountain, with the best coal in the top seam and the poorest, known as crow coal, in the lowest two. The coal was exploited by running a main adit (tunnel) into the hill, with parallel side tunnels off it. The coal was brought out through the main tunnel in small wagons, linked by a continuous rope.

A visit to the Arigna Mining Experience makes a good day's outing and a reminder of part of Ireland's industrial past. The area also had ironworks (see below) and still has a smokeless fuel plant, processing imported coal.



The geological strata at Arigna showing 5 coal seams.



Plan of a typical Arigna mine showing how the coal seams were worked.

Some contemporary accounts:

Samuel Lewis *Topographical Survey of Ireland* (1837) *http://www.visionofireland.org/descriptions/4034530*

(Samuel Lewis, *A Topographical Dictionary of Ireland* (1837); Transcription © Derek Rowlinson, 2005-10. Reproduced from Library Ireland. We are deeply grateful to Library Ireland for allowing us to use their transcription.)

"The course of the Arigna river, which runs through a deep and narrow valley, has been adopted as a line of division between the coal field of Bracklieve, on the south, and that of Slieve Curkagh on the north, in both of which the strata are nearly similar, although minor differences, such as the change of soft slate clay into sandstone slate, may be observed within a few yards. A peculiarity of these coal districts is that of the beds of coal all lying at a considerable elevation in the mountains, where their outcrop may be distinctly traced in various places. The coal district to the south of the Arigna river extends in the direction of the mountain, from south-east to north-west, about nine miles, and in breadth about two, comprising an area of 4540 acres; and the coal field to the north of that river comprises about 1940 acres; making a total of about 6480. The quality of the coal, though not equal to that of White-haven or Newcastle, is sufficiently well adapted for culinary or manufacturing purposes, being a medium between the quick blazing coal of Scotland and the coal of Whitehaven. Inconsiderable workings appear to have been made in the borders of the several seams from an early period; but the first important era in the mining history of the district was the establishment of iron-works at Arigna, in 1788, by three brothers of the name of O'Reilly. By these enterprising men, pit coal was for the first time used in Ireland in the smelting of iron-ore; and both bar and pig iron of the best quality were produced. But the speculation proved unsuccessful, and, after passing into other hands, the concern was discontinued in 1808, although it had two coal mines in the southern district for its supply, the Rover colliery, about a mile distant, and the Aughabehy colliery, the largest in the district, about three miles distant. A report on the mineral wealth of this district, made by Mr. Griffith to the Royal Dublin Society, in 1814, and the repetition of the statements therein contained by that, gentleman before a committee of the House of Commons in 1824, induced the investiture of capital in the working of these mines by several companies, who made the borders of Lough Allen the scene of revived activity and industry. The Irish and the Hibernian Mining Companies began operations in the mountains on the north side of the Arigna river, but suspicions were soon entertained by the agents both as to the reported extent and thickness of the coal; and the Hibernian Company at once abandoned the speculation as unworthy of further attention. The Irish Mining Company, however, persevered, and opened several pits, the largest of which, at Tullynaha, was worked to advantage for a long time. But the body that engaged most extensively in these works was the Arigna Mining Company, formed in London during the speculating period of 1824 and 1825, whose affairs became the subject of a parliamentary investigation and of a long and expensive chancery suit, which was not terminated until Jan. 1836. In 1824, a lease of the old Arigna works was obtained from Mr. Latouche; a colony of engineers and workmen was brought over from England in the same year; the works were restored, the coal and iron mines reopened, and 230 tons of iron were manufactured between Nov. 1825 and May 1826, at an expense of £8. 4. per ton, when the furnace became choked, in consequence of which the smelting was discontinued and the works were suffered to fall into decay until after the decision in chancery, when Mr. Flattery, in whose favour the decree was made, recommenced the works, which have been since in full operation, producing 18 tons of castings daily and affording employment to 560 men: the metal wrought is said to be equal to the best Swedish iron. Fine castings of every description are made here and shipped for Dublin, where there is already a great demand for them. In connection with these works are the collieries of Rover and Aughabehy, belonging to the old proprietors, and a new pit, in which the coal is superior in quality and the seam thicker than any of those previously discovered, has been opened at Gubberother by Mr. Flattery, who is about to form a railway from his works to the lake. The same spirited individual is erecting a building for the manufacture of bar, rod, and sheet iron. The value of these works to the manufacturing industry of the country is much diminished by the want of good roads through this mountainous district. The works are near the shore of Lough Allen and 9 miles from Carrick on Shannon, south of the Arigna river, where the royalties chiefly belong to Mr. Tennison, though one is held under the Archbishop of Tuam. There are coal mines on both sides of this mountain ridge, of which the most important is that of Aughabehy, more distant than any from the iron-works. The iron-stone of the neighbourhood is of the greatest variety, richness, and abundance; and the limestone used as a flux is of the best quality."

Robert Kane *Industrial Resources of Ireland* (1844)

http://www.ucc.ie/celt/online/E840001-001.html

"We arrive now at the last of the coal fields of this country. The **Connaught** district. It is one worthy of attention from its peculiar geographical position, and from the circumstances connected with the attempts made to establish the manufacture of iron within its bounds. Those attempts, with the history of the too notorious **Arigna Company**, shall be treated of hereafter. The localities of the coal only occupy us now.

The largest river in the British Islands falls into the Atlantic Ocean, dividing the counties of **Clare** and **Kerry**, and cutting through the centre of the **Munster** coal formation. Expanding in its inland course into a chain of extensive lakes, it intersects through a line of 247 miles, some of the richest lands in **Ireland**, washing the banks often of the thirty-two counties of which our island is made up. It has its origin in the recesses of the **Leitrim** hills, where it springs almost with its full power from a vast gulf, the depth of which has not been yet ascertained, and almost immediately expanding forms **Lough Allen**, of which the area is 8900 acres. The picture of this district, as I saw it some two years since, has never left my mind. The dark brown hills, heather clad, rose abruptly from the water, excepting towards the south, where they were separated from the lake by level spaces of marshy bog. The patches of cultivation, small and rare, far from relieving the aspect of the scene, served but to render its dreariness more oppressive. The lake, smooth as a mirror, reflected the brilliant sky of midsummer. No wave disturbed it; the noise and bustle of active industry were far away. The melancholy solitude of my walk was only broken by the approach of some wretched men, who had heard of the phenomenon of a stranger's presence in their wilds, and pressed around, asking whether I was about to do anything for the country, to give employment. Alas! it was not in my power. As I walked on, there lay around my path masses of iron ore, equally rich with the best employed in **England**. I knew that in those hills, whose desolate aspect weighed on my mind, there were concealed all the materials for successful industry. A population starving, and eager to be employed at any price. A district capable of setting them at work, if its resources were directed by honesty and common-sense. But all sacrificed to the stock-jobbing speculations of a few men acting on the gross ignorance and credulity of some others. If the industrial circumstances of this country were really known, such events as the jobbing of the **Arigna Company** could not have occurred. Let us hope that by the progress which science and education have since made, and are now making, the occurrence of aught similar may be for the future prevented.

The hills which surround **Lough Allen** form the **Connaught** coal field; they occupy large parts of the counties of **Roscommon**, **Sligo**, **Leitrim**, and a portion of **Cavan** in **Ulster**. The greatest length of the district is sixteen miles, which is also its greatest breath. The total area is about one hundred and fourteen thousand Irish acres. Seen from the south, they present a steep and straight ridge of from 1000 to 1200 feet in height. The summits flat and usually covered with bog. The centre of this district is occupied by **Lough Allen**. The circuit of the lake may be conveniently divided into four parts, with respect to its content in coal. The rocks are similar to those of the other coal fields. They consist of sandstone, sandstone slate, slate clay, clay ironstone, and fine fire clay. The strata are very regularly arranged, conformably to the limestone on which they rest, and contrary to the declivity of the hill. Slips occur as in all coal fields: they do not present anything peculiar here.

West of **Lough Allen**, the **River Arigna** divides the field into the southern and western portions. The former consists of one great mountain ridge named **Brahlieve**. At its base are the **Arigna** Iron Works. The western division extends between the **Arigna** and **Dorobally** rivers. These two portions have almost the same internal structure. Upon the limestone rests slate clay, in thickness from 300 to 600 feet. This rock is remarkable for the rich beds of ironstone which it contains. These are exposed in the channel of the **River Arigna** in incredible numbers. Then many beds of sandstone, and next, the fire clay, which as in the **Leinster** district, form the seat of the coal.

The beds of coal found in this district are three in number, and were first described with detail in **Mr. Griffith**'s report on the **Connaught** coal formation. As the extent and characters of these beds of coal will be found of high importance, and that opinions differ regarding them, I shall transcribe, in full, the most important of **Mr. Griffith**'s observations.

Of the first Bed of Coal—The fire clay is succeeded by a bed of coal, which varies in thickness from one to three feet. It is known in the country by the name of the crow coal. It contains numerous thin ***laminae*** *of black slate clay, which render it of little value, except for burning lime. When first brought to the surface it is moderately solid, but on exposure to the air it soon divides into thin flakes.*

This bed has never been wrought. If it were, I have little doubt its average thickness would be found to amount to three feet, but it has never been seen excepting at the outgoing. In the vale of the ***Arigna****, near the iron works, where the fire clay was wrought, this coal was three feet thick. This coal runs parallel to the three foot coal which lies above it, and its outgoing may be traced along the face of the hills through the greater part of the southern and western division of the district.''*

Of the three foot Coal—The future prosperity of the ***Connaught*** *coal district may be said to depend entirely on the produce of this bed, which, though of moderate thickness, is fortunately of*

great extent. Its quality as fuel for domestic purposes is excellent, and if used for smelting iron, it is among the best in the empire. According to the analysis of ***Kirwan****, 100 grains are composed of*
71.42, carbon.
23.37, mixture of asphalt and maltha.
5.21, grey ashes.
Specific gravity, 1.351.

The thickness of this coal is rarely less than three feet or more than three feet four inches. In its outgoing, commencing at the iron works, it may be traced without difficulty along the northern face of ***Brahlieve mountain****, without any material interruption, for four miles and a half; by* ***Aughabehy*** *colliery nearly to* ***Geeva*** *point in the county of* ***Sligo****, and from thence back again on the opposite side of the hill to* ***Tullylions*** *colliery, and afterwards round the eastern end of the mountain to the point above the* ***Arigna*** *works. In the western division of the district the extent of coal is not so great as in the southern. This division may contain about 1200 acres of the three foot coal, which, added to 2800 acres contained in the southern division, make a general total of about 5000 acres. From this calculation we should deduct one-fifth part to allow for impurities in the coal and the loss occasioned by slips and undulations. This at the rate of 7840 tons per acre will leave upwards of thirty million of tons of coal as the probable quantity which may be raised out of the southern and western divisions of the district. The third bed of Coal varies from eight to nine inches in thickness. It is the uppermost bed of coal in the district, and has not been met with except in the southern division.''*

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Arigna Fuels

Arigna Fuels, Aigna, Co. Roscommon

http://www.arignafuels.ie/about/history/

Coal is still processed in Arigna by Arigna Fuels, who produce smokeless fuels from imported coal. The plant is located in the village, on the old railway sidings and below the Arigna Mining Experience. The company is the major employer in the area. Smokeless fuel is needed for several urban areas in Ireland which are smoke-free zones, and ordinary smoky coal cannot be burnt. Coal is distilled in a retort to drive of the volatile materials that cause smoke, leaving behind mostly carbon, which is pulverised and formed into briquettes. Depending on the process, smokeless fuel plants can also produce oil and gas. The shift to smokeless fuel has led to several proposals for new smokeless fuel plants, including one at Foynes, Co. Limerick, with access to a deep water port.

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Iron mining and smelting

The coal mines were originally exploited as fuel for smelting iron, also obtained from deposits in the local shale. The iron ore is found as large nodules (see photo) and were originally obtained from the Arigna River, where they had been washed out of the hills.

Iron nodules displayed in the Arigna museum.

There was an ironworks at Arigna and one further north at the top of Lough Allen at Creevelea. You can still see the remains of one of the 19th century blast furnaces at Creevelea.

http://www.mhti.com/mines_in_ireland_files/creevelea.htm

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CONFERENCE REPORTS

Travels of a PhD student

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The evenings were lengthening, the Glucksman Library at the University of Limerick was quietening and the exam timetables were fast approaching the end. Alas, the 2015 Spring semester was slowly but surely coming to a conclusion. It was a time of year which I used to particularly enjoy in years gone by. I always anticipated the sense of excitement when wondering what my three months of summer holidays would entail. What new adventures would I experience? What new sights would I see? To what extent would I need to rely on my passport to grant me access to other parts of the world which I had yet to experience? However, Summer 2015 was going to be a little bit different. There were no holidays abroad or J1 trips to the United Sates booked. I was about to experience a very different summer to what I was used to, because this was to be my first summer on campus as a PhD student. It was a thought which I did not entertain very much in the beginning as I watched my former Science Education classmates, now turned teachers, embarking on their three months school holidays! Little did I realise, that I myself was about to embark on a summer filled with new adventures, new sights, new experiences, new tastes and a much greater reliance on my passport than any other summer before – yes that’s right, I’m a PhD student and my research was about to take me from Eastern Europe, to the East coast of the United States and back to Scandinavia!

Eurovariety in Chemistry Education
University of Tartu, Estonia
June 30th to July 2nd, 2015

A two hour bus journey from the airport in Estonia’s capital city of Talinn took us to the city of Tartu, which was to provide the setting for this meeting. A quaint and charming city, Tartu is characterised by many historical monuments and landmarks depicting its unsettled past as the interface between Scandinavia and Russia during the Northern War. The most prevalent historical landmark, which we encountered most days during out time in Tartu, was the Arched Bridge which was opened in 1959. This bridge replaced the Stone Bridge which was firstly damaged in a fire in 1775 at the end of the Northern War and then completely destroyed in 1941 when it was blown up by the Soviet army.

Some of the Irish contingent from DCU and UL

Eurovariety in Chemistry Education 2015 opened with Professor Miia Rannikmäe, the conference chair, welcoming delegates from 23 countries from Europe, Australia, USA and South Africa. The focus of this conference is 3rd level chemistry education. Here are some of my most prominent learning experiences.

Asking Intelligent Questions:

When delivering lectures to large cohorts of students, it is important to keep them ‘*active*’ – most certainly a key buzz word throughout science education. However, this is inherently difficult, especially in large audiences. Simon Lancaster of the University of East Anglia carried out a workshop on utilising the app, ‘Responseware’. This software allows lectures and teachers to question their students in a Multiple Choice Question format that is very similar to the way questions are asked on the TV show *‘Who wants to be a Millionaire?’* Responseware is an app that is available for students to download to any smart phone or hand held device. Students can then answer the questions posed by the lecturer by pressing A, B C or D, before their collated responses are summarised and discussed by the lecturer. One of Simon’s key messages was emphasising the importance of asking intelligent questions that would cause some sort of cognitive conflict, both within the minds of students and among groups of students. Asking closed-questions served students very little purpose in comprehensively assessing their understanding or gauging their progression. A more open-ended question would stimulate their minds when thinking about their response and developing arguments to back up their claims. During the workshop, Simon asked a seemingly straightforward question. However, when the collated responses from the audience were revealed, it turned out that the majority of responses were quite contradicting. It prompted the audience to engage with others around them in developing arguments for why they think they may be right. It also gave participants an opportunity to learn from the people sitting next to them.

Making Learning Relevant in its Context

With the global expansion of the biopharmaceutical industry all over the world, it comes as no surprise that a highly sought after and desired trait in chemistry graduates is their ability to seamlessly adapt to life in the workplace. In lieu of this, educational institutions have a responsibility to equip their students with the abilities and skills to do so. Lecturers and teachers should seek to contextualise learning and make it relevant. Achieving this was a topic which was paid significant attention throughout the conference. Philip Taylor of the European Commission presented about a summer school, which targeted master-level students with the aim of equipping them with the skills needed to work in an accredited laboratory. Niina J. Ronakainen presented on her work in revising a series of Analytical Chemistry lectures and laboratories, with the intention of teaching scientific process skills in a modern and stimulating environment. Some of the changes she described included a renewed emphasis on critical thinking, analytical reasoning and communicating as a professional throughout students' laboratory reports. Matthew J. Almond of the University of Reading described a "Skills Training" programme that addressed general, employability and research skills in its students. An example of one of modules in this programme is a generic skills module, which teaches skills in oral and written presentations, numeracy, team-working, time management and IT.

To What Extent is a Laboratory Report Really Doing its Job?

It is agreed that the traditional laboratory report comes with its fair share of limitations when assessing student understanding and performance in the laboratory or gauging their performance. Chris D. Thompson of Monash University in Melbourne, Australia talked about student-generated drawings of chemistry at the sub-micro level, as part of a laboratory report requirement. He argued that written laboratory reports are not an effective method of assessment if students are not required to include sub-microscopic, structural drawings of experimental reagents and products. Accompanying explanations of these drawings were also deemed to be crucial in probing for deeper understanding.

There were researchers from Ireland from UL and DCU, and Peter Childs gave a plenary talk on ''We're not in Kansas any more!': some challenges for teaching and learning third level (university) chemistry". The programme can be accessed at https://sisu.ut.ee/sites/default/files/eurovariety/files/eurovariety_programme.pdf

The conference was combined with the annual council meeting of the EuCheMS Division of Chemical Education, which sponsors the Eurovariety and ECRICE conferences.

The next ECRICE conference will be in Barcelona from 7-10 September 2016. http://ecrice2016.com/

Gordon Research Conference:
Visualisations in Science and Education
Bates College, Maine, USA
August 2nd – 7th, 2015.

In the early stages of my PhD research, I developed an interest and an awareness of the significance of chemistry students' acquiring the skills and abilities to conceptualise and visualise sub-microscopic structure. In March, I secured the *Chemistry Education: Activating Research* travel bursary from the Royal Society of Chemistry to attend the Gordon Research Conference (GRC): *Visualisations in Science and Education.* My PhD supervisor, Dr Anne O'Dwyer was also awarded this travel bursary. My main intention for attending this specific conference was to meet and learn from the Lappan-Phillips Professor of Science Education at Michigan State University, Melanie M. Cooper. Having completed her B.Sc., M.S and Ph.D. at the University of Manchester, England, Prof. Cooper was one of the first tenure track appointments in chemistry education in a chemistry department in the USA, at Clemson University in South Carolina in the USA. In January 2013, she moved to Michigan State University as Professor of Science Education. Her research is focused on improving the learning outcomes of students enrolled in large, introductory undergraduate chemistry modules. Along with her research team, Prof Cooper has developed, established and evaluated a first year, undergraduate chemistry module called CLUE (Chemistry, Life, the Universe and Everything). CLUE aims to foster students' ability to understand the fundamentals of chemistry on a sub-microscopic structural level, before going on to teach how this explains chemical properties (such as electron geometry, molecular shape, bond polarity, molecular polarity, intermolecular forces and chemical characteristics such as boiling and melting points), chemical reactions and energy systems. My PhD research aims to develop a laboratory-based pedagogy framework based on CLUE's emphasis of enhancing students' understanding of sub-microscopic structure.

Every year, the GRC board coordinates hundreds of conferences taking place in the US from fields of expertise such as '*Astrophysics and Astronomy'* to '*Microbes and Viruses'*. The format of most GRC's are similar regarding their programme formats, even to the mandatory lobster dinner on Thursday nights! When we arrived in Boston Logan Airport, we caught a shuttle bus to the Embassy Suites Hotel where we were greeted by dozens of people negotiating poster holders with briefcases and suitcases along with dozens of GRC workers. There happened to be six GRCs happening that week so once all of the participants were registered and had picked up their lunch boxes, we hopped on our designated bus to head off to one of the six GRC conferences that were taking place that particular week. The whole registration process couldn't have been more efficient or better organized.

Due to strict confidentiality clauses which the GRC board required its participants to agree to before the conference began, I'm restricted on reporting the unpublished content that was presented during this conference. Aside from the insights that I gained during talks and poster presentations, I felt as if I learnt equally as much from simply attending and experiencing a conference in the US!

My First Poster Presentation

As already alluded to, the presentation format of most GRC conferences is similar in that the only oral presentations are those from invited speakers. All of the remaining conference participants presented their research in the form of posters. Having already had plenty of experience of delivering oral presentations from my time in initial teacher education and from my Eurovariety presentation the previous month, my GRC poster was to be my first time to present my work in the form of a poster! Despite having initial concerns about this due to my limited experience, I soon realised that such concerns were unnecessary.

Presenting by means of a poster is a wonderful opportunity to really get to know those who visit your poster. I felt I could explain my research in a more profound way as I got asked a lot more questions in my two hour poster session, as opposed to the three or four questions which you may be asked after an oral presentation. This method of presentation provided me with many opportunities to get mounds of advice and suggestions, from not only the questions I was asked but also from the questions which I asked! This two-way communication makes for a much more authentic means of networking with others in your field of study.

Being 'Put-Up'

For me, one of the highlights of this conference was the sheer amount of organisation and attention to detail that went into its coordination. The entire week-long programme ran like clockwork and I felt as if we made good use of every minute. Each day, breakfast began at 7:30am and the last talk finished at 9:30pm. However, this was not all filled with talks and poster presentations because every day after lunch, we had 4 hours of '*free time'*. It was up to each participant what they wanted to do during this time but the GRC board had several activities planned such as kayaking, swimming, local brewery tours, bird sanctuary tours and bikes for hire. I really enjoyed this part of the day as we got to spend some quality time outdoors, basking in the warmth of the August sunshine before heading into our evening poster session. Having being rejuvenated and energised from this mid-day break, I felt more productive throughout the evening presentations.

All of the participants at the conference were put-up in the dorms of Bates College. It was less than five minutes' walk to Common's Hall where breakfast, lunch and dinner was served. I was somewhat flabbergasted at the amount of different food options on offer each buffet meal. All sorts of dietary requirements such as gluten free, lactose free and sugar free were fully catered for. There even was a vegan bar that provided a number of different dishes to choose from at each meal time!

Finding fault with the facilities, amenities or programme which was put in place for us by GRC and Bates College was an inherently difficult task.

European Science Education Research Association (ESERA) Biennial Conference Pasila, Helsinki, Finland

August 31st – September 4th, 2015.

My third and final conference of the summer was going to be the big one! Over 1,300 participants made the journey from all over the world to ESERA 2015 in Helsinki, Finland with the intention of gaining insight into one fundamental process – how to improve the process of teaching and learning science at all levels.

The destination for this conference was a conference centre at Pasila, a 5 minute train ride from Helsinki's city centre. Just two months prior to the conference start date, a significant public transport project was opened on July 1st 2015 called 'The Ring Rail Line'. This is a brand new and state of the art train line linking the airport in Helsinki to the city centre and to the rest of Finland. Running every 10 minutes during the day and every 30 minutes throughout the night, this train line was highly convenient for conference delegates to hop on at the airport in order to reach the Pasila train stop, which was about a three minute walk from the conference centre.

I was accompanied by five other members of EPI*STEM: Sibel Erduran, Peter Childs, Grainne Walshe, Louise Lehane and Laurie Ryan.

FP7 IBSE Projects: Delving into The Diverse World of EU projects

Peter and Laurie participated in this conference as the Irish partners in the European-Funded TEMI: '*Teaching Enquiry with Mysteries Incorporated'* project. This project aims to provide pre-service teachers with new skills to engage students, resources to excite students and the necessary support need to effectively introduce inquiry based learning into their classrooms.

TEMI is a project funded under the Seventh Framework Programme (FP7). In 2006, EU member states allocated 330 million euro towards (FP7) to support 'Science in Society' activities. A total of 38 collaborative Projects and Coordination and Support Actions along with 1 service contract were funded in the Science Education sector of 'Science in Society'. The findings from four of these projects, all having Irish partners in their implementation, were disseminated and discussed during ESERA throughout symposia's, paper presentations and posters.

A symposium for the project, PROFILES: *Professional Reflection-Oriented Focus on Inquiry-based Learning and Education though Science,* was organised and chaired by Claus Bolte from Freie Universitet in Berlin. This symposium was dedicated to assessing the impact of different continuous professional development programs within the PROFILES Project and had four researchers present their findings. University College Cork is the official Irish partner in this project. In a similar format, a symposium was also organised for the dissemination of findings throughout the TEMI project.

EPI*STEM's Louise Lehane disseminated findings from the 'ChReact: Chain Reaction: *A Sustainable Approach to Inquiry Based Science Education'* project. The ChReact project aims to enhance Inquiry-Based Science Education (IBSE) by developing interactive and engaging IBSE resources for their integration in student-focused lessons.

Leeanne Hinch from the Centre for the Advancement of Science and Mathematics Teaching and Learning (CASTeL) at Dublin City University disseminated findings from the ESTABLISH: '*European Science and Technology in Action Building Links with Industry, Schools and Home'* project. The ESTABLISH project serves to produce exemplary materials for both science teachers and CPD instructors that will promote the adoption of IBSE into their teaching and learning curriculums.

Dublin City University also had representatives from the SAILS: '*Strategies for Assessment of Inquiry Learning in Science'* project including Dr. Odilla Finlayson, Dr. Eilish McLoughlin and Dr. Paul van Kampen. The SAILS project aims to support second-level teachers in their adoption of IBSE. As the discussant in the PROFILES symposium, Peter Childs raised three points which could be argued to stand applicable to the dissemination of the other FP7 projects.

1. Leaving a Lasting Legacy

It is quintessential that teaching and learning innovations which are developed, established and evaluated as a result of various FP7 projects leave a lasting legacy. They must be seen to have a residual effect in years to come otherwise, the vast amount of money invested into these projects will be wasted. It was emphasised that these innovations must have a continued lifespan and that they are not just utilised for the means of securing incomes for the researchers involved or as funding accolades in bolstering CVs and resumes.

2. Being Open-Minded

An obstacle faced by FP7 project innovations during their integration into various curricula is teachers' lack of familiarity and understanding surrounding their content and methods of integration. Having had very little experience of such new innovations, such as Inquiry-Based Learning during their time as students, teachers need to keep an open mind when learning about new innovations and the methods of how they can incorporate them in their lessons. A theme that was discussed at length during the PROFILES symposium was the need for teachers to assume a sense of ownership and entitlement over an innovation. It was agreed that when teachers are included in the development and evaluation of teaching innovations, it would promote their successful and subsequent integration into curricula as they would be more open-minded and positive. Perhaps more FP7 project innovations should target initial teacher education programmes and curricula as result?

3. Overlap and Communication between FP7 Projects

Given the number of projects which are currently being funded under the Seventh Framework Programme, it should be of utmost importance and responsibility for the partners associated with each project to establish appropriate lines of communication and collaboration. The four projects which were disseminated at ESERA all contributed significant insights into different areas and aspects of science education. However, it was thought that most of these insights could benefit researchers involved in other projects. For example, PROFILES emerged with the insight of the importance of teacher assuming ownership over a teaching and learning innovation. Meanwhile, TEMI and ChReact work with teachers in initial teacher education to develop such innovations. Perhaps some form of collaboration between these projects could enhance how teachers in initial teacher education derive a sense of ownership of their own innovation which they develop. Surely this would promote its successful integration in later years when they graduate and begin their teaching careers.

EPI*STEM's Prof. Sibel Erduran

Sibel was a very prominent figure in the roll-out of ESERA 2015 as she gave one of the four keynote talks. The title of Sibel's talk was '*Reconceptualising the Nature of Science in Science Education'*. The organisers of ESERA 2015 presented each keynote speaker with the challenge of making each keynote talk as interactive with their audiences as possible. Sibel used the social networking site, Twitter to achieve this. In keeping with the challenge presented to her, Sibel asked the audience questions whereby they would reply in the form of a ‘tweet’ using #keynote4. One question which provided for fruitful debate among the audience was ‘*What is this thing called ‘science’*?’ The audiences’ contributions, opinions and responses, in the form of tweets carrying the hashtag; #keynote4 were all projected in a Twitter Timeline next to Sibel’s presentation slides. This proved to be a novel and exciting integration of ICT into a keynote talk, which allowed for everyone’s voice to be heard.

Sibel’s talk featured the presentation and description of the Family Resemblance Approach (FRA) as a means of capturing what actually is ‘*….this thing called ‘science’’*. Using a representation, based on the structure of the London eye, Sibel explained how there are many facets of how science can be perceived by different societal cohorts just like how there are many capsules on the London Eye. Some of these perceptions are derived from economic, historical, philosophical, anthropological and sociological accounts. The FRA is an attempt at reconceptualising and encapsulating a common mutuality between these various perceptions in pursuit of a holistic consensus view of Nature of Science. Sibel also featured as an author on six other papers that were presented at ESERA 2015.

Papers from EPI*STEM, University of Limerick

Grainne Walshe spoke about her PhD research on the development and evaluation of the CISA (Critical Integrated Skills and Activities) Model. CISA sets out for the design of exemplary curriculum materials that assists teachers to integrate mathematics into science. The evaluation of the CISA Model suggests that curricular models should take into account the factors which effect teachers’ curricular choices such as attitudinal, contextual and affective factors.

Grainne also disseminated the findings of another research study which she was she was involved in with other EPI*STEM members, Anne O’Dwyer and Joanne Broggy in partnership with the Mallow Development Partnership. Here, 6 workshops were developed (using resources from the IDEAS resource pack (Osborne, Erduran and Simon, 2004)) to help science teachers develop meaningful CPD in the area of Nature of Science. The evaluation of these workshops revealed that while teachers were familiar with the terms ‘*evidence*’ and ‘*argument*’ and related to their relevance in the classroom, they were unable to suggest topics within the current curriculum that would provide the opportunity for them to integrate such exercises embedded within the Nature of Science. Another interesting finding here also was that teachers only envisioned the use of argumentation during discussions on controversial, socio-cultural issues such as cloning, genetic engineering, IVF and GE food. Teachers did not identify how argumentation could be used within subject-specific contexts. For example, during classroom discussions on a particular science topic, students’ make claims when they answer questions, they engage in reasoning for why they think they are correct and they may even make rebuttals, contradicting others students’ discussion contributions in the form of answers or opinions.

Louise Lehane presented her PhD research based on the experiences of Irish Pre-Service Teachers (PSTs) when engaging in a Professional Learning Community (PLC). This PLC would see the adaption of the Core Representations (CoRe) tool under the Pedagogical Content Knowledge (PCK) lens. Her research found that while initial contestations, tensions and challenges were experienced by the PSTs during the adaption of the CoRe tool, the tool was found to be beneficial in fostering and developing inquiry orientations within a dedicated learning community.

At the end of the conference the venue was announced for the 2017 conference - it will be held in Ireland at Dublin City University in August 2017. The conference will be jointly organised by CasteL at DCU, with Eilish McLoughlin and Odilla Finlayson as the main organisers, and by EPI*Stem at the University of Limerick, with Sibel Erduran and Peter Childs. This is a large and important conference and a big coup for Ireland. It will be held at the end of the school holidays and thus possible for Irish science teachers to attend. The dates are 28 August – 1 September 2017. www.esera2017.org

If I Was To Do It All Again: My Advice

It is now September 2015. The evenings are shortening and the Glucksman library is starting to get busy as the autumn semester kicks off. If one was to rewind the clock and transport me back to the start of the summer, right back to the time when I questioned how much I was going to need my passport, here's what I would tell myself.

1. Don't be afraid

When at conferences, try to introduce yourself and learn from as many people as you can. It isn't easy introducing yourself as a first-year PhD student to an acknowledged, renowned and respected researcher but it is important to try and put these vulnerabilities aside. Try to learn as much from the people you meet at conferences as you can. Ask them questions and not just questions about chemistry education, Lewis structures, theoretical frameworks or belief systems but perhaps about where they come from, what interests them other than science education or how they travelled to the conference (a question guaranteed to overcome a lull in conversation flow!). Make contact with at least one person that you meet at each conference after you have come home. You never know what could arise in the form of potential future collaborations, citations or reunions at other conferences.

Just how it may seem unnerving introducing yourself at such an early time in your pedagogical research to experts in your field of study, it may seem just as scary and as daunting to ask a question in a packed paper session or symposium. There is no such thing as asking a '*stupid'* question. Thinking critically during presentations is a skill that you should intend on mastering in order to ask questions that will strengthen your understanding in a particular field of study.

Don't forget to do your homework

When travelling to a conference, it will prove to be extremely helpful if you have a profound understanding of two key documents – the conference programme and the map of the location where the conference is being held. Before you begin your travels, have an itinerary prepared from the conference programme of which paper sessions you want to attend and what researchers you wish to meet and learn from. Trying to decide on which session to choose from the 20 parallel paper sessions that are being held at any one time an hour before they are due to begin is a nightmare. Having an insight into the location of where the conference is on and the various modes of transport from the airport or hotel which you are staying at is also essential to keep those nightmares and headaches at bay. Now, let's not forget that having a profound knowledge of your project is also key to surviving so practicing saying what you need to say in the presentation time permitted – it's a given!

2. Embrace, Relish and Savour

Travelling to conferences is a wonderful opportunity to see the sights, hear the sounds and taste the foods belonging to the places you have never experienced before so embrace, relish and savour each sense pleased by each different culture. Use any free time you come across in the conference programme to get out and about!

Now, the passport gets shelved in favour of the research books in planning and preparation for summer conference escapades next summer!

Reference

Osborne, J., Erduran, S., & Simon, S. (2004). Ideas, evidence and argument in science (IDEAS) project.
(See http://www.nuffieldfoundation.org/ideas-evidence-and-argument-science-ideas-2004)

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*Aishling Flaherty is a PhD student in EPI*STEM and is working on a project to develop a training course and materials for graduate teaching assistants (demonstrators) in UL, in order to improve the effectiveness and laboratory experience of undergraduates. She is being supervised by Dr Anne O'Dwyer (MIC) and Professor Sibel Erduran (UL).*