Contents

Contributions on any matter of interest to second-level chemistry teachers are welcome. Normally the results of research (chemical or educational) are **not** published, except in a general form or as a review. Articles should be submitted electronically (email or disc) to **peter.childs@ul.ie** together with a printed copy.
For subscription details etc. see inside back cover.

Cover photo: The amazing crystal cave in Naica, Mexico (Photo: © National Geographic Society)

Editorial

LC Results

In this issue I present an analysis of the 2011 LC results. The results throw up some interesting findings. More students are choosing to study Biology, Chemistry and Agricultural (Ag.) Science, although Physics is still losing students. The popularity of Biology continues to increase and the number doing Ag. Science is now only 43 less than that doing Physics, and more students now take HL Ag. Science than take HL Physics. On the basis of this trend Ag. Science will become the 3rd LC science in 2012.

The Physics & Chemistry combined subject continues to wither on the vine. This subject represents a wasted opportunity. There is a market for a combined physical sciences course, particularly for small schools and others who don't have the staff to offer both Physics and Chemistry, and don't want to drop one or other of them. However, the existing course is over 40 years old and badly needs replacement. A revised syllabus was drawn up by the NCCA several years ago but never implemented. It was an innovative, context-based approach which I think would prove very popular and would help encourage more students to take the physical sciences. As far as I know it remains on a shelf somewhere, gathering dust. It would be far cheaper to implement this than to totally revise the other LC science syllabi, and change the style of assessment.

Agricultural Science also needs urgent revision as the current syllabus is also over 40 years old. There is an upsurge of interest in agriculture and agribusiness in Ireland and this surely deserves a modern and progressive syllabus.

Each year, as far as I am aware, the Chief Examiner in each subject prepares a report on the examination papers. However, each year only a selection of these reports are published, roughly on a three year cycle. Thus the Chief Examiner's reports were published in 2008, 2005 and 2002 but no report is scheduled for 2011. Why cannot the reports for all subjects, at LC and JC level, be published each year? This would be a help to teachers and students, as the reports are very informative.

The impact of cutbacks

We are still waiting to see the full impact of the economic cutbacks on the education system: increased class sizes, early retirements, reduction in funding. These are against a back-drop of increasing numbers coming up through the schools, high unemployment which leads to more people staying in education, and proposed rapid change in the system at Junior Certificate and Leaving Certificate level. I find it hard to see how major changes can be implemented when there is a shortage of funds for in-service training and CPD. The proposals for assessing practical work at LC level in the sciences is going to be very costly in money and in time and complex to organise in schools. You cannot do curriculum development in a hurry or on the cheap – well you can, but the results will be disastrous.

It is difficult to see how Ireland can support a knowledge economy and promote STEM subjects with less money, the probable loss of minority subjects (like Chemistry and Physics) in some schools, the loss of experienced teachers who won't be replaced, and reduced investment in laboratories, resources and CPD. If the government is serious about promoting STEM subjects then this will need more investment in schools and teachers, not less. At the moment, given all the pressures on and changes in the education system, it is hard to see how the quality of science teaching can be sustained and I fear it can only get worse. We also have thousands of unemployed graduates, including many teachers, and this represents a massive loss of talent and a waste of an investment. If the loss of experience teachers through early retirement in Feb. 2012 were offset by an influx of young and energetic science teachers into schools, then this would be great, but again I fear this will not happen.

Education is the key to future prosperity, especially education in STEM subjects, or so everyone keeps saying. However, what is happening on the ground in schools in Ireland is the exact opposite of what is needed.

Peter E. Childs **Hon. Editor**

Education News and Views

European City of Science 2012

http://www.dublinscience2012.ie/

2012 is going to be a big year for Dublin as it hosts the 2012 ESOF meeting in July (11-15) and as the whole year has been designated a Year of Science. You can find out what's happening from the website.

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Shaking up Irish third level education: from IT to TU

The whole landscape of Irish education at third level looks likely to change in the years ahead. At the moment Ireland has 7 universities and 14 Institutes of Technology. The ITs have been pushing for university status and following the Hunt Report (http://www.hea.ie/en/node/1303) in 2011 they have been talking about becoming Technological Universities (TU). Several consortia have announced proposals for mergers to become Technological Universities: Waterford and Carlow; Dublin IT with Tallaght, Blanchardstown and Dun Laoghaire; Limerick, Tralee and Cork to form the Munster Technological University; Athlone, Dundalk, Galway-Mayo, Letterkenny and Sligo to form the 'BMW Technological University'.

On Feb. 13th. The Higher Education Authority produced a discussion paper, *Towards a Future Education Landscape*, which lays out a plan for the future and criteria for the new technological Universities. Samller colleges will also be forced to merge with larger institutions.
(http://www.hea.ie/en/node/1462)

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Practical work in Ireland

You can read an interesting article by Declan Kennedy on 'Practical Work in Ireland' in the Eurasia Journal of Mathematics, Sciencxe & Technology Education, 2012, 8(1), 21-34 available on line at:
http://www.ejmste.com/v8n1/EURASIA_v8n1_Kennedy.pdf (accessed 1/3/12).

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STEM Resources online

The National STEM Learning Centre in the UK, based in York, has some excellent e-resources available online from:
http://www.nationalstemcentre.org.uk/elibrary
This is located in the same building as the National Science Learning centre in York.
The National STEM Centre now publishes *Catalyst* magazine and back issues are available on its website.

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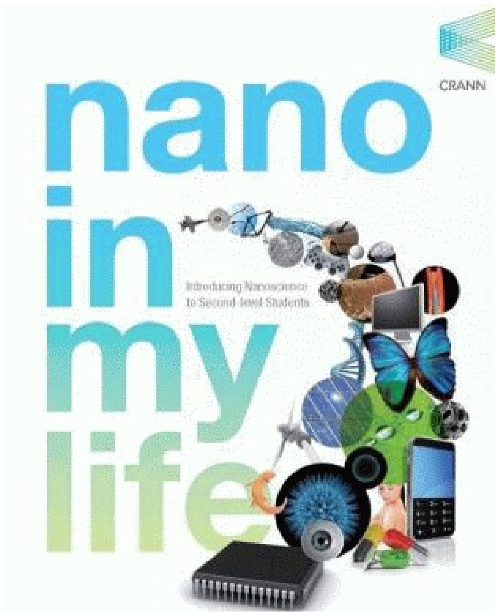
'What next for Nano?' National Poster Competition



The "Nano in My Life" DVD resource pack was launched at CRANN's **A**dvanced **M**icroscopy **L**aboratories in Trinity College on Thursday 17th November. It is an excellent resource for introducing students to cutting edge science and ideal as a Transition Year module. ISTA have teamed up with CRANN and we are running a poster competition called ***"What next for Nano?"*** The finalists will have their work displayed in **The Science Gallery** and the winners will be announced at the **50th ISTA Annual Conference held in Trinity College on 20th-22nd April 2012**. Full details on www.ista.ie

Andrea Geraghty, Sadbh O'Toole & Sarah Halpin above and below from Eureka Secondary School at the Advanced **M**icroscopy **L**aboratories **in Trinity College for Nano pack launch.**

Mary Mullaghy (ISTA), Patrick Geoghegan (Trinity College), Mary Colclough (CRANN), Peter Brabazon (DSE).

ISTA Senior Science Quiz Final 2011 Results

Congratulations to all the Finalists of ISTA Senior Science Quiz, generously sponsored by PharmaChemical Ireland.
During National Science Week, 831 Leaving Certificate science students participated in the quiz nationwide. The Final was held in Trinity College and attended by 39 teams.
Thanks to all the ISTA teachers who helped with the organisation and Aoibhinn Ní Shúilleabháin who was guest quizmaster.

The National winners were:
1. Coláiste Chríost Rí, Capwell Road, Turner's Cross, Cork.
2. Scoil Chaitríona, Mobhi Road, Dublin 9.
3. St. Mary's College, Ballysodare, Co Sligo.
4. St Mary's College, St Mary's Road, Galway.
5. Summerhill Hill College, Sligo.

Kyle Malone, Aoibhinn Ni Shuilleabhain, Chris Mintern & Paul Ryan from Coláiste Chríost Rí, Capwell Road, Turner's Cross, Cork

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Institute of Chemistry of Ireland News

The ICI Council has recently selected the speakers for the Eva Philbin Annual Award Lecture Series 2012 and the Boyle-Higgins Lecture 2012. The recipients are ***Professor Lesley Yellowlees*** of Edinburgh University, (www.chem.ed.ac.uk/staff/academic/yellowlees.html), and ***Professor Malcolm Smyth*** of Dublin City University (www.dcu.ie/chemistry/ssg/malcolm_profile.shtml), respectively.

Professor Yellowlees (above) works in the area of Photovoltaics for Solar Energy, and was recently elected President of the Royal Society of Chemistry, the first woman to hold the position.

Malcolm Smyth (above) from DCU will present the Boyle-Higgins Lecture in three different venues in 2012.

New Awards for Chemists Practicing in Ireland in 2012

The Eva Philbin Award is typically given to a distinguished chemist, usually from abroad, and the Boyle-Higgins is typically given in recognition of a career in Irish chemistry. As part of IYC2011, Council has decided to institute ***two new awards*** that are aimed specifically at chemists practicing in Ireland. One will be for an ***industrial chemist***, with a second intended for those in ***academic research/teaching***. A condition of the awards will be that nominees must be a member, though interested candidates can join ICI and apply for an award at the same time. As well as a Certificate and Prize, it is intended that the Winners would give a public lecture and contribute a related article to Irish Chemical News. If these awards prove popular and competitive, as we expect they will, we hope to roll out additional awards in later years. Details of these two new awards, and the application procedures, will be available early in the New Year.

Separately, ICI will give a new prize at the Universities Colloquium open to GradICI members.

ICI's bid to bring the EuCheMS General Assembly to Dublin for European City of Science 2012 was successful and will be held in the Autumn.

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Spectroscopy in a Suitcase

Richard Oakley
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Through the RSC's Spectroscopy in a Suitcase (SIAS) scheme (supported by the national HE STEM programme), school students gain hands-on experience of spectroscopic techniques and their applications. The scheme is run so that the event is completely free for the school that is participating. All the teacher needs to do is coordinate with the local contact to organise a convenient time to run a SIAS workshop.

From small beginnings, over the last 5 years SIAS has become increasingly popular and well travelled. In 2011 alone, over 6,000 students participated in SIAS events. The number universities involved in delivering SIAS has increased from 7 in 2010 to 19 for the start of 2012.

Delivered by post graduate students and outreach experts, the events have a strong emphasis on encouraging school pupils to consider studying chemistry and the career opportunities available. In addition, the direct contact with post graduates gives A-Level students the opportunity to ask question about life at university.

The format of the day includes: an introduction to spectroscopy, a more in depth discussion on Infrared and UV/Vis spectroscopy, and then instruction on the practical exercises. A whole SIAS workshop takes 4-5 hours with a break in-between the UV/Vis and IR practical sessions. The images below are an example of two recent SIAS events and demonstrate the interactive nature of the SIAS programme.

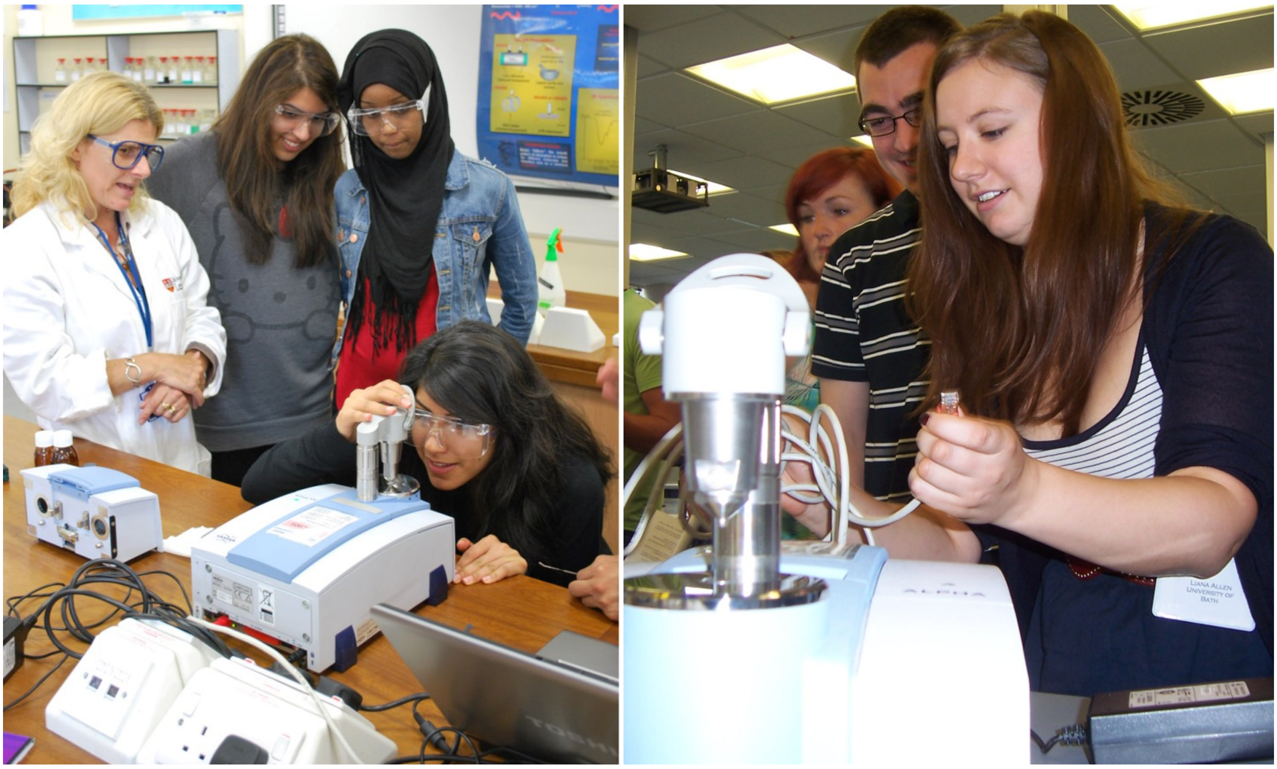

Figure 1. Students get hands on experience of using cutting edge research equipment.

The following statements are quotes from the feedback forms that students are asked to fill in anonymously after an SIAS event:

"Loved the spectroscopy activities, being a smaller group made it easier to participate in activities. Liked printouts ☺"

“The activity was interesting and fun, students were helpful and fun to talk to”

“I liked the fact that we were allowed to use high-spec, university equipment with a very hands on approach”

In July, two sets of equipment were established in Wales in partnership with the universities of Cardiff and Bangor, and to support this expansion, the accompanying resource packs were also translated into Welsh. The SIAS programme has also now been expanded to Scotland (University of Edinburgh) and to Northern Ireland (Queens University) thanks to funding from the RSC and the Wolfson Foundation, so that now, SIAS is reaching every part of the UK.

Furthermore, as part of the SIAS programme there is a spectra school website, that provides an online database of fully interactive IR, NMR and mass spectra for a range of organic compounds, and information on spectroscopy in general (http://spectraschool.rsc.org/). This on line spectroscopy resource is currently being redeveloped for release in July 2012, when it will include further detail on a multitude of spectroscopic methods and include animations, videos and an interactive spectra tool. A screenshot of the new spectra school website can be seen below.

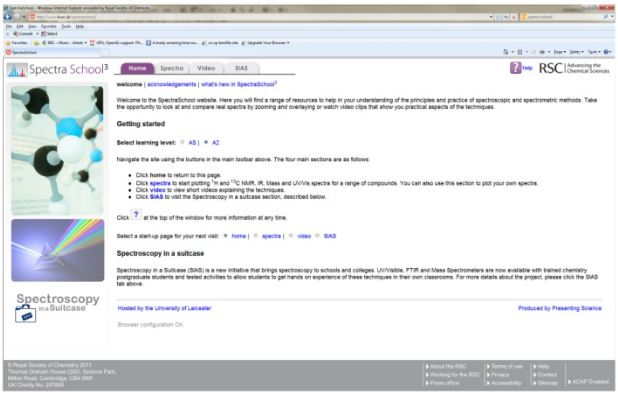

Figure 2. Screen shot for the new Spectra School website.

The RSC is committed to supporting the SIAS programme, and has guaranteed to fund SIAS activities after the end of the current HE STEM Programme funding in July 2012.

Full details of the scheme and the locations of the equipment can be obtained from the RSC web site www.rsc.org/sias For more information or to arrange a visit, please contact hestem@rsc.org

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News from the chemical industry

In 2011 Irish exports rose by 4% to €92.9 billion, up from €89.2 billion in 2010. The chemical and pharmaceutical sector exports were worth €56 billion, 60% of the total and 7.2% up on 2010. These figures indicate the health of the sector, despite the world economic recession. The pharmachemical sector has kept the Irish economy afloat during a period when world trade collapsed and new jobs continue to be announced. Although direct employment is relatively small, considering the value of its production, ~25,000, the industry has important spin-offs to the wider economy. You can read the latest news on the industry at the Pharmachemical Ireland website: www.pharmachemicalireland.ie.

In the last six months from Sept 2011 to Feb, 2012 the industry has announced over €1 billion of investment in Ireland. The latest announcement made on 27th. Feb, 2012 was a €330 million investment by Eli Lilly in West Cork for a new biotech manufacturing plant, which will create 200 jobs.

Matt Moran, Director of Pharmachemical Ireland comments: *"The pharmaceutical and biopharma industry is playing a vital role in Ireland's export-led recovery. The sector accounts for over 50% of the total Irish exports and employs over 50,000 directly and indirectly, 50% of these hold a third-level qualification. Eight of the top 10 pharmaceuticals companies in the world have major operations in Ireland, benefiting from a favourable tax regime, a highly-skilled workforce, strong compliance record and easy access to European markets. The extraordinary flexibility of the Irish economy and labour market has been recognised by international investors. Investment into Ireland grew strongly in 2010."*

This is good news for chemistry in Ireland that we need to pass on to our students.

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Organic Chemistry in Action! An Action Research Project to improve the teaching of Organic Chemistry by using the findings of Chemistry Education Research (CER)

Anne O' Dwyer and Peter E. Childs

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Introduction

Organic Chemistry in Action! is an evidence-based resource designed to facilitate the teaching and learning of Second Level and Introductory Third Level Organic Chemistry. Organic Chemistry is a significant part of the Leaving Certificate syllabus (~ 20%) and the examination (~25%), and so, an appropriate amount of time should be devoted to it. It is necessary for Leaving Certificate candidates to gain a detailed understanding of this area of the course, together with the accompanying mandatory experiments. Organic formulae [1], curved arrow diagrams [2, 3], mechanisms [4], and laboratory classes [5], have all been identified as difficult topics. The main areas of difficulty in Leaving Certificate Organic Chemistry in Ireland were firstly identified [6]. These findings were supported by previous Irish studies [7, 8]. Using these findings and insights from Chemistry Education Research, the intervention programme was developed. It was developed as part of an Action Research project. Action Research combines the use of research-evidence and theory as well as direct feedback from practicing teachers. The intervention materials were designed with specific reference to the current Leaving Certificate syllabus [9]. The materials are flexible enough to be used with introductory third level Organic Chemistry and the proposed new Leaving Certificate syllabus [10].

The '*Organic Chemistry in Action!*' programme covers the syllabus content of Sections 5.1, 5.2, 5.3, .5.5 and 5.6 of the

syllabus as well all parts of Section 7: 7.1, through to 7.5. Section 5.4 (Heats of Reaction) of the syllabus is omitted from this Teaching Package. The total number of lessons specified (54) is just less than the 57 class periods that are recommended in the syllabus guidelines for the sections covered. This allows for three class periods to be used at the teacher's discretion e.g. if a particular topic requires more class time. Given that the standard school timetable is five periods per week (three singles and a double), this programme takes 11 and a half weeks to complete. (This would change with a different allocation of time.)

The design criteria

The ten key design criteria (shown in Figure 1) chosen for the *Organic Chemistry in Action!* programme were informed by the relevant findings in Chemistry Education Research and developed with consideration of the specific requirements of the programme. Teaching and learning strategies were integrated with the design criteria with a specific focus on the relevance to the areas of difficulty that were identified by teachers and **pupils in Ireland.**

Figure 1 Ten Design Criteria for the Organic Chemistry in Action! programme

A key feature of the structure of the programme is that it is modelled as a spiral curriculum rather than the traditional rigid, linear curriculum. This approach involves separating Organic Chemistry into cycles, rather than consecutive topics (see Figure 2). The first cycle provides the pupils with an insight into the fundamentals of Organic Chemistry, but at less depth. The later spirals force the learner to recall and relearn the topics already covered in Organic Chemistry.

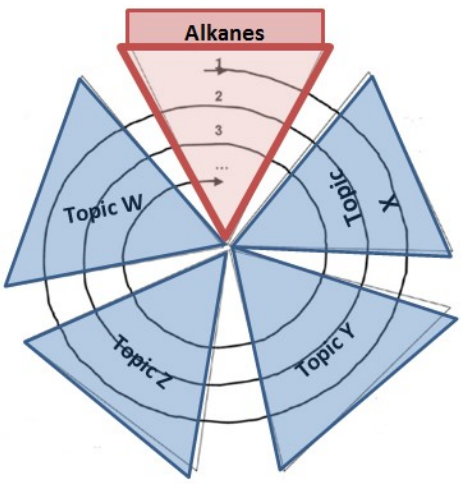


Figure 2a Illustration of the spiralling introduction of Alkanes in the Organic Chemistry in Action! programme

This spiral approach to teaching Organic Chemistry has proven to be effective in previous studies [11, 12, 13]. It is hoped that such an approach to teaching Leaving Certificate Organic Chemistry will facilitate the learners' understanding of the topic rather than resorting to rote learning as has often been the case.

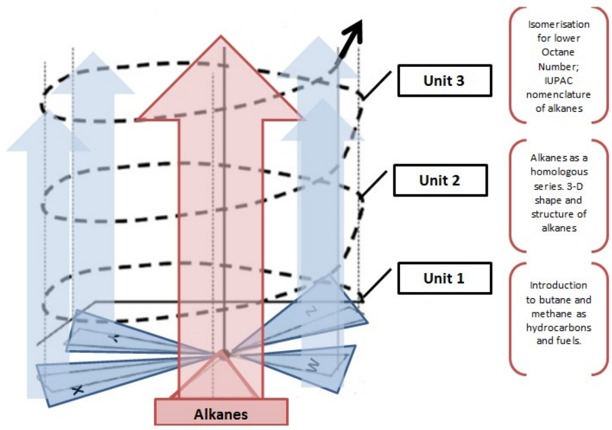


Figure 2b The spiral curriculum in action

Figures 2a and 2b illustrates the spiral curriculum using alkanes (Topic X) as an example. Butane and methane are introduced in Unit 1 as hydrocarbons and as fuels. Unit 2 covers the 3-D structure of alkanes and alkanes as a homologous series, IUPAC nomenclature is also introduced. Isomerisation is revised in Unit 3 from the perspective of lowering the octane rating of fuels, while in Unit 4 the chemistry of the alkanes is revisited to understand the type of reactions they will undergo. This spiral continues throughout the eight units of the *Organic Chemistry in Action!* programme. In Unit 6, the formation of chloroalkanes is introduced, together with the mechanism of this reaction. Topics W, X, Y and Z etc. would be developed and spiralled in the same manner.

The 'Organic Chemistry in Action!' teaching materials

Figure 3 Contents of the Organic Chemistry in Action! resource box

This Intervention Programme provides participating teachers with printed Pupils' Workbooks for all pupils in the class, a Teacher's Guidebook and a Resource Kit of necessary teaching materials. These are shown in the photograph above (Figure 3) and each part of the resource box is described below.

a) Pupil Workbook:

There are two Pupil Workbooks. Pupil Workbook I includes the content for units One to Four, and Pupil Workbook II includes the content for units Five to Eight (see Table 1). At the beginning of each unit, a Chemistry Chronicle is included in the Pupil Workbook. These are context-based storylines related to the content of the unit (see Figure 4 for an example). The learning outcomes for the unit are then listed. There are activities and questions throughout and at the end of each lesson for formative assessment of the pupils' understanding. These are useful as they give the teacher immediate feedback of whether a concept has been correctly understood or not by the pupils.

Results, findings and conclusions from the experiments and activities can also be recorded in the workbook. This workbook should contain all of the content necessary for the pupils to know in Organic Chemistry for the Leaving Certificate and can act as a convenient revision aid later. It does not require the use of a separate text book, but a textbook can be used as supplementary reading.

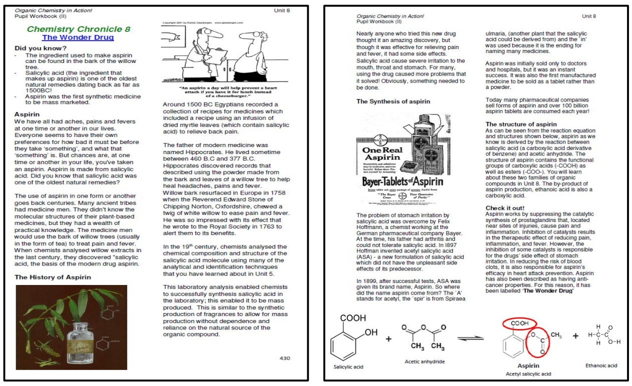


Figure 4 Chemistry Chronicle: The Wonder Drug (Unit 8)

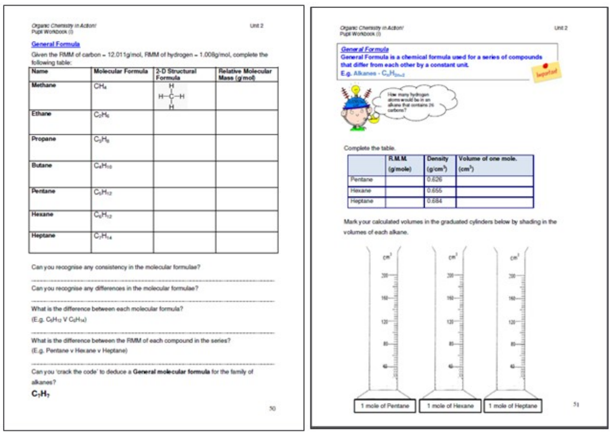


Figure 5 Pages from Pupil Workbook I (Unit 2) - Introduction to an homologous series.

The mandatory experiments are integrated into the Pupil Workbook with details of the procedures, space for recording results and observations as well as follow-up questions to assess pupil understanding. However, these experiments still have to written up separately in the pupils' mandatory laboratory notebooks.

The Pupil Workbooks are presented in such a way as to facilitate the pupils' understanding. Special elements include differently designed text boxes to highlight *Interesting Insights* (applications of Chemistry), *Safety Notes* (before every practical activity) and *Important Boxes* (definitions that need to be learned). The Higher Level material is identified in the same way as in the Teacher Guidebook by use

Pupil Workbooks	Name of Unit	Number of lessons	Syllabus content	Mandatory experiments
Pupil Workbook I	**1: Every Living Thing**	5	5.1 5.2 5.3 7.3(d) 7.4 7.5	7.7: Separation of mixtures using Paper Chromatography.
	2: Chemistry in Chains	7	5.2 7.1 7.2 7.3(a) 5.3	5.2: Preparation and Properties of ethyne.
	3: There's no fuel like an old fuel	7	5.1 5.3 5.5 5.6 7.2	
	4: Changing the Chains	7	5.2 5.3 7.1 7.2 7.3(a)(b)(e)	
Pupil Workbook II	**5: Naturally Organic**	8	7.2 7.4 7.5	7.1: Recrystallisation of Benzoic acid and determination of its' melting point. 7.6: Extraction of Clove oil from cloves by Steam Distillation. 7.7: Separation of a mixture using Thin Layer Chromatography.
	6: New molecules from Old	5	7.2 7.3 (a)(c) (f)	7.3: Preparation and properties of ethene.
	7: Oxygenated Hydrocarbons	6	*2.6* *3.5* 7.1 7.2 7.3(d)	7.4: Preparation and properties of ethanal.
	8: Further oxidation	9	*4.2* *3.5* 7.2 7.3 (b) (d) (e)	7.2: Preparation of Soap. 7.5: Preparation and properties of ethanoic acid.

Table 1 Outline of the Organic Chemistry in Action1 programme with reference to the Leaving Certificate syllabus content.

of a continuous grey bar on the margin. Other symbols are used to highlight new vocabulary as it is introduced, teacher demonstrations and times for discussion.

Much of the workbook is composed of skeletal notes (i.e incomplete notes), which are completed by the pupils during the lessons (see Figure 5 for a typical two-page spread).

b) Teacher Guidebook:

The Teacher Guidebook contains the learning outcomes and overall aims of each unit. For each lesson, the learning outcomes are listed along with an assessment for each outcome. Any possible learning difficulties or pupil misconceptions that may arise in the lesson are highlighted to the teacher. Details of all activities, demonstrations and experiments for each lesson are provided (e.g. time required, necessary preparation before class, chemicals and apparatus required and appropriate safety precautions). Details and answers for the pupil activities are included in the lesson outline as well as further optional and modified activities that may be used as part of the lesson or for future lessons. The sources of any activities and resources used are listed at the end of each lesson for use at the teachers' own discretion. A flowchart is illustrated on the first page of each lesson in the Teacher Guidebook. This provides a summary and sequence of the activities and topics included in the lesson. It also highlights any preparatory work that needs to be carried out before the lesson e.g. preparing solutions or apparatus.
The teacher is informed at the beginning of each lesson how the content fits into the spiral curriculum, and reminders are included of previously developed concepts that the pupils would have to re-apply in the lesson, and references are made to future lessons where the content will be extended and further developed.

It is the researcher's intention that this will facilitate the teachers' teaching of the lesson as well as the pupils' overall understanding. The relevance and integration of the PowerPoint slides are outlined in each lesson. The material that is related to the Higher Level syllabus only is distinguished by use of a continuous grey bar on the margin.

c) Teaching Resource Box:

Participating teachers were provided with all necessary teaching materials and resources for teaching and preparing the lessons. Figure 4 shows the contents of the *Teaching Resource Box*. The uses of the main contents of the box are outlined in Appendix 1 that follows. While some resources were particularly important for certain lessons, many of the resources e.g. Pupil Model Kits, Teacher Model Kits, Classroom response cubes and the Game Cards were used in almost all of the lessons.

Figure 6 Contents of the Teaching Resource Box

Two types of molecular modelling kits were provided: one for the teacher for use in demonstrations and another per every two pupils in the class. The Teacher Model Kits were commercial kits sourced from
Molymod®. However, the Pupil Model Kits were custom-made for the project with the appropriate number and types of atoms, bond

linkages and orbitals necessary for the
.

The USB memory stick in the kit contains PowerPoint presentations which are specifically designed to address the teachers' and learners' needs for each lesson in the programme. These provide a strong visual aid for the pupils' learning and help to facilitate understanding of difficult concepts. The PowerPoint presentations include video links and animations of reactions and processes that the pupils would not otherwise be able to see in the classroom. The PowerPoint presentations are an essential part of some lessons e.g. Instrumentation in Unit 5. The memory stick also includes PDFs of the Teacher Guidebook and Pupil Workbooks to facilitate the teacher's reproduction of certain pages or activity sheets if necessary. Software for PowerPoint-Viewer 2010 is also included for the teachers to download, in order to ensure the animations and illustrations in all PowerPoint presentations could be viewed as required by the pupils.

Implementation

This intervention programme was trialled in nine schools in Ireland from September 2011 to February 2012. Feedback from the participating teachers and pupils, as well as comparisons with eight control groups using the traditional approach, are now being used to evaluate the intervention.

The '*Organic Chemistry in Action!*' teaching materials will be revised in light of this feedback and in compliance with the proposed new Leaving Certificate Chemistry syllabus [10]. The development of these resource materials was partly supported by *Merck Sharp & Dohme* and *Eli-Lilly*.

If you are interested in using the revised materials in your teaching of Organic Chemistry, please contact Anne O' Dwyer at anne.m.odwyer@ul.ie.

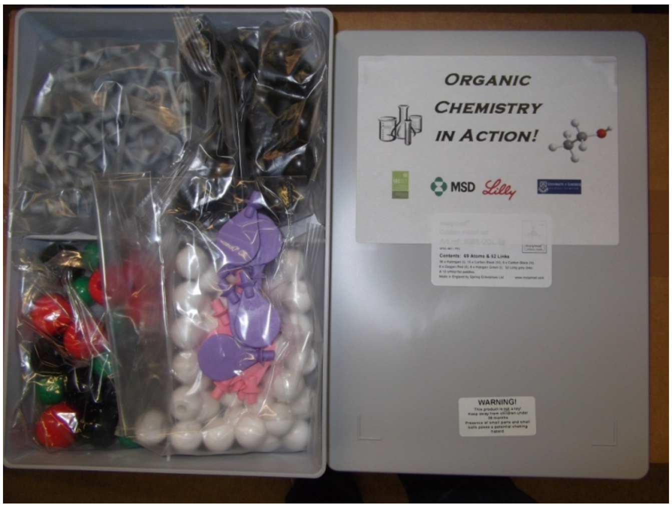
The custom-made model kits (see Figure 7) can be ordered through CERG at €25 per set. The contents of the Pupil Model Kit is outlined are outlined below (Table 3).

activities included in the Pupil Workbooks

Table 3 Contents of the Pupil Model kits.

	Colour	Specification	Number
Carbon atoms	Black	Sp^3 4 holes 109˚ bond angle	15
	Black	Sp^2 5 holes	6
Oxygen atoms	Red	2 holes 105˚ bond angle	6
Halogen atoms	Green	1 hole	6
Bond Links	Grey	Long Flexible	52
Molecular orbitals	6x pink 6 x purple	2-D	12

Figure 7 Organic Chemistry in Action! Pupil Model Kit



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Appendix 1 Contents and uses of materials

Resources	**Uses**
Plastic building blocks	To introduce the concepts of isomerisation and limiting reagents
Pupil Model Kits	To facilitate understanding of shape, structure and bond angles of organic compounds.
Teacher Model Kit	To illustrate the sigma and pi bonding in ethane, ethene, ethyne and benzene.
Labels	For use with activities identifying 3-D models and 2-D structures and other purposes.
Balloons	To illustrate the VSEPR theory to understand molecular shape of organic families.
Poppit beads and Paperclips	To illustrate the formation of polymers as chains of repeating units, to recognise the monomer units.
Polystyrene spheres (20mm, 25mm, 30mm)	To illustrate the homologous series.
6 sets x Game Card sets printed on coloured card	For assessment of topics e.g. reactions, reaction mechanisms.
Classroom response cubes.	For use with multiple-choice questions on the lesson PowerPoints.
Compound concertina	To learn the IUPAC prefixes and to understand tha each alkane differs by a CH_2 unit.
TLC sheet	For use with the TLC activities.
Classification Poster	To be completed as concepts are developed in each unit , for the classroom wall.
Memory Stick	PowerPoint presentations for each lesson and PDFs of the teacher and pupil materials.

The relevance of re/crystallisation

Very often when a topic like crystallisation is covered in Junior Certificate Science or recrystallisation in the organic chemistry section of the Leaving Certificate Chemistry course, they are taught in a very abstract manner, even though they involve practical work, without any relevance to everyday life. Students are entitled to ask: "What's the point of this?" Crystallising copper(II) sulphate crystals from solution is a nice, colourful experiment but it is very much 'laboratory science' not 'real-world science.' We need to illustrate the practical techniques with real examples and pictures to make it relevant to real life. For example, why not use recrystallisation to produce pure samples of sugar or salt (sodium chloride) from contaminated samples (e.g. mixed with dirt or sand). The procedure has a real purpose and significance, as this is how our salt and sugar are produced. When Ireland still had a sugar industry (extracted from sugar beet) a key step in the process was the recrystallisation of sugar from solution. Most of our salt comes from the crystallisation of salt from brine solutions, whether obtained from the sea or from underground brine deposits.

All the solids we use in the laboratory, or buy in the pharmacy, whether organic or inorganic, were made by crystallisation from solution and often this is used to purify them (recrystallisation) e.g. sugar, salt, aspirin, oxalic acid, sodium hydrogencarbonate, citric acid etc.

Most rocks and minerals were formed by crystallisation from solution or from a molten mixture e.g. the Giant crystal Cave in Mexico (see next page), geodes or the quartz crystals often seen in rocks. The salt crystals on rocks by the seaside or by the Dead Sea are also examples of crystallisation in action.

Re/crystallisation is far more common than we think, but you wouldn't know it from the way ti is taught in school. Virtually every solid we meet – whether metals, ionic crystals, molecular solids or covalent solids is crystalline. Crystallisation is widely used in the food industry, chemical industry and pharmaceutical industry for purification and producing the final product. We need to give our students a real appreciation of the importance and relevance of this simple laboratory technique. It is much more relevance than copper(II) sulfate and benzoic acid crystals.

You can grow large crystals of sugar (or salt) on a string in a saturated solution. See http://kapalama.ksbe.edu/faculty/dokroess/crystalwebquest/process.html for details of growing different crystals.

In 2009 a conceptual Artist, Roger Hiorns, filled a disused flat in London with copper(II) sulfate solution and allowed it to crystallise out slowly. The result was a magical room full of blue crystals. You can see this at http://shape-and-colour.com/2008/09/11/roger-hiorns-seizure/. Now that's what I call crystallisation!

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The amazing crystal cave

The photos below and on the cover shows some of the gypsum crystals found in a cave in Mexico in 2000 and made public in 2007.
http://news.nationalgeographic.com/news/pf/82948445.html

Image © National Geographic Society

The size of these crystals can be seen in comparison to the people in the photograph. These are some of the largest natural crystals ever found and are due to very special conditions. They are made of gypsum, a hydrated form of calcium sulphate, and were formed when anhydrous $CaSO_4$ (anhydrite), dissolved in the mineral-rich water, crystallised out at a temperature of just below 58°C. Gypsum is stable below 8°C and anhydrite above this temperature. To get such large crystals, measuring up to 11 m long and weighing 55 tonnes, the crystals have to grow very slowly from a saturated solution, probably over thousands of years. The Cave of Crystals, Cueva de los Cristales, is located 300 m below Naica in Mexico. It was found by miners excavating tunnels for a mining company. These crystals grow in enclosed caves from a saturated solution, much like crystals grow inside geodes.

A typical geode – cut in half to show the crystals within

Image © National Geographic Society

More information:

http://books.mcgraw-hill.com/EST10/site/supparticles/Gypsum-megacrystals.pdf

For a slide show from The crystal Cave see:
http://www.slideshare.net/random13579/naica-crystal-cave

For a 10 min video of the cave:
http://www.youtube.com/watch?v=KSbId57pzm4

The Cave's own website:
http://www.naica.com.mx/english/internas/interna3_4.htm

Chemistry of calcium sulphate, $CaSO_4$

Calcium sulphate is sparingly soluble in water and thus is found in large deposits as gypsum, $CaSO_4.2H_2O$, including some in Ireland in Co. Cavan. Heating gypsum to around 100-150 °C drives of part of the water leaving plaster of Paris, $CaSO_4$. ½H_2O (also known as hemihydrate). This useful materials is used to make plaster by rehydrating it with water, when it turns back into solid gypsum. This is used to make plasterboard for insulation and also for setting broken limbs. Further heating to 180 °C drives off the remaining water to leave anhydrite, $CaSO_4$.

$CaSO_4.2H_2O \rightarrow CaSO_4.\tfrac{1}{2}H_2O \rightarrow CaSO_4$

Gypsum Industries mine gypsum at Knocknacran, County Monaghan and it is first crushed and then transported to Kingscourt for processing. After further crushing it is heated in a kiln to produce the hemihydrate, ready for making plasterboard. The company has been manufacturing in Ireland since 1936.
(http://www.gypsum.ie/about.aspx)

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Painting a brighter picture: using Art to enhance the learning of Chemistry

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Introduction: Chemistry versus Art or Chemistry harnesses Art?

Many teachers of Chemistry are familiar with the problem of low levels of interest and engagement with the subject. The same students commonly rate creative subjects highly. Other recent authors have identified the common culture of Science pedagogy, with its very positivist treatment of Science, as a contributory factor (Cachapuz, 2010). The focus on well-established material often denies students insight into the tentative and fluid nature of scientific enquiry. Learners are left feeling that they have nothing of originality to offer but must, instead, follow well-trodden paths and recall someone else's journey accurately (Lee and Erdogan, 2007; Murray and Reiss, 2005). This intellectual disengagement then leaves the student with little motivation to tackle the difficulties inherent in the subject, such as those imposed by the three levels of representation (macroscopic, sub-microscopic and symbolic) first described by Johnstone (1991). School Art lessons, on the other hand, offer many alternative means of representation and every student has opportunities to create a unique interpretation, which has meaning to them and is valued within the discipline. This is often motivating and may also be associated with positive social and academic development by students (Deasy, 2002).

The situation described suggests that an interdisciplinary approach could benefit students. There certainly are historical precedents for chemists and artists working together, such as was exhibited by the eminent chemist Sir Humhry Davy's publication on the ancient pigments of Rome and Pompeii. And as recently as 2001 the American Chemical Society took 'Chemistry and Art' as its theme for National Chemistry Week. Nevertheless, the dichotomy described in Snow's (1959) book, '*The two cultures and Scientific Revolutions*', continues to operate in U.K. secondary schools, where the two subjects are generally viewed in school as being entirely distinct.

A partial answer may reside in Snow's second edition (1963), which included an essay on a third, mediating, culture in which non-scientists bridge the gap between the scientists and humanists. Interdisciplinary working between Science and Art teachers has previously been highlighted as a fruitful area for teachers to explore and there is an abundance of practical suggestions on possible approaches (Cappachuz and Ferreira, 2010; Hohn and Harsch, 2009; Furlan, Kitson and Andes, 2007; Greenberg, 1998). The research described here assessed the scope for Chemistry and Art teachers to work together in an interdisciplinary way that would benefit students in both their Art and Chemistry studies.

Methodology

The researcher (CR) was undertaking a one year teacher training course and was working in her second placement school. The work was undertaken as a piece of Process Evaluation Action Research (Livesay, 2002; Rappoport, 1970), stemming as it did from the trainee's concern about de-motivated students. Her proposed solution, formulated in collaboration with a trainee art teacher, was to offer four voluntary sessions, summarised in Table 1, which were billed as 'an Art club with a difference'. These two trainees jointly undertook the role of problem solvers, and undertook joint teaching and evaluation of the activity.

Table 1 A summary of the four taught lessons

Topic	Art activities	Science activities	Scientific concepts
Graphite and charcoal	Looking at the effects of pencils containing different proportions of graphite, compared to the effect of charcoal on drawing pictures	Making graphite circuits Making charcoal	Graphite's many uses including fuel, electrical conductor and adsorbent; reduction of wood through chemical change; the layered nature of graphite.
Inks	Mixing inks on pictures	Chromatography of ink	The different solubility of dyes in water and oil
Wax resist	Making lava lamps and wax resist paintings		
Breaking down materials	Noting the appearance of materials as they are broken into smaller pieces		Structure of different materials linked to their properties and uses.

Questionnaires were administered before the start of the club and again after the sessions were completed; data from the questionnaires was augmented by interviewing four of the students. In addition, the two trainees made field notes during the sessions, transcribing student comments and actions. At the end of the series of sessions, the students were asked to make a video to explain about the club, and this captures free responses about the impact of the intervention. The administration and collation of all findings were compliant with ethical guidelines and all those whose comments are used were willing volunteers (British Educational Research Association, 2004).

The sample size was small, with a total of 10 students attending and completing questionnaires. Whilst the sample size limits the usefulness of the quantitative data generated, it also furnished the opportunity to gather rich qualitative data, predominantly comments made during the sessions. These comments were subjected to thematic coding (Alexiadou, 2001), in order to identify the major themes embodied in student comments.

Results and discussion

Art improved students' perceptions of Chemistry

There was a change in attitude towards Chemistry as a subject. At the start of the sessions students were asked to rank their school subjects in order of preference. Chemistry appeared as one of the bottom three positions at the start of the intervention but, by the end, was in 9 out of 10 students' top three subjects. Their experiences seem to have convinced them of the value of the subject, with two commenting that:

"To be a really good artist you do need to know about chemistry!"

"I think chemistry is good. It makes you think about things, like in art"

Their realisation that Chemistry could support other curriculum areas was not confined to Art. Students reported feeling that Chemistry was more useful now they had seen some of the ways it is linked to other aspects of their life. After taking part in the club, students independently identified a central role for Chemistry in cooking, specifically in understanding the role of the ingredients and the reactions that take place during cooking, and also identified how chemical concepts were helpful in understanding the properties of materials as would be needed in Design Technology and Physical Education. Their increased awareness of the scope of Chemistry also enabled participants to identify suitable areas for future exploration in the club, including the different properties and chemistry of modelling materials, making pictures with iron filings using magnets, a comparison of different dyes and textiles, the connection between properties and uses of textiles, including how properties were incorporated into clothes design and the Chemistry of pottery glazes. However, these findings suggest that at present the way in which this age of students learns Chemistry does not persuade all of them of its value. This is a shame when our interview data corroborates previous findings (Bennett and Lubben, 2006), indicating that Chemistry taught in a meaningful context is less off-putting for the learners.

Participation appears to have boosted self-confidence, which might reasonably be expected to improve their participation in both Art and Chemistry classes.

"I never thought I could make my own art equipment!"

"I didn't even know what chemistry was, but I'm doing work that year 10s (i.e. students two years senior) *do now".*

Whilst this might be a consequence of high levels of teacher attention, or teacher expectancy (Jacobson and Rosenthal, 1992), rather than any specific aspect of the activities, it is doubtless a positive outcome of the intervention. Expressions of this enhanced self-esteem suggest that existing classroom activities may not succeed in giving students sufficient experiences of success. The growth in confidence expressed in post-intervention interviews was associated with a higher self-reported level of involvement in Science lessons and a greater willingness to try activities in class. This attitude was exemplified by comments such as:

"I want to carry on with this I'm actually enjoying science a bit more now"

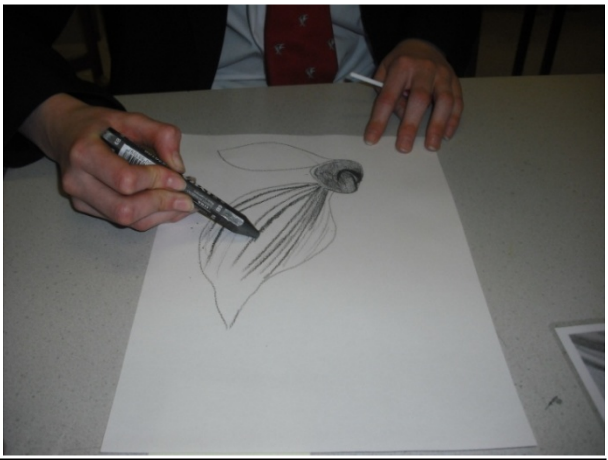
"I like the fact that we don't have to have an end to it, just trying it out to see what happens".
"Why can't we do more things like this in science?"

Art gave students a tangible experience of abstract concepts

The difficulties inherent in Chemistry which are due to the abstract nature of the models are well-recognised (Johnstone, 1991).The combination of a limited number of abstract ideas concurrent with a relevant concrete experience seems to have been effective at securing students' understanding of the chemical concepts. Although it is common to attempt to give illustrative experiences whilst teaching, the club seems to have been especially successful. Allowing for the fact that students were self-selected the data is nevertheless very positive. It is possible that the limited number of concepts, coupled with a significant time spent on practical experience, helped increase students' assimilation of concepts. This gain in understanding was observed in all four activities.
For example, when students used their fingers to smudge the graphite, they related this to the fact that graphite is made up of strongly bonded layers:

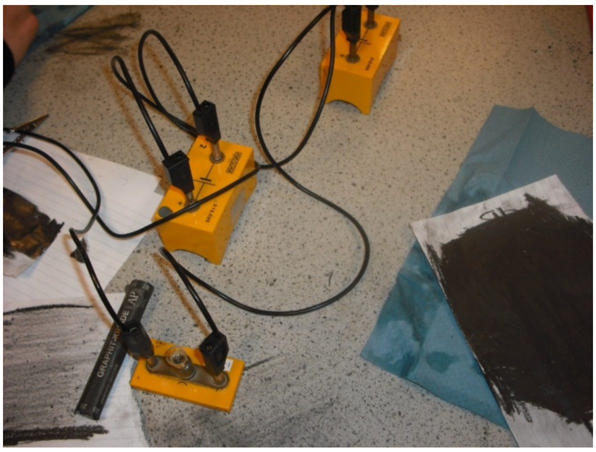
"I can actually see the bonded layers being applied to the paper"

"The graphite is making up layers on the paper and you can keep adding to the layers to get a darker shade"



Using graphite to produce art work incorporating techniques such as smudging and layering to create particular effects. The use of graphite in art was discussed and linked with its chemical properties

After this discussion, students were able to make a scientific sketch of the layers of graphite and explain what was happening when these were applied to the paper.



Graphite used in the original artwork above was used to complete a simple circuit. Students discussed how the chemical structure of graphite enabled it to conduct electricity and looked at various uses for graphite other than as a medium for creating art.

Similarly, during the wax resist activity, students were able to make detailed observations of water-based paint running over and off the wax and

describe how water 'stuck to water' and 'wax to wax', which culminated in the use of the terms hydrophobic and hydrophilic. They also commented on how easy it was to melt wax and how quickly it solidified on the paper, which led to ideas about using melted wax to paint with and the limitations and benefits. The students demonstrated that they were starting to relate the properties of materials to uses in art in a more global way, illustrated by a student saying,
"*I understand what it means now if you talk about the 'properties' of a material"*

The work with the digital microscope provided an opportunity to consider what materials are made of, which might be considered the ultimate question of Chemistry. Students were gaining an appreciation of chemistry through developing an understanding of how a seemingly solid single object can be broken down into component parts. Students were fascinated with the way textiles are made up and particularly the components of gemstones and rocks, which were discussed during the science part of the activity. It is easy to see how the shift in their understanding illustrated by the comments below would pave the way for a consideration of the atomic theory of material,

"*It just looks one colour, but it's full of different grains"*

"The coloured parts of the rock show us different chemicals"

At the conclusion of the four sessions, 7 of the 10 participants said they felt that they understood Science better than they had at the outset.

Art activities stimulated scientific discussion

The activities appeared to stimulate meaningful discussion of the basis of the properties of the art materials. One difference between the club and the use of materials as a stimulus in a Science lesson may have been the less closed format offered by the club. Whilst the trainee Science teacher was able to moderate discussions to ensure that valid models and concepts were deployed, she was not perceived as working towards a clear learning outcome; this encouraged students to engage in more exploratory talk (Barnes, 1976). Moreover, the activities were open to modification in response to student demand. For example, when the students looked at the chromatography results they attempted to explain how the inks were wicked up the paper. They then discussed the implications for this in terms of their artwork, the different types of paper that are suitable for ink drawings and how the colours blend together. They compared the paper used for chromatography and the paper used for their artwork and, as a result of their discussion, decided to experiment with different types of paper. The trial with different papers had not been planned by the teacher, but came about due to the students' interest. Similarly, whilst making charcoal conversations took place regarding the desirable properties of charcoal in relation to its use in art and the effect that differing amounts of clay hardener have on the properties of a pencil. The conversation was relaxed and relatively unstructured, switching between the properties of charcoal and what happened when creating different artistic effects using the graphite.

This shows the first attempt to make charcoal. Students then conducted internet research to identify that the wood needed to burn more slowly with less oxygen present to improve the quality of the charcoal. They then conducted a similar experiment, but with the wood covered in a layer of sand.

However, the conversation was far from aimless. After an unsuccessful attempt to make charcoal by simply burning wood, they were able to describe the differences in the properties of burnt wood and artist's charcoal. This then prompted them to research the conditions necessary to produce charcoal and why this made a difference to its properties. Field notes show that the session on wax resist pictures resulted in students deciding to conduct a series of investigations into the effect of different thicknesses of wax and different quantities of paint on the final picture. The gain in scientific thinking was summed up by one student as,

"I would just draw, I never really thought about the materials I was using, but now I do and I ask more questions to find out what will work the best."

An associated shift, and one which received positive comment from other science teachers, during the course of the activities was an increasing confidence in using technical terms to talk about the materials, such as,

"I can see the paint rolling off the wax, because it is hydrophobic"

The Chemistry and Art club benefited the participating teachers

The initiative was felt to have been of mutual benefit to both the participating teachers. Both were able to identify a number of shared approaches to some aspects of their subject and its pedagogy, in the light of which both subsequently revised aspects of their classroom practice. The Science teacher said that she had found confidence to extend her presentation of Science and to actively challenge stereotypes about scientists that she encountered. She also began to look for opportunities in lessons to portray the creativity of Science. The Art teacher started to use some of the approaches to material that had been trialled at the club, and borrowed Science equipment to do this. Thus a higher level of collaboration took place between an extended group of colleagues. Both staff identified similarities and common ground based on art and chemistry both being practical subjects. However, both participants expressed concern for the sustainability of this type of initiative because of the time demands that the planning stage had created.

Other Science teachers were positive about the enthusiasm for Science, and scientific knowledge, that the club had engendered. Nevertheless, reservations were expressed about devoting time to activities which were not **seen** as directly underpinning examination performance were expressed as well as concerns about working in an area in which they lacked expertise. It is interesting to note that teachers did not generally perceive the work as having direct connections with the curriculum, despite the important concepts that were developed, as described above.

Conclusion

Focusing on cross-curricular aspects of Chemistry improved students' recognition of the subject's scope and the value of the knowledge provided by the study of Chemistry. Students showed an improvement in their ability to apply their learning, and a greater engagement with the science, outcomes which are in keeping with current educational initiatives in the U.K. Although the approach was demanding of staff time at the planning stage, the positive shift in both students' attitudes and knowledge indicated that the investment of time was justified. The longer term outcome of interdisciplinary working could not be ascertained by this small scale pilot study. The participating teachers felt that the activities gave them worthwhile professional development. Despite this, the response of other teachers to the initiative suggests that, in a content-driven assessment framework, the affective and cognitive gains observed are not viewed as sufficient justification for expending time and effort on such enrichment activities.

Acknowledgement

We wish to acknowledge the staff and pupils at Walton High School and Cheslyn Hay Community High School for their participation in, and support for, the pilot study.

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Charlotte Roberts was a P.G.C.E. student at Keele from 2008-10, and who now teaches in a Staffordshire School. She undertook the research which led to this article whilst in her placement school. Charlotte has recently held a successful exhibition on microscopy and photography, and continues to explore ways of fusing her interests in Science and visual arts in school.

Don't be afraid of hard work. Nothing worthwhile comes easily. Don't let others discourage you or tell you that you can't do it. In my day I was told women didn't go into chemistry. I saw no reason why we couldn't.

Gertrude B. Elion
21/1/1918-21/2/1999
Nobel Prize for Medicine in 1988

2011 LC Results

Peter E. Childs

We have been publishing an analysis of the LC science results and CAO points for science-related courses since 2001. Each year a 3 year overview is given. The examination statistics are available at the Department of Education and Science website at: www.examinations.ie and were published in the Irish newspapers on 19/8/11, the day the LC results were released.

The overall number sitting the examinations is marginally down on last year's number by 0.3%. Of the 57,532 candidates who sat Leaving Certificate examinations this year, 37,955 (66.0%) candidates followed the Established Leaving Certificate Programme, 16,386 (28.5%) the Leaving Certificate Vocational Programme while 3,191 (5.5%) candidates followed the Leaving Certificate Applied Programme. In 2011 54,341 students took the Leaving Certificate (this is the sum of LC (Established) and LCVP), down slightly on 2010 (54,481).

However, the numbers passing through the school system are expected to continue rising for several years and you can find growth predictions on the website of the Department of Education and Skills. At primary level enrolment is expected to increase from 509,000 in 2010 to 540,000 in 2014 (+6.1%) to ~561,000 in 2030 (+10.2%). Second-level enrolment is expected to increase from 317,000 in 2010 to 334,000 in 2014 (+5.4%) to ~360,000 in 2030 (+13.6%). At third level the number of students is expected to increase from 161,000 in 2010 to 190,000 in 2014 (+18.0%) to ~282,000 (+75.1%) under some assumptions. These are projections based on various assumptions about birth rates and staying on rates at age 16 and transfer rates to third level.

Ireland has the highest birth rate in the EU (2.1 children per woman) and in 2009 76,021 children were born. The birth rate is still increasing and in the first quarter of 2011 was 19,950 (17.8 per 1000), or an annual figure of nearly 80,000 (see Index Mundi data at [http://www.indexmundi.com/**ireland**/birth_rate.html](http://www.indexmundi.com/ireland/birth_rate.html)). This means that in 2013-14 entry into primary school will be over 75,000 a year, which will work its way up through the school system. These growth figures will be affected by emigration in the years to come. In June 2011 the Minister of Education announced that 40 new schools would be set up to cater for the growing school population 20 primary and 20 post-primary schools. Another change in the composition of the school population is an increasing number of non-nationals, for many of whom English is a second language. Non-nationals make up ~10% of the population, but the % in some schools can be higher than this. (For a recent report see Emer Smyth *et al*., *Adapting to Diversity: Irish schools and newcomer students*, ESRI Research Series #8, June 2009, http://www.ucd.ie/issda/static/documentation/esri/diversity-report.pdf)

We must take account of the changing examination cohort if we are to make sense or an increase or decrease in numbers doing a subject, as the raw numbers are related to the size of the total cohort. (See below to find out what actually happened to the popularity of science subjects in 2011 and which were the winners and losers).

The same is true for the UK A-levels where number of entries rather than number of students is usually published and this makes it impossible to see how popular a subject is compared to the size of the cohort and whether enrolment is going up or not. The raw numbers alone are not enough as students take different numbers of subjects. It is difficult to find out the number of candidates taking A-levels as this number is not usually reported. Knowing the size of the cohort and the number of candidates (entries) in a particular subject allows us to compare the popularity of different subjects across different school systems.

Comments on the 2011 results

Unless specified otherwise all the statistics are from the SEC or DES websites. Table 1 shows that all the sciences except Physics and Physics & Chemistry gained both numbers and % share and Agricultural Science and Biology made the largest % gains. Over the period 2002-2011 all the sciences gained numbers except Physics and Physics & Chemistry, which have shown a steady decline. Biology continues to be the dominant LC science subject (taken by 55.8% of the cohort) and the only science subject in the top 10 subjects (Table 8). The LC cohort decreased slightly this year by -0.26%, and Biology, Chemistry and Ag. Science all gained in market share (see Table 8). The LC cohort declined from 2002 to 2007 and since 2008 has been increasing (Tables 8 and 9). Figure 2 shows the % taking the main science subjects since 1999 i.e. this is normalised for the change in size of the LC cohort.

Since 2002 Biology, Chemistry and Agricultural Science have all gained significantly, especially Biology and Agricultural Science (see Table 1). Physics and Physics & Chemistry have both decreased over this period. In 2012 Chemistry had the highest % doing the Higher Level course of the science subjects but it is now joint top with Ag. Science, with 81.7% (Table 2). Chemistry also shows the best gender balance (small excess of girls), whereas Biology has much more girls than boys doing it, and Physics much more boys than girls (Table 5). Physics is clearly in decline and this year's figures suggest that Agricultural Science may well become the third most popular science even by next year. There is clearly a continuing swing towards the life sciences. Physics & Chemistry has been on its last legs for some years and continues to decline, despite a small increase this year - it is definitely a dead man walking of a syllabus, and it is a great pity that the new and innovative replacement, which was drawn up by the NCCA many years ago, has never been implemented. Sadly the new syllabus in Physics & Chemistry is still gathering dust on a shelf in the NCCA – it was a radical and innovative syllabus and it deserved an airing – it could have provided a popular alternative to the full Physics and Chemistry syllabi. If the course is not going to be revised it should be dropped as it must be one of the oldest/longest-lasting science syllabi in the world by now, along with Ag. Science!

Table 1 Changes in numbers doing LC Science subjects 2009-2011 (gains in bold)

Subject	Δ2010-2011	Δ% 2010-11	Δ2009-2010	Δ% 2009-10	Δ2002-2011 (Δ %)
Biology	**+1,100**	**+3.8**	**+1,089**	**+3.9**	**+8,285 (+37.5)**
Chemistry	**+129**	**+1.7**	**+145**	**+2.0**	**+1,180 (+18.2)**
Physics	-229	-3.4	-178	-2.8	-2,135 (-24.7)
Phys+ Chem.	**+47**	**+11.1**	-84	-16.2	-403 (-49.4)
Ag. Science	**+686**	**+10.2**	**+515**	**+9.8**	**+3,583 (+124.0)**

From these figures it can be seen that Biology, Chemistry and Agricultural Science are growing in numbers and % share, whereas Physics is declining and Physics & Chemistry is ~ static. Biology is still far and away the most popular science subject, trailed at a distance by Chemistry and Physics: four times as many students take Biology as take Chemistry and Physics. It is clear that the Physics & Chemistry syllabus is dying on its feet, whereas Agricultural Science is growing steadily (+124% since 2002). All the sciences are quite elitist with Chemistry and Ag, Science heading the poll with 81.7% respectively doing the HL course (Table 2).

This marked disparity between Biology and the Physical Sciences is more marked in Ireland than is most other countries.

Table 2 LC Science - % doing Higher Level and Ordinary Level 2011

	2011	HL 2011 (%)	OL 2011 (%)	%LC cohort 2011	%LC cohort 2010
Biology	30,349	22,677 (74.7)	7,672 (25.3)	55.8	53.7
Chemistry	7,677	6,272 (81.7)	1,405 (18.3)	14.1	13.85
Physics	6,516	4,782 (73.4)	1,734 (26.6)	12.0	12.4
Phys.+Chem.	472	379 (80.3)	93 (19.7)	0.87	0.78
Ag. Science	6,473	5,287 (81.7)	1,186 (18.3)	11.9	10.6

Figure 2 Change in % doing Biology, Physics, Chemistry (and Ag. Science) 1999-2011

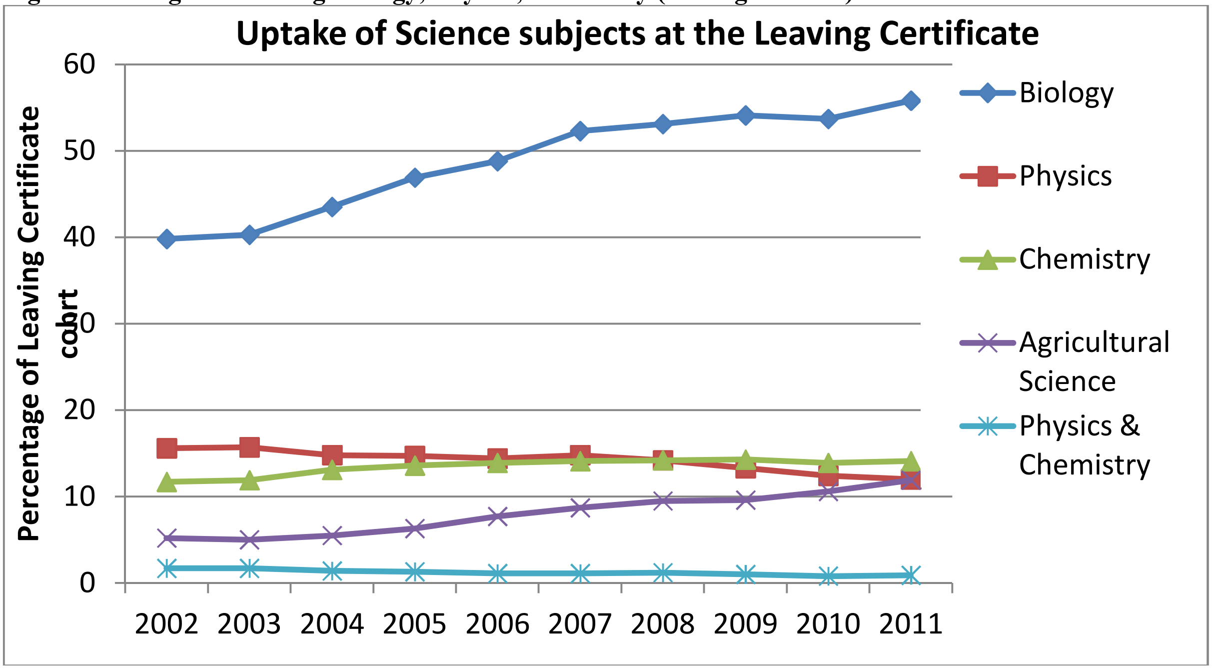

Table 3 % of different grade bands 2007-2011

a)Chemistry **Higher level** Ordinary level

Year	**2011**	**2010**	**2009**	**2008**	**2007**	2011	2010	2009	2008	2007
%A	**21.9**	**20.8**	**21.6**	**23.5**	**21.0**	9.1	7.6	9.2	11.7	8.0
%A+B	**52.4**	**50.1**	**52.9**	**54.6**	**54.1**	36.4	29.8	34.6	42.2	31.8
%A+B+C	**76.0**	**75.3**	**77.5**	**78.7**	**79.0**	64.7	54.9	63.1	75.0	58.5
%E,F,NG	**8.6**	**6.1**	**7.0**	**5.8**	**5.5**	12.8	18.5	15.3	13.9	16.8

b) Biology **Higher level** Ordinary level

Year	**2011**	**2010**	**2009**	**2008**	**2007**	2011	2010	2009	2008	2007
%A	**15.6**	**17.4**	**16.0**	**16.6**	**19.5**	2.2	3.1	3.6	4.8	2.7
%A+B	**43.0**	**44.9**	**43.0**	**43.9**	**46.7**	22.8	29.6	26.3	29.7	24.5
%A+B+C	**69.9**	**71.6**	**69.9**	**71.5**	**71.7**	59.3	62.7	59.1	63.2	57.8
%E,F,NG	**8.3**	**9.2**	**8.8**	**7.9**	**7.9**	13.2	14.1	15.3	11.1	15.0

c) Physics **Higher level** Ordinary level

Year	**2011**	**2010**	**2009**	**2008**	**2007**	2011	2010	2009	2008	2007
%A	**20.2**	**20.8**	**20.3**	**19.9**	**21.4**	14.8	17.4	17.0	15.5	13.5
%A+B	**46.0**	**49.6**	**49.6**	**46.4**	**49.7**	44.3	49.0	49.7	47.3	43.8
%A+B+C	**72.9**	**73.3**	**72.9**	**70.8**	**75.8**	72.2	72.8	74.3	73.8	72.9
%E,F,NG	**8.0**	**7.0**	**7.8**	**8.6**	**7.5**	11.2	11.6	10.0	8.7	9.7

At HL Chemistry (21.9%) and Physics (20.2%) students get more A1 or A2 compared to for Biology (15.6%), although this represents 3 times more students getting As in Biology. This reflects the wider intake into Biology and probably that Chemistry and Physics attract a smaller number of higher ability students. These results are fairly consistent over 5 years as can be seen above. At OL the differences are more marked – Physics students get 14.8% As at OL, whereas Chemistry students get 9.1% and Biology students 2.2%. The failure rates at HL for all three main sciences are very similar as they are at OL, but remember that for Biology these represent greater numbers of students. There is no marked change in the grading over this period for any of the three main science subjects.

In Table 3 you can compare the grades obtained in each subject at Higher and ordinary level. Four bands are shown: %As, %A+Bs, %A+B+Cs and %E+F+NG (fails). Chemistry and Physics are more selective subjects i.e. they are done by smaller numbers and a higher % take the Higher Level papers, indicating that these are taken by better students. We would thus expect a higher % of good grades and less % of fails if the student populations doing Chemistry and Physics are more selective. This is what we observe. From 2006-10 the average % getting As in HL papers in Chemistry was 21.7% and 20.4% in Physics, compared to 17.2% in Biology. This does not mean that Biology is harder than Chemistry or Physics: it means that a larger number of students take Biology and have a greater ability spread, compared to Chemistry and Physics. This is also consistent with the average % of fails in HL Chemistry of 6.4% 2006-10, compared to 7.6% in HL Physics and 8.2% in HL Biology.

At Ordinary Level we would expect to see smaller % of good grades, as weaker students opt for the ordinary level papers - often at the last minute, and a greater % of fails. We would also expect more % fails in Biology than Physics and Chemistry because of the greater numbers and greater ability spread of students choosing Biology. The average % getting As in ordinary level Chemistry was 8.7% from 2006-10, with 15.4% getting As in Physics and 3.6% in Biology. The anomaly here is the high % of As in Physics. When we look at the % fails in the ordinary level papers from 2006-10, 16.0% fail Chemistry, 13.7% fail Biology and 9.8% fail Physics.

We would in fact expect an even higher % of good grades in both Chemistry and Physics given the highly selective populations doing these subjects. An important study by Kellaghan and Millar (2003) compared performance in different LC subjects by comparing a student's performance in pairs of subjects. A preliminary report on the study was given in the *Report of the Task Force on the Physical Sciences* (2002). This found that a student on average got lower grades in Chemistry and Physics compared to other subjects they took, indicating that it is actually more difficult to get high grades in these subjects. The difference was between half and 1 ½ grades, which is a significant difference. This important study should be repeated at intervals to check on the comparability of marks across different subjects. It agrees with the anecdotal perception of students, parents and teachers that it is harder to get good grades in Chemistry and Physics, notwithstanding the already high % of As and Bs in these subjects. If this effect was allowed for, an even greater % of students would get As in Chemistry and Physics than they do at present and this might make the subjects more attractive.

Table 4 Gender breakdown of grades 2011

	%As overall	**%As females**	**% As males**
Chemistry	21.9 (HL) 9.1 (OL)	21.9 (HL) **11.9 (OL)**	21.9 (HL) 6.1 (OL)
Biology	15.6 (HL) 2.2 (OL)	**2.5 (HL) 2.5 (OL)**	1.7 (HL) 1.7 (OL)
Physics	20.2 (HL) 14.8 (OL)	20.0 (HL) **22.5 (OL)**	**20.2 (HL)** 13.3 (OL)

Table 4 shows the gender breakdown of the HL and OL results for A grades. In several cases females outperform males (larger % shown in bold above), although the differences are small. The trend for females to outperform males in state examinations has become more apparent year on year. We cannot say from these data whether this difference is due to intrinsic ability or to better study methods and harder work. The better LC results by females mean that the number of females entering third level exceeds that of males, and more males drop out of fulltime education at all levels.

Table 5 shows the overall gender breakdown of the five science subjects i.e. HL and OL students are combined in these figures.

Table 5 The overall gender balance in the LC Science subjects 2011

Subject	No. females (%)	No. males (%)	Ratio F:M 2011	Ratio F:M 2010
Biology	18,698	11,651	1.60:1	1.75:1
Chemistry	4,242	3,435	1.23:1	1.29:1
Physics	1,618	4,898	0.33:1	0.33:1
Physics & Chemistry	200	272	0.74:1	0.61:1
Agricultural Science	2,391	4,082	0.59:1	0.55:1

Biology is heavily dominated by females and Physics is dominated by males. Chemistry shows the closest gender balance.

Table 6 shows the top 10 LC subjects from 2008 to 2011. Maths retains its first place and nearly everyone who stays on a school until age 17/18 does maths and does an examination in it. Biology is in 4th place and the most popular Science subject. Five subjects are taken by >50% of the LC cohort. Geography has replaced French as the 5th most popular subject. Interestingly in the UK Biology, Chemistry and Physics are all now in the top 10 subjects.

Table 6 Top 10 LC subjects from 2011 to 2008 (HL+OL)

Subject	2008 Total (HL+OL)	2009 Total (HL+OL)	2010 Total (HL+OL)	2011 Total (HL+OL)	% LC cohort 2011
Maths (+FL)	50,116	51,902	**52,290**	**51,991**	**95.7**
English	49,382	51,032	**51,499**	**51,455**	**94.7**
Irish (+FL)	44,660	45,636	**41,043**	**44,397**	**81.7**
Biology	26,607	28,160	**29,249**	**30,349**	**55.8**
Geography	24,360	25,061	**26,175**	**27.305**	**50.2**
French	27,698	27,675	**27,574**	**26,766**	**49.3**
Business	18,733	18,425	**18,790**	**18,083**	**33.3**
Home Econs.	12,497	12,936	**12,535**	**12,400**	**22.8**
History	11,850	11,990	**11,910**	**12,106**	**22.3**
Art	10,283	10,693	**10,786**	**10,782**	**19.8**

In Table 7 the grades for all five science subjects are shown from 2006 to 2011, at both Higher and Ordinary level.

Table 7 2007-2010 LC Science Results at HL and OL
(Current year in bold)

Chemistry	No.	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
HL 2011	**6,272**	**11.4**	**10.5**	**10.5**	**10.9**	**9.1**	**7.9**	**8.3**	**7.4**	**4.8**	**4.5**	**6.1**	**5.6**	**2.4**	**0.6**
HL 2010	6,298	9.7	11.1	9.7	10.2	9.4	8.5	8.6	8.1	5.4	5.0	6.3	5.3	2.2	0.6
HL 2009	6,037	12.3	9.3	10.4	11.0	9.9	8.5	8.1	8.0	4.5	4.9	6.2	4.7	1.8	0.5
HL 2008	5,904	12.9	10.6	10.7	10.4	10.0	8.8	8.0	7.3	5.4	4.6	5.5	4.2	1.3	0.3
OL 2011	**1,405**	**3.3**	**5.8**	**7.5**	**8.9**	**10.9**	**9.3**	**8.6**	**10.4**	**7.8**	**7.0**	**7.8**	**6.8**	**4.8**	**1.2**
OL 2010	1,250	2.2	5.4	4.9	8.6	8.7	9.1	9.1	8.1	7.9	7.7	9.8	10.1	6.8	1.6
OL 2009	1,366	3.0	6.2	5.9	8.6	10.9	10.8	8.6	9.1	5.3	6.8	9.4	8.7	5.6	1.0
OL 2008	1,210	5.3	6.4	9.2	9.7	11.6	9.8	7.9	7.9	6.4	4.8	7.3	7.8	4.9	1.2
Biology	**No.**	**A1**	**A2**	**B1**	**B2**	**B3**	**C 1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E**	**F**	**G**
HL 2011	**22,677**	**6.3**	**9.3**	**7.9**	**9.4**	**10.1**	**9.0**	**9.3**	**8.9**	**7.6**	**6.6**	**7.1**	**6.6**	**1.6**	**0.1**
HL 2010	20,971	8.9	8.5	8.4	9.1	10.0	8.5	8.9	8.3	6.9	6.3	7.0	6.9	2.0	0.3
HL 2009	20,101	7.7	8.5	8.1	90	9.9	8.9	9.1	8.9	7.2	6.7	7.2	7.0	1.6	0.2
HL 2008	18,323	8.5	8.1	8.1	9.3	9.9	9.2	9.3	9.1	7.0	6.4	7.2	6.2	1.6	0.1
OL 2011	**7,672**	**0.6**	**1.6**	**3.9**	**6.6**	**10.1**	**11.2**	**13.1**	**12.2**	**10.6**	**8.3**	**8.7**	**9.1**	**3.7**	**0.4**
OL 2010	8,278	0.7	2.4	5.3	9.3	11.9	11.5	11.5	10.1	8.1	6.7	8.4	8.7	4.5	0.9
OL 2009	7,999	1.0	2.6	5.2	7.5	10.0	11.0	11.3	10.5	9.6	7.8	8.4	9.9	5.0	0.4
OL 2008	8,284	1.5	3.3	5.7	8.2	11.0	10.9	11.4	11.2	9.6	7.4	8.7	8.1	2.8	0.2
Physics	**No.**	**A1**	**A2**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E**	**F**	**NG**
HL 2011	**4,782**	**8.9**	**11.3**	**7.0**	**9.3**	**9.5**	**9.0**	**8.8**	**9.1**	**7.4**	**5.6**	**5.9**	**5.9**	**1.7**	**0.4**
HL 2010	4,877	8.8	12.0	8.4	10.8	9.6	9.2	9.4	5.1	8.8	6.0	5.0	5.2	1.4	0.4
HL 2009	4,693	10.6	9.7	10.2	10.2	8.9	8.6	8.6	6.1	7.2	5.8	6.3	5.1	2.4	0.3
HL 2008	4,929	12.7	7.2	10.5	8.0	8.0	7.7	8.7	8.0	6.4	5.8	8.4	6.2	2.0	0.4
OL 2011	**1,734**	**6.0**	**8.8**	**6.2**	**10.6**	**12.7**	**6.7**	**10.3**	**10.9**	**4.4**	**6.2**	**5.9**	**7.6**	**3.2**	**0.4**
OL 2010	1,868	8.0	9.4	9.0	9.8	12.8	7.5	7.2	9.1	3.9	4.4	7.3	5.8	4.2	1.6
OL 2009	2,230	5.7	11.3	9.2	10.0	13.5	8.2	8.2	8.2	5.4	4.5	5.8	5.7	3.3	1.0
OL 2008	2,183	6.6	8.9	9.2	11.1	11.5	8.3	8.9	9.3	4.4	5.7	7.5	6.0	2.1	0.6
Phys+Chem	**No.**	**A1**	**A2**	**B1**	**B2**	**B3**	**C 1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E**	**F**	**G**
HL 2011	**379**	**12.9**	**9.5**	**7.9**	**9.2**	**10.0**	**6.9**	**6.9**	**8.4**	**5.5**	**6.1**	**5.8**	**8.2**	**2.4**	**0.3**
HL 2010	355	8.2	11.3	7.9	12.1	6.2	10.1	4.5	7.0	4.8	6.2	6.2	8.5	3.7	3.4
HL 2009	408	7.8	9.3	7.8	10.3	8.6	7.6	9.1	9.3	6.1	6.4	7.1	5.9	3.7	1.0
HL 2008	454	16.7	9.0	7.7	10.1	8.8	6.6	4.6	9.3	4.6	2.4	7.0	7.3	4.4	1.3
OL 2011	**93**	**2.2**	**2.2**	**2.2**	**4.3**	**17.2**	**7.5**	**4.3**	**10.8**	**6.5**	**4.3**	**12.9**	**10.8**	**11.8**	**3.2**
OL 2010	70	1.4	2.9	2.9	2.9	5.7	2.9	5.7	14.3	7.1	7.1	18.6	12.9	10.0	5.7
OL 2009	111	1.8	3.6	0.0	2.7	9.9	1.8	8.1	16.2	9.0	9.9	10.8	11.7	10.8	3.6
OL 2008	144	2.1	2.1	2.8	6.9	6.3	10.4	8.3	9.7	9.7	7.6	9.7	11.1	9.0	4.2
Ag. Science	**No.**	**A1**	**A2**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E**	**F**	**NG**
HL 2011	**5,287**	**6.3**	**6.8**	**7.9**	**8.3**	**8.5**	**8.9**	**9.7**	**9.4**	**9.3**	**7.8**	**8.6**	**7.5**	**1.1**	**0.1**
HL 2010	4,675	3.8	6.1	7.7	9.2	9.9	10.5	10,8	10.2	9.3	7.5	7.7	6.3	1.1	0.1
HL 2009	4,164	5.7	6.9	8.0	8.7	9.4	9.8	9.3	10.4	9.3	7.0	7.4	6.6	1.4	0.0
HL 2008	3,712	7.2	6.3	8.0	8.4	8.8	10.0	10.1	9.4	8.4	7.0	8.2	6.7	1.3	0.1
OL 2011	**1,186**	**0.0**	**0.3**	**0.4**	**1.9**	**5.1**	**7.5**	**11.6**	**13.3**	**12.4**	**13.6**	**14.8**	**13.8**	**4.6**	**0.8**
OL 2010	1,112	0.1	0.3	1.8	5.2	7.3	11.0	11.9	13.5	12.8	12.0	11.0	9.9	3.2	0.2
OL 2009	1,108	0.0	0.4	1.2	3.0	5.1	7.3	11.9	13.4	14.3	10.6	13.4	13.3	5.8	0.5
OL 2008	1,025	0.1	0.7	1.9	2.9	7.9	9.3	13.6	13.0	14.3	10.7	12.3	10.8	2.4	0.1

(LC Grading at Higher Level: A1 90-100%; A2 85-89%; B1 80-84%; B2 75-79%; B3 70-74%; C1 65-69%; C2 60-64%; C3 55-59%; D1 50-54%; D2 45-49%; D3 40-44%; E 25-39%; F 10-24%; NG 0-9%)

Table 8 shows the change in the LC cohort (Established + Applied) from 2002 to 2011, together with the % of the cohort taking Biology, Chemistry, Physics and Agricultural Science (these are shown graphically in Figure 1 above). Biology is clearly in the ascendant and numbers and % share have climbed steadily since the new syllabus was introduced and examined first in 2004. The new Physics and Chemistry syllabi were first examined in 2002 and since then Physics has been on a slow decline and Chemistry on a slow increase, so that Chemistry overtook Physics in 2009 and the gap continues to widen. More students are doing Chemistry now than at any time in the last 10 years. Agricultural Science numbers continue to increase and it is now marginally behind Physics and, if the current trend continues, by 2012 Agricultural Science will have replaced Physics as the third most popular science subject.

Table 8 Changes in the LC cohort and science subjects (2002-2011) (For Biology 2002 and 2003 results were for the old syllabus.)

	LC	Biology		Chemistry		Physics		Ag. Science	
	Cohort	Total	%	Total	%	Total	%	Total	%
2002	58,489	22,064	37.7	6,497	11.1	8,651	14.8	2,890	4.9
2003	56,229	22,669	40.3	6,698	11.9	8,806	15.7	2,972	5.3
2004	55,183	24,027	43.5	7,229	13.1	8,152	14.8	3,237	5.9
2005	54,069	25,362	46.9	7,366	13.6	7,944	14.7	3,625	6.7
2006	50,995	24,885	48.8	7,071	13.9	7,335	14.4	3,912	7.7
2007	50,870	25,792	50.7	6,926	13.6	7,251	14.3	4,267	8.4

Table 9 shows the change in size of the LC cohort from 2005 to 2011. After a minimum number in 2007, the number doing the LC has now increased above 2005 levels and is due to continue increasing in the foreseeable future due to the increased birth rate working its way up through the schools system. This will have major implications in the near future for school places and later for places at third level.

Table 9 Change in LC numbers 2005-2011

Year	LC Established	LCVP	Total LC (Est) + LCVP	LCAP	Total
2005	39,792	14,281	54,073	3,318	57,391
2006	36,932	14,023	50,955	3,155	54,110
2007	36,790	14,080	50,870	3,056	53,926
2008	37,639	14,505	52,144	3,445	55,589
2009	39,112	15,084	54,196	3,259	57,455
2010	38,885	15,596	54,481	3,358	57,839
2011	**37,995**	**16,386**	**54,341**	**3,191**	**57,532**

The Mathematics problem

Every year there is a big discussion in the papers about Mathematics - the small number doing the HL paper and the high % of fails at HL and OL. The results in Mathematics are of great interest to science teachers, and 3rd level science lecturers, because Mathematics is the language of and underpinning foundation of Science, particularly the physical sciences. It is also vital for engineering subjects at school and at 3rd. level. Both mathematical literacy and language literacy are vital for success in all science subjects. Weakness in basic numeracy can be a significant barrier for students taking science and engineering at 3rd level.

Ireland's performance in Mathematics is not as bad as some of the critics make out. I think we should be optimistic because so many people continue to study Mathematics until the end of school, despite it not being officially compulsory – Ireland has one of the highest enrolments in Mathematics to age 17/18 in the world (see Table 10). Ireland should actually be in the top group as 95.7% take Mathematics at some level.

Table 10 % of upper secondary students taking Mathematics in various countries
(Nuffield Foundation, www.nuffieldfoundation.org)

Countries	**% Upper secondary students taking maths**
Czech Rep., Estonia, Finland, Japan, S. Korea, Russia, Sweden, Taiwan	95-100
Australia, Canada, France, Germany, Hungary, **Ireland,** Netherlands, New Zealand, Singapore, US	50-95
Scotland, Hong Kong, Spain	20-50
England, Wales, N. Ireland	< 20

This **should** mean that almost everyone leaving school and entering 3rd level is mathematically literate and numerate to some extent. However, as all teachers know well, studying something is no guarantee that you have understood or mastered it, as third level lecturers are also well aware.

The data in Table 10 have been expanded in a report on maths education in the UK from the Nuffield Foundation in the UK, *Is the UK an outlier?,* published in 2010, available at: http://www.nuffieldfoundation.org/sites/default/files/files/Is%20the%20UK%20an%20Outlier_Nuffield%20Foundation_v_FINAL.pdf It compared the situation in maths education in the UK at upper secondary level (post 16 = LC level) with that in 20 other countries, including Ireland. Here is a statement from the introduction to the report: *"The findings are stark. In England, Wales and Northern Ireland fewer than one in five students study any mathematics after the age of 16 (Scotland does slightly better). In 18 of the 24 countries more than half of students in the age group study mathematics; in 14 of these, the participation rate is over 80%; and in eight of these every student studies mathematics. When it comes to the mathematics education of its upper secondary students the UK is out on a limb."*

Ireland is unusual in that Mathematics is not compulsory at any level in second-level education, but in reality everyone does it at some level at upper secondary level. In fact Mathematics is the most popular LC subject (Table 7). Science is also not compulsory at any level in Irish post-primary education but a majority of students take at least one LC science subject, mostly Biology. There is currently a campaign in the UK to increase the uptake of Mathematics and even to make it a compulsory subject up to age 18.

The results for Mathematics for 2011 to 2008 are shown in Table 10 below. Table 6 reminds us that Mathematics is the most popular LC subject (95.7%) even though it is not formally compulsory. This means that virtually everyone who completes the senior cycle in Ireland has done a course in Mathematics. In the UK, for example, the majority of students drop Maths after the junior cycle and only a minority carry on with it to A-level. This should mean that Ireland has one of the most mathematically literate populations in Europe, if not in the world.

The % who did the Higher Level paper was 15.8% in 2011, 15.4 % in 2010, 15.5% in 2009 and 16.3% in 2008. The introduction of Project Maths (first examined in 2011) does not seem to have a significant effect on the % of students choosing HL Maths, as was hoped when it was introduced. Project Maths was rolled at a both JC and LC level in all schools from Sept. 2011. It has been criticised by some people for a perceived dumbing down of the mathematics content, as the emphasis is on practical mathematics. The lack of evaluation of the pilot phase before rolling out the full scale implementation has also been criticised. It remains to be seen as to whether Project Maths will increases the % taking HL Mathematics and whether it will result in students entering third level being better prepared in Mathematics for problem solving and application of the subject. The jury, as they say, is still out.

The number and % doing HL Maths is greater than that doing HL Chemistry or Physics, due to the much greater overall uptake of Maths, although we might well expect them to be the same students (see Table 11). Considering that almost the whole LC cohort does Maths, the % failures at HL (3.7%) and OL (9.8%) are quite small. Doing a course does not necessarily mean that one will pass it and the wider the ability range of students taking a subject, the greater the % of fails we would expect. Maths is not like the science subjects as Maths is taken by almost everyone and the sciences are self-selected. Biology has become the default science subject taken by 55.7% of LC students, whereas Physics and Chemistry are done by the more academic students, as reflected by the high % of HL students. I am not sure if we should realistically expect a much higher % of students to take HL Maths than do at present, although we could reasonably expect the number capable of doing HL Physics and Chemistry to be similar to that doing HL Maths ie. ~15 of the LC cohort.

Table 11 below shows the Maths grades from 2011-2008 at HL, OL and FL (Foundation Level).In 2011 1,984 students from 24 pilot schools took Project Maths. Of these 318 (16.0%) took HL, 1,437 (72.4%) took OL and 231 (11.6%) took FL. In the total LC Maths results (which includes Project Maths) 15.8% took HL and 72.1% took OL. Although the sample is small, it does not seem that Project Maths has encouraged more students to take the HL papers, although the % getting A,B,C grades (but not A grades) has gone up However, in the same pilot schools at Junior Certificate "a significantly higher proportion of candidates presented at Higher Level (52%) as opposed to the proportion in the cohort as a whole (45.6%)." (http://debates.oireachtas.ie/dail/2011/09/15/00059.asp). If this works its way up through the system this may result in more confidence and thus more students taking HL papers at LC in two years time.

Table 11 LC Maths results 2011-2008 at HL, OL and FL

Maths	No.	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
HL 2011	**8,237**	**5.7**	**7.5**	**10.2**	**11.5**	**12.4**	**12.9**	**11.7**	**8.9**	**7.4**	**5.0**	**3.7**	**2.3**	**0.7**	**0.1**
HL 2010	8,390	7.3	7.0	8.3	10.1	10.6	12.5	11.6	10.3	8.1	5.5	5.0	2.9	0.6	0.2
HL 2009	8,420	6.7	8.1	9.4	11.7	12.2	11.8	11.8	8.9	7.2	5.1	3.8	2.6	0.6	0.1
HL 2008	8,510	7.7	6.9	8.6	10.0	12.1	11.2	11.7	10.0	6.8	5.4	5.3	3.5	0.7	0.2
OL 2011	37,505	4.1	7.3	9.4	10.4	10.6	10.0	9.3	8.5	7.5	6.4	6.7	6.9	2.6	0.4
OL 2010	37,903	4.5	6.8	8.5	9.6	10.0	9.9	9.9	9.5	8.1	6.8	6.8	6.8	2.6	0.4
OL 2009	37,272	5.7	7.0	8.3	9.2	9.7	9.5	9.3	8.6	7.9	7.0	7.3	7.6	2.5	0.3
OL 2008	35,808	4.9	7.6	9.1	9.7	9.4	9.6	8.8	8.2	7.2	6.4	7.0	8.0	3.7	0.5
FL 2011	6,249	3.5	6.2	8.7	12.3	13.6	13.0	11.7	8.8	6.8	5.4	4.9	3.8	1.2	0,2
FL 2010	5,997	3.8	6.5	10.9	13.1	14.1	13.0	10.7	8.0	6.3	4.9	4.0	3.4	1,2	0.2
FL 2009	6,210	4.2	6.7	10.0	12.8	13.2	11.9	10.8	8.2	7.1	5.1	4.9	3.7	12	0.2
FL 2008	5,803	3.9	5.9	8.8	12.4	13.4	12.5	10.4	9.3	6.8	5.8	5.0	3.7	1.8	0.2

Table 12 Comparison of HL Maths, Chemistry, Physics and Biology 2011

	Maths	Chemistry	Physics	Biology
Number HL (% cohort)	8,237 (15.1)	6,272 (11.5)	4,782 (8.8%)	22,677 (41.7)
% doing HL	15.8	81.7	73.4	74.7
% As	13.2	21.9	20.2	15.6
No As	1,087	1,374	966	3,338
%A+Bs	47.3	52.4	46.0	43.0
% fails E,F,NG	3.1	8.6	8.0	8.3

More students take Maths than any other subject but it has one of the smallest % doing the HL paper (15.8% in 2011). The disparity with the three main science subjects is clear from the data above. Maths at HL also performs less well than the three science subjects in the % getting As and A+Bs, but less students fail it.

An important question we should ask is, **"Is every pupil in senior cycle capable of taking HL Maths?"** A higher % take HL Maths for the Junior Certificate than at the Leaving Certificate, though not as high as for JC Science, but this is not as demanding a course as LC Maths, just as JC Science is not as demanding as the LC science subjects. In order to do HL Maths (and HL Physics and Chemistry as well) a pupil needs to be able to think abstractly, handle concepts, understand logic etc. This means they have to be able to think at a fairly high level, what educational psychologists (after Piaget) call the 'formal operational level'. The evidence of large scale studies of second level students in the UK (e.g. Shayer and Adey, 1981), as well as evidence collected in Ireland (Childs and Sheehan, 2009) indicates that only a small percentage of students (<20%) at ages 16/17/18 is capable of the abstract, logical , conceptual thought needed by Mathematics and the Physical Sciences. This still true for first year college students, although the % capable of formal thought is higher (30-40%),especially for self-selecting courses which require a high level of Mathematics and the Physical Sciences.

So perhaps the major reason why more pupils don't take HL Maths is that they are not able to cope with the intellectual demands of the course, given their own state of development. If they did it, they would almost certainly do badly. We should also not be surprised if a significant number of students fail Maths at LC level, given that most of the school cohort at that age takes maths (95.7%) and thus there must be a significant number of weak students (those in the lower tail of the ability spectrum) doing OL and FL maths. Given the heavy conceptual demand of Mathematics, and given that most of these students are only operating at a concrete operational level, their inability to do well in maths is not surprising. Mathematics and numeracy are not the same thing, as any mathematician will tell you, and the emphasis for most students must be on basic numeracy. This skill remains a weak spot for many students when they leave school or go on to 3rd level, despite having done many years of Maths and even having got good grades in HL maths.

The same argument applies to those who choose to study Physics and Chemistry, mostly at HL – they may represent the % of the school population capable of doing these abstract, conceptual and mathematical subjects (10-15%). By the same argument, because not all pupils are capable of the type of thinking required in Maths and the Physical Sciences, we would expect to find them either avoiding the subject (for Chemistry and Physics) or opting for the OL or FL course (in Mathematics). We would also expect to find some pupils who cannot cope with the subjects at all and even though they take them, they fail. If we are taking almost the whole age cohort (at JC) and >80% at LC, we would expect a significant proportion of students to be of low ability (half are certainly less than average), who cannot cope with the demands of even OL material.

We can only expect everyone to pass examinations, at JC or LC level, **if** we lower the standards enough so that everyone gets through. The examinations and the results then become largely meaningless as we are ignoring the innate differences between pupils. The present arrangement in Mathematicss where it is offered at 3 levels seems to be ideal: everyone has a chance to do Mathematics at a level that suits their own intellectual development. We should expect and require basic numeracy for everyone, but everyone cannot and will not be a mathematician. What we should be doing is making sure that all those who are capable of doing HL Mathematics are in fact doing it, as it is from this pool that the future scientists and engineers as well as mathematicians will come. The negative image of HL Mathematics, Chemistry and Physics as hard, demanding subjects almost certainly means that some students (perhaps particularly females) are put off trying them, even though they could do well. This means we need to raise expectations, reduce fears and provide good role models to promote the value of doing HL Mathematics and the Physical Sciences.

The other change in relation to Mathematics in 2010 was the decision by all the universities to offer bonus points for Mathematics from 2012 until 2015, with a review in 2014. Anyone getting a D3 of higher in HL Maths will get 25 extra bonus points. This ***might*** encourage more students to attempt the HL course.

The large number of Mathematics teachers without a formal qualification in the subject was highlighted in a report from the University of Limerick and this has led to the Minister of Education and Skills to announce a programme to upskill out-of-field teachers, to start in 2012. (http://www.nce-mstl.ie/files/Out-of-field%20teaching%20in%20post-primary%20Maths%20Education.pdf)

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The Element Makers No. 13

Jean-Charles Galissard de Marignac (24/4/1817 – 15/4/1894)

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The Edict of Nantes was promulgated in 1598 by King Henry IV giving legal rights to Protestants and thus bringing to an end the religious wars which plagued France at the time. However, in 1685 Louis XIV revoked the edict rendering Protestantism illegal. The following years saw the persecution of Protestants, with many going into exile seeking a better life. The Marignac family, resident in Vézenobres of the Languedoc region, endured the life in France for some years but finally, in 1709, left and settled in Geneva, Switzerland and it is here in Switzerland that the subject of this essay begins his life.

Jean-Charles Marignac's parents were Jacob (2/10/1773 – 31/6/1864), a Judge and Councilor, and Suzanne Le Royer (1790-15th June 1870). From their marriage three children were born: Marie (1815-1872), Jean Charles (24/4/1817-15/4/1894) and David (25/3/1826-1909).

Jean-Charles Marignac, now just fifteen years old, entered the Académie de Genève in 1832 as a "Belles-Lettres" (literature) student. Up to this time the Academy was Theological and Philosophical in nature but was in the process of change. The number of students was small: fifty-three were accepted in 1832 as Theology, Law, Philosophy and Literature students only, and if Marignac had continued his studies here it is likely that his contributions would have been to some other area rather than to science.

After three years at the Academy, Marignac, now aged eighteen, by virtue of his French ancestors, was accepted as a student in 1835 at the École Polytechnique , Paris, as an internal student rather than a foreigner. He came 9th out of 132 taking the entrance test, and in 1837 graduated as head of his class, being awarded the Marquis de Laplace prize, which comprised the five volume works of Pierre-Simon Laplace (1749 – 1827) himself. While here Marignac attended the chemistry lectures of Alexandre Dumas (1802 – 1870). Dumas, when in Geneva studying at the Academy, lived in the house of Marignac's parents and thus took a benevolent interest in the academic progress of the young boy, now in adulthood. Marignac continued his education by entering the École des Mines and remained here until 1839, studying the analysis of minerals, and was awarded only a second class honours degree in 1838.

Marignac now undertook further study, firstly in various parts of Europe; firstly in Scandanavia, examining the latest mineralogical processes, secondly in the winter months between 1840-1841, on the recommendation of Professor Dumas, of Organic Chemistry with Justus von Liebig (1903-1873) in Giessen, mid-west Germany and finally, for a few months, in the celebrated Sèvres porcelain works, near Paris, under the direction of Alexandre Brongniart (1770-1847). It was at Giessen that Marignac made his only contributions to Organic Chemistry with his research on the oxidation of tetrachloronaphthalene and the production of phthalic acid. During the rest of his life he was to publish some one hundred and ten papers on other aspects of Chemistry.

Jean-Charles Galissard de Marignac
A photograph taken in his prime

In 1841 following the death of the Professor of Chemistry, Benjamin Delaplanche (1800-1841), Marignac returned to Geneva as the new Professor of Chemistry at the Geneva Academy, combining it with the Professorship of Mineralogy there in 1845. The Academy was to become part of the new University of Geneva in 1878 and at this point Marignac retired from his professorial positions, his chair of Chemistry being filled by Karl James Peter Graebe (1841-1927). He then set up a private laboratory in his home, where he conducted further experiments from that point on until 1887, when old age forced him to rest.

From the beginning of his time as Professor of Chemistry ,Marignac worked alone, without laboratory assistants or collaborators. Inspired by a wave of criticism of Berzelius' atomic weights in the years 1842 to 1843 he published his analyses of the atomic weights of chlorine, silver and potassium, in which he achieved an exactitude never before attained. One might have supposed that Berzelius would not have welcomed a revision of the atomic weights published by himself, but this was not the case. Indeed Berzelius was most laudatory of Marignac's results saying to him …

"I place the highest value on your experiments concerning atomic weights. The patience with which you repeat a large number of times, the sagacity with which you vary your methods, making use only of those which can give reliable results, and the conscientious manner in which you give the numbers dictated by the balance ought to assure for you the complete confidence of chemists."
[*Note Jons Jacob Berzelius (1779-1848) produced a table of atomic weights based on oxygen being 100 in 1818 and issued a revision in 1826. Berzelius's table is to be found in No. 2 of this series.*]

Earlier, in 1815, the English chemist William Prout (1785 – 1850) had postulated that atomic weights, totally inexact at the time, ought be multiples of that of hydrogen, although he allowed that some might be related to another element e.g. oxygen. The international chemical practitioners immediately divided into two camps, those in support of the notion and those against it.

Marignac, while drawn to Prout's notion due to its simplicity, however undertook to test the accuracy of the notion by making exhaustive experiments to determine the atomic weights of elements. In 1858 he published his results on the atomic weights of barium, strontium and lead and by

1870 he had determined the atomic weights of some 28 elements to the same degree of accuracy as shown by his 1842-43 results. His various publications of his findings gained him an international reputation and he was awarded the 1886 Davy Medal by the Royal Society of London for his work in this area.

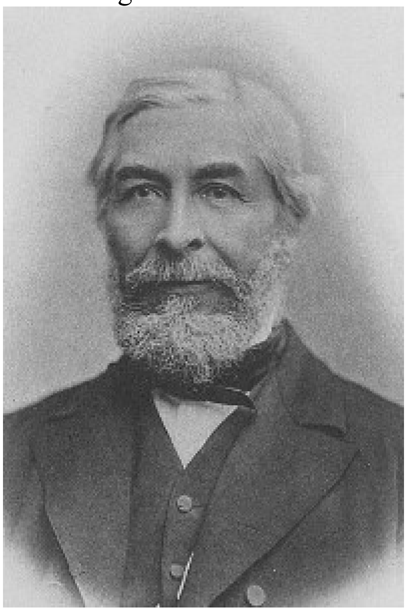
At the time when he assumed the Chair of Chemistry in 1841, there was a concerted effort being made throughout Europe to get definitive results for the percentage composition of oxygen in the air. During January and February 1842 Marignac produced results using the methods of his former Professor in Paris, Dumas and Jean-Baptiste Boussingault (1802 – 1887), giving the oxygen percentages from three samples taken on January 11th, 18th and February 3rd as 20.81, 20.80 and 20.77 percent respectively.

Between the years 1847 and 1857 Marignac was a joint editor of the Swiss journal *Archives des Sciences* but stepped aside in order to concentrate on his researches.

Marignac spent some time working on the composition and crystal forms of the mercury nitrates, published a memoir on didymium and its combinations and then turned his attention to resolving one of the vexed questions of the time, the exact melting and boiling points of sulphuric acid. The best estimates of the time were 34^{o} C for the melting point and 325^{o} C for the boiling point. By a series of repeated freezing of the acid and decanting of the liquid portion Marignac finally arrived in 1853 at values of 10.5^{o} C for the melting point and 338^{o} C for the boiling point. He was able to show that even the purest sulphuric acid then available had up to one percent water dissolved in it and it was this small amount of water that had given the diverse readings before this.

The nineteenth century saw a vast chemical effort on finding and isolating the rare earth series of elements and Marignac was not to be found wanting in this search. From his first days as Professor of Chemistry he began studies of minerals that he suspected might contain elements of this series. In 1853, using the spectroscope invented by the German Joseph von Fraunhofer (1787-1826), he announced the discovery of samarium from the sharp absorption lines in the spectrum of didymium. The element itself was to be isolated later in 1879 by Boisboudran (No. 7 of this series).

In later years, using the improved spectrometer of Bunsen (No. 5 of this series), he was to announce the discovery of two other elements. In 1878 he discovered the element ytterbium, which he found by the decomposition of the earth erbia, first by dissolving it with nitric acid, followed by heat and then by dissolving in water. Two oxides were found: the red erbia and a colourless one that he called ytterbia, after the Swedish town where erbia had been found. From spectroscopic observation of ytterbia he concluded that he had indeed found a new element. Later, in 1907, Georges Urbain was to separate the ytterbia into two separate fractions, which he called neoytterbia and lutecia, which contained the elements now known as ytterbium and lutetium, Ytterby, the small Swedish village, is unique in having four elements derived from its name: yttrium, ytterbium, erbium and terbium, all four elements found in the dense black rock found there, the mineral gadolinite.



Jean-Charles Galissard de Marignac
A photograph taken in later life

In 1880, from a study of the spectral lines in didymium and gadolinite, he announced a third new element, which he called gadolinium. This element was to be isolated by Boisbaudran in 1886.

In 1840 Christian Friedrich Schoenbein (1799-1868), a German-Swiss chemist, had discovered ozone as a new substance but thought that it contained nitrogen and possibly hydrogen.

Marignac spent some time on this matter and concluded from his experiments, in 1857, that ozone was composed of the element oxygen alone, being an allotropic form. He was to note that spark discharge through pure dry oxygen failed to produce ozone and that trace parts of water were needed for the reaction to take place. Later results from other chemists were to confirm Marignac's findings as correct.

At the same time as the studies on sulphuric acid, Marignac also was working on various compounds of hydrofluoric acid. In 1858 he noted that the fluorostannates and the fluorosilicates showed isomorphism and further, while examining the fluorosilicates of zirconium, boron, tungsten and other elements, he prepared silicotungstic acid, the first of the complex inorganic acids created.

Other researches of Marignac were on the compounds of niobium and tantalum, in 1866, and on the chloroplatinates of cerium, lanthanum and didymium and on isomorphism in the nitrates of the later two elements, as well as in phenacite ($2BeO+SiO_2$) and willemite ($2ZnO + SiO_2$). During this stage of his research he showed that silica should be represented by the formula SiO_2 rather than the SiO_3 previously held.

In Physical Chemistry, Marignac undertook research into solutions and the effect of heat on salt solutions. Here he supported Avogadro's hypothesis that each molecule of a gas had the same volume at any fixed temperature and pressure. Marignac, as a result of this work, concluded that salammoniac (NH_4Cl) when vaporized broke up largely into its individual constituents.

Martignac was always looking for improvement in all aspects of Chemistry. As early as 1858 he had adopted the method of notation of chemical compounds, then known as the two volume formula (for water this is H_2O), and over the years bemoaned the reluctance of French chemists to change from equivalent weights to atomic weights, long after the other European chemists had done so. In 1860 he attended the International Congress held in Karlsruhe to try and regularise nomenclature, notation and atomic weights and although the Congress failed to finalise these matters, Marignac was vocal in his support of the motions.

Marignac was honoured by the scientific community in being elected a Member of various Academies and Scientific Societies:

Correspondant of the Academy of Sciences of the French Institute,
Member of the Academy of Sciences of Berlin,
Member of the Academy of Sciences of Turin,
Member of the Academy of Sciences of Sweden,
Member of the Academy of Sciences of Lincei in Rome,
Member of the Royal Society of London,
Member of the Uppsala Society of Sciences,
Member of the Moscow Society of Sciences,
Member of the Manchester Society of Sciences and
Member of the Boston Society of Sciences.

In the year 1845 Marignac married Marie Dominicé (2nd Sept. 1825-22nd June 1920), the marriage producing five children: Charles Adolphe (23/5/1847-7/10/1936), Edouard (30/4/1849-2/4/1871), Francois-Ernest (22/5/1851-26/3/1941), Laura (1/12/1854-26/10/1931) and the short-lived Augusta-Léonie (29/5/1861-25/2/1862). Edouard was to die while still a student at the École Polytechnique in Paris.

From 1884 Marignac suffered from chronic heart disease and passed away on the 15th April 1894. The obituary notice in the *Popular Science Monthly*, Sept. 1894 suitably summarises his life: *"He was modest to excess, and led a retired life of labour, the fruits of which made his name known throughout the world."*
A salt, potassium stannosulphate, was commonly known as Marignac's salt.

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The importance of scientific literacy

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Science is an important school subject and should be compulsory up to JC level. A basic level of scientific literacy should be an essential part of everyone's education. At the moment <90% of students take science and more boys than girls do it. It is an important part of education and a foundation for five different LC subjects (Agricultural Science, Biology, Chemistry, Physics, Physics and Chemistry). Not doing JC science closes many doors and career choices, as does not doing any science subject at all for the LC (~60% take one or more LC science subjects). Science at JC and then LC should be an important foundation for developing scientific literacy in students, who will go on to become the citizens of the future, but not all will continue with science and even fewer will become professional scientists. This topic has been discussed recently in greater depth (Childs et al, 2010).

What is scientific literacy?

Scientific literacy has been defined in a number of ways and two examples are given below:

by the OECD for the PISA surveys:

"An individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen

(OECD 2006, p.12)

The 21st. Century GCSE course defines it in this way:

"We would expect a scientifically literate person to be able to:

- *appreciate and understand the impact of science and technology on everyday life;*
- *take informed personal decisions about things that involve science, such as health, diet, use of energy resources;*
- *read and understand the essential points of media reports about matters that involve science;*
- *reflect critically on the information included in, and (often more important) omitted from, such reports; and*
- *take part confidently in discussions with others about issues involving science."*

(http://www.21stcenturyscience.org/rationale/scientific-literacy,903,NA.html)

I would like to distinguish between scientific literacy and science literacy, although most people don't make this distinction: one is about breadth (scientific literacy) and the other about depth (science literacy). A university science degree should mean that someone is science literate in the subject of their degree, but it does not guarantee that they are scientifically literate – they may know nothing about areas of science outside their area of specialisation. The ultimate example of specialisation is the PhD, which involves a study in depth of a narrow area. This has been unkindly described as knowing more and more about less and less until one knows everything about nothing! Good grades in science examinations do not guarantee or measure scientific literacy – they may just indicate one is good at passing examinations! As someone said, education is what is left after all that has been learned (to pass examinations) has been forgotten.

Science at JC level (and also in the TY) has an important role to play in developing scientific literacy, as well as a preparation for future studies. Often these two purposes of science education are described as 'science for future citizens' i.e. scientific literacy and 'science for future scientists' i.e. science literacy. Traditionally science courses, particularly at LC or A level, were designed for the elite who would go on to be professional scientists – science for scientists. As education has become less elitist and more students stay on to age 18 and go on to third level, the ability range and interest profile of students has changed. We have a much broader spectrum of ability, often down as far as the mean or below, and a wider range of interests – not everyone who studies science wants to be a scientist. This change in the student population and the purpose of the state examinations means that we need to change the focus of the curriculum and assessment. We need to think about providing both for future scientists and future citizens, and for the latter our course may be the last formal science they do. This is particularly true at JC (or GCSE) level.

The question we must ask then is our science curriculum fit for its new purpose? Is it still aimed at the small proportion of very able students (suited for higher level and further study of science) or does it take account of weaker students and their needs? Will all students come out of the JC Science course scientifically literate (according to our definitions above) or merely able to pass the examination? Passing the examination in itself does not mean one is scientifically literate, if the science studied cannot be related to everyday life and if it does not help students to understand science-based issues. In an earlier article in this series (Childs, 2006) I stressed the importance of relevance in teaching science – taking science out of the school laboratory and showing how it relates to real life, and bringing the real world into the laboratory. Too often science is taught as an abstract, theoretical and irrelevant subject, which many students find boring and pointless. They see the facts but not the big picture, and cannot see the forest for the trees. They don't see the connections to their everyday life and unless the teacher shows them and helps them to make connections they will never do so and will remain scientifically illiterate, despite studying science.

International studies of scientific literacy (Miller, 2006) show that despite exposure to science at school for most of the population in modern democracies, levels of civic scientific literacy are low – never above 35% (Sweden) and Ireland comes in at 9%. The European average is only 14%, so whatever we are doing it isn't working. Surprisingly the USA comes out near the top of this league table with a score of 28%, although the Americans have expressed dissatisfaction with the quality of their secondary science education and they have not done well in the PISA assessment.

So why do Americans end up so unexpectedly good? The answer seems to lie in the nature of American college education. Firstly, a high proportion of the age cohort in the USA proceed to some form of college education and secondly, everyone has to do some science courses at college. Students of the humanities or liberal arts must fulfil certain course requirements in science, and science students must take liberal arts courses. This produces more rounded graduates who are less specialist, but more generalist. US colleges have put a lot of effort into designing science courses for non-scientists, with an aim of developing scientific literacy, and it appears to have paid off. For example, the successful course and book *Science Matters: achieving scientific literacy* by Robert M. Hazen and James Trefil (Hazen and Trefil, 2009).

The 21st. Century Science GCSE course in the UK deliberately sets out to develop scientific literacy by making the science content issue-based, and it has been criticised for dumbing-down science. This is the statement of the course aims.
"The model offers all students the chance to develop the scientific literacy that they need to play a full part in a modern democratic society where science and technology play a key role in shaping our lives - as active and informed citizens. In addition, for some students - perhaps a minority - we have produced courses which provide the first stages of their training as a scientist, or for a career that involves science." (www.21stcenturyscience.org/rationale/)

In Ireland the percentage of the age cohort going on to third level is now over 60% but student's choice of courses are narrowly demarcated – science, engineering, medicine, arts, business etc. There is often a requirement in most institutions that science students should take some arts courses e.g. business or languages, but rarely do arts students have to do courses in science or technology, although they may have this option. Two examples where this option is available, but only as an elective not a core requirement, are the Technology Awareness Programme at UL (Walsh, 2010) and the Science and Society Course at UCC (Reville, 2010). These aim to give a broad coverage of topics in science and technology (see Tables 1 and 2). It is this type of course that is needed to develop scientific literacy for citizens, but to be effective it should be an essential part of all courses. Science, technology and medical students also need this sort of course as much as arts, humanities and business students, as they are in danger of becoming science literate but not scientifically literate.

Table 1 Themes covered in the Technology Awareness Programme at UL

TAP Major Theme	*Sample* Sub-themes
Environment	Population and extinction, Pollution, Waste management.
Energy	Alternative energy sources.
Biotechnology	Genetically modified organisms, Cloning, DNA profiling.
Agriculture and Food	Improving crop production. Processing and preserving foods.
Health and Medicine	Revolutions in healthcare: sanitation, antibiotics, vaccination, gene therapy. Studying epidemics, HIV/AIDS crisis. Developing pharmaceuticals.
Philosophy of Science	Introduction to philosophy, history of development of scientific thought and methods.
Chemistry	Discovery of the elements. Developing the chemical industry. Chemistry and cleaning, cooking, forensics, sport, cosmetics.
Materials	Metals, polymers and plastics, ceramics, composites, smart materials.
Information technology	Computers, computer networking, broadband, designing and constructing a webpage
Sociology of Science	Structure of scientific society, methods of science. Controversies involving science, e.g. BSE, Foot and Mouth disease, MMR vaccination
Transportation	Physics applied to transport. Development of the motor car, flight, traffic control, space travel.
Problem-solving and Innovation	Scientific ways to solve problems. Innovation: how it works?
Course review	Innovations in themes studied in first three semesters. Future science, including nanotechnology, the science of aging, biomedical engineering……..

Table 2 Topics covered in the Science and Society Course at UCC

Topic	No. of lectures
Ways of knowing about the world	1
The nature of science	1
What has science discovered about the physical world	2
What has science discovered about the biological world	2
The nature and importance of technology	1
Science and modern economy	1
Science and engineering: which came first?	1
New biological techniques	1
Science and religion	1
Ethics and science	1
Ethical issues in science	2
When science goes wrong	1
Why is mathematics so successful in describing the natural world?	1
Science and the environment	1
Science and health	1
Science and the humanities	1
Democracy, expertise and scientific citizenship	1
Pseudo-science and anti-science	1
The public understanding of science	1
Science in Irish history	1

To make sense of science and technology in everyday life, to able to weigh up evidence and make informed decisions, to understand science-based issues requires breadth of knowledge of both key facts and the big ideas in modern science, but also some understanding of the scientific method and the role of evidence, risk, probability etc., often referred to as the Nature of Science (NOS). To understand and adjudicate on contemporary science-based issues like GM crops, nuclear power, fluoridation of water, biofuels, global warming, the list is endless, needs a basic understanding of science and its methods. Without this people are swayed by pseudoscience and anti-science propagandists or by emotion, and the glossiest, loudest, most persuasive message wins out, even if it is wrong. We need a significant level of scientific literacy in the electorate for democracy to work properly in the 21st century and for the right policy decisions to be made. This also applies to the government and public representatives (TDs or MPs), where people with a STEM background are few and far between.

Ignorance and prejudice are the enemies of discernment and right-thinking. School science, particularly at the level where most of the school population still takes it (at JC and GCSE level), should play a greater role in developing scientific literacy, but only if it is an explicit aim of the curriculum, if it is integrated into the teaching of the science, and if it present in the course assessment. Research by Lynch and Childs (2006) and Lynch (2006) in relation to the 2000 LC Chemistry syllabus showed that having an aspiration in the syllabus of 30% coverage/content/time on social and applied aspects of Chemistry (i.e. STS, the basis of scientific literacy) is not enough. The STS emphasis has to be reflected in the examination for it to be present in the classroom and in the textbooks. This was not true in the first three years of the new LC Chemistry syllabus and there was an inconsistent assessment of the topic in the LC examinations. This is another example of a good idea being wasted and spoiled by poor implementation and a lack of integration between syllabus, pedagogy and assessment. It is no good having a good aspiration in the course objectives or in the syllabus unless they are delivered in practice. An objective which is not properly implemented and assessed is not worth the paper it is printed on. Giving a few pictures of famous scientists to identify is not the same as teaching STS and does not develop scientific literacy.

How can teachers develop scientific literacy?

The first place to start is by making sure that every science lesson, both theory and practical, makes a point of relating the material being taught to the world outside. This can be done by the teacher bringing examples into the lesson, by asking students to think of examples, by relating the science to current issues in the media, and by asking questions based on everyday stories and scenarios, where the students have to use the science to explain what is going on. Such story-based questions also develop higher order thinking skills as well as scientific literacy.

For example, there was a lot of science in the big freeze of January 2010. How does salt make ice melt and why can one use other compounds, like urea or ethanol, instead of salt to do the same job? What are the side-effects and problems of pouring too much salt or urea on the roads? Why are planes not de-iced by spraying sea-water over them? You get the idea?

One way to develop scientific literacy is to start a Science Notice Board using cuttings from newspapers and magazines, particularly dealing with local or Irish issues. Students should be encouraged to bring in cuttings, especially related to the topics being covered in class, and the material can be used to illustrate and bring to life the dry, boring, irrelevant (from a student viewpoint) science being covered in class. You could then use the Science Notice Board as the basis of class quizzes, maybe at the end of term. If you can get your pupils to bring in things to school and start asking questions about things they have read or seen, then you are winning the battle to make science relevant to their lives.

When an issue is being discussed in the papers and on radio and TV which is science-based e.g. GM foods, MMR vaccination, nuclear power, fluoridation, use the opportunity to discuss the science (at an appropriate level) in your classes. ***Carpe diem!*** Seize the moment and use the public debate as a teaching opportunity – the issues will often be directly relevant to one or more LC science subjects, and some to JC topics. Get the class to research the issues for and against the topic, make sure they understand the basic science and then debate the issues.

Transition Year is a key opportunity to develop scientific literacy by going outside the normal school curriculum. The TY Science modules from UL are all context-based, STS-focused and interdisciplinary, allowing one to develop scientific literacy through interesting topics. The module on Issues in Science, developed by Ciara Hayes (Hayes, 2010), for example, takes a number of controversial issues in science and provides a forum for students to address the science involved and to debate the issues. Risk analysis is an important aspect to consider when science and technology meet society, and we need to be able to assess the probable consequences of some action. Table 3 shows the topics covered in this module, and each unit can be taught on its own.

Table 3 Topics covered in the TY Science Module "Issues in Science"

Unit 1 Risk assessment
Unit 2 Genetically modified foods
Unit 3 Stem cell research
Unit 4 Biofuels
Unit 5 DNA Identification
Unit 6 Nuclear power
Unit 7 Electromagnetic radiation
Unit 8 Fluoridation of water supplies

Ruth Jarman and Billy McClune from N. Ireland have developed interesting teaching materials based on science in the news (Jarman and McClune, 2007) and their book *Developing Scientific Literacy: Using News Media in the Classroom* is a good introduction.

Scientific literacy matters

We have failed as science teachers, I believe, if our students leave our laboratories and classrooms without being able to appreciate the importance of science in everyday life, do not know some of the important facts in science and do not understand at some level the big ideas of science, and do not understand how science works and how evidence is used to support or undermine a case. In the case of science we want our 'graduates', at second or third level, to have a sufficient level of scientific literacy to allow them to make sense of the science they meet in their everyday lives; to be able to read, understand and criticise items in the news; to be able to make informed, evidence-based decisions about science-based issues and be able to make an informed contribution to the public debate of such issues. A wider diffusion of scientific literacy in society would prevent people being swept along by every mad idea and biased propaganda and making poorly-informed decisions based more on emotion than reason, more on prejudice than facts. Surely this should be one of our major goals as science teachers? Let us take science outside the classroom and laboratory and show our students its relevance to the world around them. Let us bring the real world into the classroom using current issues as a focus and teach our students how to think scientifically about the issues they meet today and will face in the future.

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Laboratory Accidents

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Introduction

Practical work is a vital element of any Science lesson, however, taking precautions in order to minimise the risk is also important. This article is the first in a series which will take a critical look at many accidents that have taken place in the Science laboratory, discussing the chemistry involved and the precautions which could have been taken to prevent the accident.

The first thing to discuss is the importance of carrying out a risk assessment on all experiments which are conducted in the laboratory, and all ones which you plan to perform in the future. Both experiments and demonstrations are fun, exciting and important to use to ignite pupils interest in the subject and as teaching tools, however, you can often find instructions for experiments and demonstrations on the internet which are not safe, and don't have any safety instructions. New books and websites contain safety information but older books and websites do not. Therefore it is vital that a safety audit be carried out before both the teacher and pupils are exposed to potential hazards.

Ice on fire

The first laboratory accident which will be described occurred while carrying out a demonstration called 'Ice on Fire'. The chemistry behind this spectacular demonstration involves the reaction between calcium carbide and water to produce ethyne (acetylene) gas and calcium hydroxide:

$CaC_2(s) + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2(g)$

Source of image:
http://www.blippitt.com/flammable-ice-video/

The procedure for this demonstration is to place a few grains (~1g) of calcium carbide into a dry metal dish or pyrex bowl, using a spatula. Quickly add the ice into the dish on top of the calcium carbide. The moist ice reacts with the calcium carbide to produce ethyne (acetylene) gas and calcium hydroxide. The ice can then be quickly lit with a long taper, to produce smoky flames on the ice, giving the illusion that the ice is on fire.

There are a number of dangers associated with this demonstration. The accident which occurred involved two individuals doing this demonstration. It was the job of the first to secretly place the calcium carbide in a dry dish and hand the dish to the presenter who would then add the ice and light the gas. However, the dish

Source of image:
http://www.sciencemuseum.org.uk/~/media/186BB990C84E49CB9504ECACCB33DF69.ashx

was **not** fully dry, and when the calcium carbide was added it immediately began to react with the moisture at the bottom of the dish, forming a cloud of ethyne gas. When the presenter added the ice and lit it, their hand was engulfed in the flame.

What can be learned from this accident? Firstly, when doing this demonstration it is of vital importance that the dish used is kept dry and is checked again before adding the calcium carbide. Keep a towel close to the dish so that it can be dried before any calcium carbide is placed in it. Secondly, it is better to use a long gas lighter, or taper, rather than a match, as this puts distance between the demonstrator and the flame. This demonstration should not be done near any sources of ignition and only very small amounts of the calcium carbide should be used. All possible flammable substances need to be kept away from the area in which the experiment is to take place. The calcium carbide should be stored in a tightly sealed metal container in a "dry" box away from all oxidising agents and water. Also, the teacher/demonstrator should be wearing appropriate Personal Protective Equipment, such as a laboratory coat, safety glasses and flame proof gloves. The flames can be extinguished with dry sand. Water should never be added to quench the flames as it will react further with the calcium carbide to produce more flammable gas. It usually goes out by itself if a small amount of calcium carbide is used.

The whoosh bottle

The next accident which will be looked at is one which occurred during the 'whoosh bottle' demonstration (see Kitchen Table Demonstrations, 2008) , also known as the methanol cannon, which is a useful demonstration to dramatically illustrate a combustion reaction. This demonstration involves igniting a mixture of alcohol and air in a large polycarbonate bottle (as used for bottled water). The resulting rapid combustion reaction, often accompanied by a dramatic 'whoosh' sound and flames, demonstrates the large amount of chemical energy released in the combustion of alcohols. This demonstration can also be used to illustrate the proportion of carbon in the alcohol molecules. The flame colour varies depending on the proportion of carbon: methanol and ethanol produce a very quick, vigorous reaction with a

Source of image:
http://www.digitaldapp.org/demos/documents/whooshbottle.pdf

'whoosh' sound and a blue flame shoots out of the bottle; propan-1-ol and propan-2-ol, gives a similar, but slower 'whoosh' sound and the reaction is slightly slower, and easier to observe, with blue and yellow flames observed 'dancing' in the bottle. The presence of water reduces the likelihood of dancing flames.

The chemical equation for the reaction with methanol is:
$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O + \text{heat}$.

The accident which occurred during this demonstration took place in a school setting. A teacher was doing this demonstration, but was using an old and much used polycarbonate bottle.

After the alcohol was placed in the bottle and the bottle had been shaken to vaporise the alcohol, the excess liquid was **not** poured out. The resulting accident involved the liquid alcohol in the bottle catching fire, and the pressure in the bottle was too much and it exploded sending shards of the bottle around the classroom. A very dramatic and dangerous result!

Steps which can be taken to avoid this type of accident occurring are as follows: All surplus liquid should be poured back into its original bottle or a beaker, using a filter funnel to avoid spilling, draining the vessel as completely as possible. The original bottle or beaker should be put back to the rest of the alcohol stock, away from any potential sources of ignition. The neck of the 'whoosh' bottle should also be wiped to remove any excess drops of alcohol. A white tile is very effective to stop the reaction if you feel that it has become too vigorous, by placing it over the neck of the bottle, and thus cutting off the source of oxygen. Fire blankets should be on hand as well as the appropriate extinguishers. Use a long gas lighter when holding a flame to the mouth of the 'whoosh' bottle or attach a wooden splint to the end of the metre rule or stick using adhesive tape, angling the splint so that when the metre rule is horizontal, the splint is sloping downwards. This can be used to light the neck of the bottle. Select a safe, level place for the demonstration, with at least 2.5 m clearance above the top of the vessel to the ceiling above, and no flammable materials above it. Safety screens should be put in place and wear all necessary Personal Protective Equipment (safety goggles, lab coat and flame proof gloves).

The other issue which occurred in this instance was that the bottle used was old, and cracked. A large polycarbonate bottle must be used. These can be found in workplace water dispensers and have a volume of 16 - 20 dm^3. Ideally a clean, dry bottle is required for each demonstration. It takes time to clean and dry once it has been used for a demonstration. For this reason, up to 4 bottles may be required. The bottle must be made of polycarbonate (marked PC) and of no other material. While the polycarbonate bottles can be reused for this demonstration (once cooled and dried) over and over again, they must be checked every time for cracks and potential sources of weakness. If any are noted, then the bottle should be disposed of and not used in this demonstration. It is also important never to reuse a bottle immediately after it has been used, as it may still be hot or contain a flame.

Organic wastes only

The final accident which will be examined in this article is one which occurred in an organic chemistry laboratory. A student, while attempting to make up a solution of acidified potassium permanganate in a test tube to test for the oxidation of alcohols, used concentrated sulphuric acid instead of ~2 M of sulphuric acid. [This should have been done by mixing equal volumes of dilute (~2 M) sulphuric acid and dilute (~0.02 M or less) potassium permanganate solution.]

Source of image: http://sanmccarron.blogspot.com/2011/05/underwater-fireworks.htmlhbottle.pdf

Concentrations are not critical: the solution should be dilute enough to see through. Upon realising the mistake the student wished to dispose of the acidified permanganate solution and threw the contents of the test-tube into the organic waste bottle. This resulted in a loud bang and an explosion which splashed the contents of the organic waste bottle back onto the student, who suffered acid burns to his hands.

This unwanted reaction can be demonstrated on a small scale using the 'thunder in a test tube' demonstration (About.Com Chemistry), which illustrates the oxidation and reduction of alcohol. The procedure for this demonstration is as follows: in a fume hood pour concentrated H_2SO_4 in a test-tube to a depth of ~3 cm. Carefully add ethanol, so that the liquids do not mix and form two layers, to a depth of ~3 cm. Support the test-tube in a vertical position in a fume hood. Drop a few crystals of $KMnO_4$ into the test tube. There are a number of reactions taking place here. Sulphuric acid transforms the purple permanganate (MnO_4^-) into the highly reactive, green dimanganese heptoxide (Mn_2O_7), a powerful oxidising agent. As the dimanganese heptoxide forms at the interface, it floats up and reacts with the ethanol and oxidises the alcohol to ethanoic (acetic) acid. This violent reaction creates a popping flash. When added to a strong oxidising agent (dimanganese heptoxide), ethanol is oxidised and the heat evolved causes bursts of light as some of the ethanol burns. (See http://www.youtube.com/watch?v=NCpG9eIfThk to watch this experiment.)

How could this accident have been prevented?

This accident could have been both much more serious, and was preventable. Luckily the organic waste contained a very small amount of waste, had the container been closer to full the burns the student received could have been much more severe. This accident was preventable in variety of ways. The student should have read the instructions more carefully, and used the correct concentration of acid, and the concentrated sulphuric acid should not have been available at a bench where it was not required for use. You can never state enough that organic waste is **only for organic waste products**, and **nothing else**. This student involved was wearing all appropriate personal protective equipment, which in this instance saved him from more severe burns. Always ensure that appropriate personal protective equipment is worn. All chemicals should be clearly labelled and have their concentrations stated to ensure no confusion.

To safely dispose of this unwanted mixture, the student should have poured carefully into excess water in a sink and washed it away.

Prevention is better than cure

All of the accidents described in this article were preventable, had appropriate precautions and thought been applied before the experiment or demonstration. Remember that the teacher is often the person most at risk in a demonstration as you are closer to the action! You should always wear eye protection, a lab coat, and gloves where required. Where necessary you should have a full-face protector and safety screen. If you are demonstrating to a class the pupils must also be protected - they should wear safety glasses and if necessary a safety screen should be used. You should also make sure that you have a suitable fire extinguisher and fire blanket available. Don't forget to consult Material Safety Data Sheets regularly when completing a risk assessment or keep them on file in an easily accessible folder in the laboratory. The Professional Development Service for Teachers has an excellent supply on their website: http://chemistry.slss.ie/ph_materialsafetydata.html . When MSDS are consulted, if the worst happens. then appropriate first aid can then be given. By completing a risk assessment, you are forced to stop and think about what you are doing, to imagine any possible dangerous scenarios, and to put in place appropriate measures to avoid them.

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This is the first of a series of articles on Laboratory Accidents. If you were involved in an accident at school please share it with your colleagues – no names will be used! Your experience might help prevent an accident.

At my urgent request the Curie laboratory, in which radium was discovered a short time ago, was shown to me. The Curies themselves were away travelling. It was a cross between a stable and a potato-cellar, and, if I had not seen the worktable with the chemical apparatus, I would have thought it a practical joke.

Wilhelm Ostwald on seeing the Curie's laboratory facilities.
— Wilhelm Ostwald
Quoted in R. Reid, *Marie Curie* (1974), 95.

The First Robert Boyle Science Festival: Lismore, November 2011

Opening remarks by Richard P. Wayne

The Science Festival held in Lismore to celebrate the 350th anniversary of the publication of Boyle's *Sceptical Chymist* must be judged a tremendous success. Indeed, it was a success on several levels, including the 'academic' programme, the social interactions, and the opportunity to display the attractions of Lismore and County Waterford. Our meeting was centred on the fabulous Pugin Hall of Lismore Castle, which Lord and Lady Burlington kindly made available for us. I was most honoured to be invited to present a lecture at such an interesting meeting.

Lismore Castle has a varied and important connection with truly significant scientific work. Not only was Robert Boyle born here, but after the house was bought by the Dukes of Devonshire, there was another connection with a most illustrious scientist. Henry Cavendish (1731–1810) was the grandson of the second Duke of Devonshire. One of Cavendish's main topics of research was atmospheric composition, which relates directly to the earlier studies of Boyle (and Hooke), as well as to my own interests in atmospheric chemistry. And it should not go unrecorded that the London home of the Royal Society of Chemistry is Burlington House (just round the corner from Cavendish Square).

The lectures struck me as representing a well-judged and varied selection. They spanned topics ranging from history, through policy matters, to atmospheric science. Discussions that I had with members of the audience convinced me that the primary aim of the Festival, 'to share the wonderful heritage of science with non-scientists', had been amply achieved. The target audience was universally enthusiastic about what they had heard and learned, and about the ways in which the material had been put over clearly and intelligibly. Beyond that, though, I found that the lectures that I listened to were fascinating, instructive and even inspirational to me as a practicing scientist. The other lecturers assured me that they felt the same way. Not including my own contribution, I found the standard of presentation exceptionally high.

The social aspects of the Festival had evidently been arranged with care in order to allow the scientific messages to be reinforced, and to cement the new friendships that were developing. On the Saturday evening, *On the Boyle* was a successful opportunity for the audience to meet and interact with the lecturers, as well as to listen to some Irish music and see some (very noisy) dance.

There was really something for everyone at the Festival. I have already alluded to the accessibility of the lectures to non-scientists as well as to their interest to the scientists in the audience. Events were laid on, as well, for children and their parents. The Chemistry Magic Show at the Lismore Heritage Centre was highly popular. I spent some time at the Community Centre on the Sunday afternoon looking at what was provided at the Family Science Day. There were fine demonstrations and excellent hands-on experiments that held the children (and me) in thrall. I was truly impressed by the enthusiasm and presentational skills of some of the young people running the various stalls. The climax to all this was the superb firework display in the Millennium Park that rounded off the Festival. Despite the threatening dampness on a November evening, the rain held off, and it seemed that most of young Lismore turned out for the show.

Of course, events like this Festival do not just 'happen'. The staff of the Lismore Heritage Centre put an enormous effort into the organisation, and they were assisted by a committee consisting of representatives of Lismore Castle, University College Cork, Waterford Institute of Technology and the local chemical industry. What is more, the organisers managed to secure substantial numbers of sponsors, no mean achievement in these difficult times. The sponsors must feel that they obtained a first-class return on their investment, and we should all be grateful to them.

I found the Heritage Centre staff wonderfully friendly, hospitable and helpful. They had judged quite perfectly the balance between effective control of the Festival and excessive detailed interference. The Irish are good at this sort of thing. Thank you everyone!

Scientific lectures

With *Boyle, Hooke and their Physio-aerial Discoveries* Dr Allan Chapman will examine the events that led to the Boyle-Hooke airpump being built in 1658-9 and the fundamental discoveries made with it. The scientists' dawning understanding of meteorological systems and disease transmission will also feature in Dr Chapman's discussion as will the Christian inspiration that motivated Boyle's science.

Professor Bob Watson's *The Effect of Human Activities on Earth's Atmosphere* presupposes that during the last 100 years human activities have modified our atmosphere with adverse effects on health, biodiversity and much else. Professor Watson's presentation will discuss the scientific evidence behind these issues and the technological and policy responses at national and international levels.

Earth has a "peculiar atmosphere", whose composition does not appear to obey the laws of physics and chemistry: this is the genesis of Professor Richard Wayne's lecture *Earth's Peculiar Atmosphere.* Professor Wayne will discuss our atmosphere's dissimilarity to those of our planetary neighbours Venus and Mars and examine how this peculiarity is a result of the existence of life on Earth.

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Transition Year Science

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This is the first of a regular series of articles on Transition Year Science. The purpose of these articles will be to give initially a general overview of Transition Year and Transition Year Science, and then to provide teachers with useful tips and ideas for teaching the subject in the year. These will range from ideas on how to use the resources that are currently available, to examining current relevant and popular topics and developing these into Transition Year Science classes.

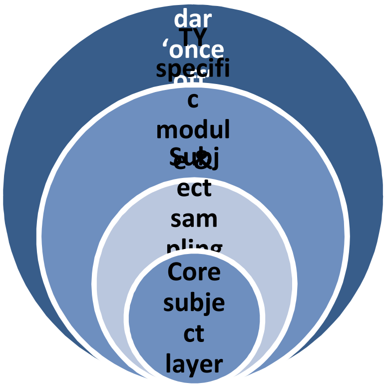
Background to the Transition Year

The Transition Year Programme (TYP) is a one year optional programme offered to students in their fourth year of second level education, between the junior and senior cycles. Schools are not obliged to offer the programme, and if they do, pupils are not required to take it, unless the school chooses to make it a compulsory programme. Table 1, below, indicates the current trends in the numbers of pupils taking the programme, and schools offering it.

Table 1: Percentages of schools and pupils offering the Transition Year

Year	Percentage of schools offering the Transition Year	Percentage of pupils taking the Transition Year
06/07	71.3	46.7
07/08	73.7	47.1
08/09	73.3	50.6
09/10	76.0	53.3

How schools offer the TYP varies from school to school, with each school having the autonomy to design and implement its own curriculum in line with the Transition Year Guidelines (Department of Education and Science 1993). Figure 1 illustrates the 'onion model', which indicates the main areas of the Transition Year (TY) course that schools should offer.



Calendar layer:
Work Experience, Outdoor pursuits, Social outreach, Field Trips, Visiting Speakers, Drama/Musical Production etc

TY specific module & subject layer:
Mental Health Matters, Mini Company, Photography, Tourism Awareness

Subject sampling layer:
Environmental Studies, Physics, Spanish Drama, Home Economics, Business Studies

Core subject layer:
Physical education, I.C.T., Mathematics, Gaeilge, English, R.E.

Figure 1: The Transition Year Curriculum (Adapted from the Transition Year Second Level Support Service 2007)

The four areas of the TYP are the core subject layer, the subject sampling layer, the TY specific module and subject layer and the calendar – 'once off' layer. The core layer includes subjects such as English, Irish, Mathematics, Physical Education and Religion. Science may be offered in either the subject sampling layer with other subjects such as Spanish, Business Studies etc or as a modular programme in the TY specific module and subject layer. The calendar layer is designed for once off events, such as field trips, work experience, outreach and visiting speakers.

Science in Transition Year

"Transition Year is an opportunity for pupils to become familiar with a broad range of Science activities. Pupils should be encouraged to study areas of Science not heretofore encountered" (Department of Education 1993c, p. 27)

The Transition Year, being a year with no syllabus and no curriculum other than some broad educational guidelines, offers a lot of freedom. This freedom offers teachers the opportunity to contextualise Science in terms of its role in pupils' life and in society (i.e. Science and Technology in Society, STS). This STS focus has been found to be beneficial to pupils in their learning of Science, enhancing their overall experience of the subject and their perceptions of Science and Science teachers, and narrowing somewhat the gender gap in terms of interest in Science (Smith and Matthews 2000). The uptake of Science in Ireland has been on the national agenda for many years, since the noticeable drop-off of pupils taking Science subjects in the nineteen-eighties. This national focus has been concentrated, particularly on the uptake of the Physical Sciences.

Transition Year Science sampling also offers not only an opportunity for pupils to make informed decisions about their subject choice at senior cycle, but also an opportunity to promote the 'real-life' applications of the subject before they make the crucial choice of subjects. The Association of Secondary Teachers in Ireland believe that Transition Year Science should aim to develop pupils' *"scientific skills and to promote a greater awareness of the role of science in their lives"* (Association of Secondary Teachers Ireland 1992, p. 16)

Smith and Matthews (2000) note that *"...the scope of the syllabuses at Junior Certificate and Leaving Certificate are narrow, being largely concerned with matters internal to science rather than to the role of science (and technology) in society"* The opportunity provided to teachers by the Transition Year could be crucial in the development of scientifically literate citizens, the promotion of positive attitudes towards Science and interest in and uptake of Science. Science needs to be appreciated for the intrinsic pleasure it can offer an inquiring mind and it should be taught in this fashion. Transition Year is a unique opportunity to do just that, with the freedom and autonomy it offers to schools and teachers, allowing pupils who might have otherwise not appreciated Science, to learn to become excited by it and to love it. A good Science sampling programme in Transition Year can lay the foundations for a rich and rewarding scientific career for many pupils. Transition Year is not part of the Leaving Certificate cycle and time should not be spent on covering Leaving Certificate material. However, it may augment the Leaving Certificate syllabus as well as building upon Junior Cycle material. It is an opportunity to provide students with a balanced exposure to the sciences (Department of Education and Science 2002).

Developing and extending the ways in which Science is taught is one of the goals of the Transition Year Programme, as the guidelines state: *"A key feature of Transition Year should be the use of a wide range of teaching/learning methodologies and situations."* (Department of Education 1993c) A *"Transition Year Science module should explore the links between science and society"* (Department of Education 1993c).

Some of the Transition Year Science modules which strive to do this are the range of ones produced by Dr. Peter E. Childs at the University of Limerick.

'TY Science' Modules

Dr. Peter E. Childs at the University of Limerick, in conjunction with trainee science teachers, has developed a wide range of resources for the Transition Year Programme. These resources are known as 'TY Science' modules. The 'TY Science' modules were first developed in 2002-3 and ten 8-9 week modules have now been developed, piloted, revised and made available to teachers at low cost (€10 per module). Some of the modules have been fully evaluated through pupil and teacher questionnaires and diaries, and the others were revised on the basis of teacher's diaries and questionnaires (Childs *et al.* 2010).

Two more modules, with the themes of 'Smart Materials' and 'The Science of Toys', are being developed, piloted and evaluated this year (2011/12). The students involved have developed the modules as part of their Final Year Projects, providing them with experience of curriculum development and implementation. The modules are designed to meet the TYP guidelines and build on Junior Science, with an emphasis on active learning. The TY Science modules offer science teachers a wide choice of suitable resources to choose from to meet the TYP objectives and provide a stimulating introduction to Leaving Certificate science courses. The project has utilised the innovative ideas and the energy of trainee teachers in collaboration with the expertise and experience of teachers in Irish schools.

Each resource is produced in the same format. There are 8 week-long units – each consisting of one single lesson and one double lesson, with an optional extra single lesson. Each unit relates to the overall theme of the module but, can be taught independently, allowing teacher to pick and choose the material that best suits their pupils. These 8 units make up the module. The modules that have been produced to date are:

- The Science of Sport
- Forensic Science
- Cosmetic Science
- Environmental Science
- Science of Survival
- Food Science
- Science and Medicine
- Issues in Science
- Energy
- Waste

The basis of these modules is a constructivist approach, with an emphasis on practical work, active and problem-based learning. This approach is central to achieving the overall goals of Transition Year Science curricula.
These modules are presented in the form of a photocopiable student's handbook and teacher's guide. One of these modules also comes with accompanying CD-ROM containing PowerPoint presentations. The modules are available for sale as a teaching package and over 600 have been sold to date, with positive feedback from teachers and pupils (Childs *et al.* 2010).

Further information on Transition Year Science and the TY Science resources that are available for the subject are discussed more fully in the NCE-MSTL's 'Research and Resource Guides' (Hayes 2009; 2010; 2011), which are freely available at www.nce-mstl.ie.

We would be very interested to hear about any interesting lessons, modules or topics that you have developed for your Transition Year Science class. Please contact Sarah Hayes (sarah.hayes@ul.ie) or Peter Childs (peter.childs@ul.ie) with any information or queries.

References:

Association of Secondary Teachers Ireland (1992) *Transition Year Option: A Teacher's Handbook.*, Dublin: ASTI.

Childs, P. E., Hayes, S., Lynch, J. and Sheehan, M. (2010) 'Developing scientific literacy: TY science and science scrapbooks' in Eilks, I. and Ralle, B., eds., *Contemporary Science Education – Implications from Science Education Research about Orientations, Strategies and Assessment'*, Aachen: Shaker.

Department of Education (1993) 'Transition Year Programmes Guidelines 1994 - '95'.

Department of Education and Science (2002) *Report of the Task Force Report on the Physical Sciences*, Dublin: Statement in conjunction with the National Council for Curriculum and Assessment Department of Science and Education.

Smith, G. and Matthews, P. (2000) 'Science, technology and society in transition year: A pilot study', *Irish Educational Studies,* 19(1), 107-119.

Transition Year Second Level Support Service (2006) 'Parents', [online], available: http://ty.slss.ie/parents_his.html [accessed 23/01/2008].

Dr Sarah Hayes completed her PhD in chemical education in 2011 and is now doing a postdoc with Dr Peter Childs in the Chemistry Education Research Group at UL. Her PhD was on the place of science in the Transition year.

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Diary 2012

2012

Atlantic STEM Conference 2012
29 March
Tullamore, Co. Offaly
www.eventelephant.com/atlanticconference2012

N-W IOSTE Conference
Science and technology education research and its impact on practice
April 18-20
University of Limerick
Sarah.hayes@ul.ie
http://ioste-nwe.wikispaces.com/

Irish Variety in Chemistry Education
May 10
Dublin Institute of Technology, Dublin
Claire.mcdonnell@dit.ie

50th ISTA Conference
April 20-22
Trinity College, Dublin
www.ista.ie

Dortmund Symposium
Issues of Heterogeneity and Cultural Diversity in Science Education and Science Education Research
17-19 May
University of Dortmund
http://www.chemiedidaktik.uni-bremen.de/symp2012/

SMEC 2012
Teaching at the heart of learning
7-8 June
Dublin City University
Sarah.brady@dcu.ie
www4.dcu.ie/smec/2012/index.shtml

Euroscience Open Forum
11-15 July
Convention Centre, Dublin
www.dublinscience2012.ie/

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

22nd BCCE 2012
July 29 – August 2
Pennsylvania State University
www.2012bcce.com/

Variety in Chemistry Education
August 30-31
Edinburgh

31st ChemEd-Ireland
Sat. October 20
Dublin City University, Dublin
Odilla.finlayson@dcu.ie

Technical Tips for Teachers (T^3)

Anita Mahon
Lab Technician, Villiers School, North Circular Road, Limerick nindi17@eircom.net

Cleaning and storing glassware

If routine washing does not clear stains, soak overnight in a solution of 1 dishwasher tab /litre water. Stubborn stains can be removed by soaking the glassware in conc. sulphuric acid. This must be done with care: use goggles, gloves and put a sign on the sink to warn other staff. After 24 hours return the acid to the container and rinse the glassware well.

Never wipe the inside of a beaker with your hand - just rinse them with water and wipe the outside. Serious accidents have been caused by trying to clean the inside of beakers. Leave them to drain on a drying rack.

Potassium permanganate stains can be removed by soaking the glassware in 20% iron(II) sulphate solution ($FeSO_4$,aq), acidified with dilute sulphuric acid. Alternatively an acidified 10% solution of sodium sulphite ($NaSO_3$, aq) or sodium hydrogensulphite ($NaHSO_3$, aq) can be used. These are reducing agents and react with and destroy the potassium permanganate. The solutions must be acidic or brown precipitates will be formed.

If possible get a dishwasher for the lab: **I would recommend the following one from Curry's Item Code: 005013** KENWOOD KDWTTB10 Compact Dishwasher. Rinse glassware before putting it in the dishwasher.

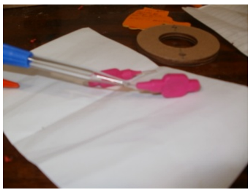
Burettes can be cleaned by soaking in acidified hydrogen peroxide solution or sodium hydroxide solution in Industrial Alcohol.

(How to make sodium hydroxide solution in Industrial Alcohol:

- Dissolve 120 g of sodium hydroxide in 120 cm^3 water. Allow to cool.
- Dilute to one litre with 95% ethyl alcohol and mix well.)

Never put NaOH solution in a burette, as it will damage the stopcock.

If the tip of a burette gets blocked it can be cleared using a mini toothbrush (Boots), used for cleaning between the teeth.



To clean out test-tubes, first remove all solid material using a long forceps. (Forceps dissecting s/s 290mm rounded end, Catalogue Number DSN390010 SciChem)

Keep a selection of plastic boxes for cleaning and soaking.

Do not stack glassware in the sink: it will get broken and the combination of chemicals may cause poisonous fumes.

Storing glassware:

When storing glassware always have a safety rail on the outside of the shelf, to stop things rolling off.

Don't store glassware under benches as students may kick them there; also the students will be removing them from an area that is badly lit.

Make sure that all glassware is visible in an area with good lighting. Discard all cracked glassware.

Keep a designated bin for broken glassware and dispose of it safely into a skip.

The most frequent accidents in laboratories, to students and staff, are caused by glassware.

Above are some storage solutions that are inexpensive.

Always keep things visible, clean and clearly labelled.

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SMEC 2012

"Teaching at the heart of learning"

In 2012 CASTeL will also host its biennial Science & Mathematics Education Conference (SMEC), which will be hosted this year in conjunction with the ESTABLISH mid-project Conference at Dublin City University on the 7th-9th June 2012. This year the focus of the conference will be on "Teaching at the heart of learning" (http://www4.dcu.ie/smec/2012/). We invite your participating at this international conference and the call for abstracts is now open with themes of: Classroom Practice, Evaluation & Assessment, Teacher Education and Reflective Teachers. We are delighted to announce our plenary speakers for this event are renowned experts in science and mathematics education, including Prof. William McComas, Prof. Janet Ainley, Prof. Paul Black and Prof. Ton Ellermeijer. A particular focus of this combined 2012 conference will be the opportunity for up to 20 science teachers from across the 11 countries of **ESTABLISH** consortium to come together to share their experiences and examples of Inquiry in their classrooms. If you would like to become involved in this aspect of the conference, and share your experiences on inquiry in the classroom, we would be delighted to hear from you. Up to **20 Irish science teachers will be awarded sponsored registration** for this event and the successful recipients will be selected following conference registration, so early contact is recommended.

Opportunities for Teacher Education Programmes

2012 will see a significant increase in the number of teacher education programmes facilitated by CASTeL. From involvement in the FP7-funded projects ESTABLISH (www.establish-fp7.eu) and SAILS (www.sails-project.eu), a number of **in-service teacher education programmes** will take place between March and October 2012 focussed on supporting science teachers to adopt and implement inquiry-based science education into their teaching. These short programmes, typically ~10 hours in duration, are well suited for supporting teachers towards the changes suggested by the Junior Cycle workshops will be offered as evening courses and at weekends and, in a number of school-based locations in the Leinster region. A summer workshop on inquiry will also be held at DCU from the 5th to the 6th June 2012. Through their participation in these workshops, teachers will be given the opportunity to experience Inquiry activities, and supported in implementing and developing their own inquiry activities in the classroom, at both junior and senior levels. As an outcome of these programmes teachers will benefit from sharing and collaborating with other teacher and gain confidence in their own ability to use such methodologies for the teaching of science.
Participating teachers will receive the resources and laboratory materials necessary to try out such activities in their own classrooms. Thanks to the generosity of the AMGEN foundation (www.scienceteachertraining.com) several of the teacher programmes offered in the coming months will be focused on the area of Life Sciences and be particularly suited to teachers of Biology and Chemistry.

If you would like further details on these or any of CASTeL's activities or to register for teacher education programmes, please contact us at castel@dcu.ie or 01-7006343

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31st ChemEd-Ireland

Saturday October 20th 2012

This year's ChemEd-Ireland will be held in DCU on Saturday October 20th. The conference will be organised by Dr. Odilla Finlayson and her colleagues. No details are available yet but we hope to have something for the next issue.
Odilla.finlayson@dcu.ie

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22 ICCE/11 ECRICE

15-20 July Rome

There is still time to register and book to attend this important joint conference on chemical education, being held in the eternal city. Combine some sightseeing with chemical education.
For full details check out the website:
http://www.iccecrice2012.org/

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