Contents

Disclaimer

The views expressed in *Chemistry in Action!* are those of the authors and the Editor is not responsible for any views expressed. *Chemistry in Action!* does not represent the official views of any institution, organisation or body. Any unsigned articles or items are the responsibility of the Editor and if reprinted the Editor should be credited. If any errors of fact are published, or anyone's views are misrepresented, then the Editor will be glad to publish either a correction or a reply.

The Editor is not responsible for any actions taken as a result of material published in *Chemistry in Action!*. Any experiments or demonstrations are done at your own risk and you should take all necessary safety precautions, including wearing eye protection. Teachers may copy materials from *Chemistry in Action!* freely, without prior permission, for use in their schools. Articles and other material in *Chemistry in Action!,* except those originating in other publications, may be used freely in other educational publications without prior permission. Please acknowledge the source and author and send a copy of the publication to the Editor. Prior permission is needed if material is being used in commercial publications.

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

For subscription details etc. see inside back cover.
Cover design: Tony Hartnett, Shoreline Graphics, Ballyvaughan, Co. Clare
Cover photo: The changing UL campus over 30 years. (Photos: University of Limerick)

Editorial

30 not out!

This issue marks the 30th. birthday of *Chemistry in Action!*, launched in May 1980 at the Institute of Chemistry of Ireland's Congress in Sligo. It had its origins in Uganda in the early 70s, when I taught chemistry at Makerere University, Kampala from 1970-1976. A new A level syllabus was introduced and we decided to run a refresher course for chemistry teachers in the Chemistry Department called *'A Modern Approach to Chemistry'*. This led to me starting a low-cost newsletter for chemistry teachers with the same title. It was supported financially by donations from local industry. When I left Uganda in 1976, on my way to Ireland as it turned out, I left the newsletter in the hands of Dr. Olwa Odjek, one of my Ugandan colleagues.

I came to Ireland in July 1978 with my wife and family to take up a job teaching chemistry at Thomond College of Education, Limerick. In 1979 Peter Start of UCD brought the 5th. ICCE to Dublin and I had a poster on producing a chemistry teacher's newsletter. An Irish chemistry teacher stopped to talk and said 'Why don't you start something similar in Ireland?' So I did, and having raised some support from chemical companies, the first issue was launched in May 1980 and sent out to all Irish second-level schools. I quickly found that it wasn't getting into the hands of teachers and so I switched to a policy of sending it to a named teacher, building up an individual mailing list.

The magazine now goes to ~650 Irish teachers and 1,000 copies are sent to UK schools via the Royal Society of Chemistry. It is sent free of charge to the school address of any Irish chemistry teacher who requests it. This is possible because the costs of publication and distribution have been covered by annual donations from a number of Irish chemical companies and other institutions. Their logos feature on the outside back cover and without them publication would not have been possible for the last 30 years. Sadly with the effects of the economic recession some sponsors have withdrawn and this may put this funding model in jeopardy.

When I started *Chemistry in Action!* in 1980 I was young and enthusiastic and had spare energy. I didn't think I, or it, would still be going strong 90 issues later. Each issue now averages 54 pages, most of it content as it doesn't contain adverts, and so over 30 years I must have produced over 4,000 pages.

I would like to thank Marie Walsh, now a lecturer in LIT, who has helped me with the magazine since 1989. I would also like to thank the porters and post-room staff at UL who have dealt with three major mailings each year. The printing is done in UL, apart from the covers (done by McKerns Printing), and over the years Eamonn Sheahan and Eamonn O'Connor have done a great job. For the last few years the cover design has been done by Tony Hartnett of Shoreline Graphics. The sponsors have been very important since the beginning and since I started many of the people who first supported me have retired - Pat Lynch at AAL, John Condon at Merck Sharpe and Dohme, Sean Ward at Schering Plough Innishannon, amongst others. I would also like to thank the many people who have written articles over the years, especially the speakers at the ChemEd-Ireland conferences, who have willingly written up their talks for publication. I would also like to thank the many chemistry teachers over the years who have thanked me for *Chemistry in Action!* and have asked me questions, some of which I have remembered to answer.

This Spring issue, as is usual, contains the Proceedings of the last ChemEd-Ireland conference, held in UL last October, plus some retrospective articles to mark the 30th. birthday. I hope you will find the articles interesting and informative. The next milestone will be issue #100 and I hope I will still be around to see it.

I hope that the magazine has been a help over the years to inform, encourage and equip chemistry teachers to do their job better. If the magazine has a mission statement it would be: **"Improving the teaching and learning of chemistry"** and I hope it has gone some way towards achieving that aim.

Peter E. Childs
Hon. Editor

Education News and Views

Who teaches maths?

An important report on out of field maths teaching (teaching by non-specialists) was launched by Dr. Anne Looney from the NCCA on 16/2/10 at the University of Limerick. It was written by Dr. Ailish Hanningan and Dr. Máire Ní Ríordáin from the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL).

Dr. Máire Ní Ríordáin and Dr. Ailish Hanningan at the launch

Dr. Máire Ní Ríordáin, co-author of the report said; "*The study found that 48% of teachers in the survey who are teaching mathematics in our post-primary schools have no qualification in mathematics teaching.*" These teachers are mainly qualified science and business studies teachers. Out-of-field teachers of mathematics for the most part are deployed in Ordinary level (non-exam years), Foundation level, Leaving Certificate Applied, and resource teaching in mathematics."

The study also found that qualified mathematics teachers are mainly assigned by principals to Higher and Ordinary level mathematics, particularly the exam years and Senior Cycle. "*This highlights a significant divide in post-primary schools between students who are taught by qualified mathematics teachers and those who are taught by out-of-field teachers of mathematics, with younger and weaker students most often taught by out-of-field teachers*" as highlighted by co-author Dr. Ailish Hannigan.

It is important to establish effective mathematics teaching for all year groups in Junior and Senior cycles as this is a significant contributory factor in student success in mathematics at all levels. As Dr. Ní Ríordáin said "*This is necessary to counteract the negative impact of these out-of-field-teachers of mathematics in the early years of Junior Cycle where students' attitudes and abilities need to be nurtured.*"

The phenomenon of out-of-field teachers of mathematics who are otherwise qualified post-primary teachers is a systemic problem that is attributable to the operation of an 'open teachers' register' since before the foundation of the State. This problem is not unique to Ireland but with approximately half of the mathematics teaching force in this category it does represent an immediate challenge of sizeable proportions. Dr. Ní Ríordáin emphasised that "*Younger teachers in the study (under 35) are less likely to be qualified than older teachers so the situation will not improve over time without intervention by appropriate agencies.*"

The teachers and principals surveyed recognised the importance of qualifications to teach mathematics. Dr. Hannigan stressed that *"There is a real need for continuous professional development courses for teachers teaching mathematics. 76% of the unqualified teachers said they would avail of a qualification if one was provided, while 88% of principals who responded would encourage teachers to gain appropriate qualifications*." This is a positive finding and leads to a recommendation by the authors, supported by the National Centre, that postgraduate qualifications in mathematics teaching be introduced for these out-of-field teachers.

Dr Anne Looney, CEO, National Council for Curriculum and Assessment (NCCA) reiterated this point; *"Given that teacher recruitment is at a standstill, the first response to the finding has to be to focus on the teachers we have in the system and on supporting their work – the work of both of the specialist and the non-specialist teacher. This is underway with a comprehensive programme of professional development in place for the new maths courses being introduced, supported by the National Centre for Excellence in Mathematics and Science Teaching and*

Learning at UL, and I know planning is underway within the Department of Education and Science and funding secured for more support for the current teaching force in both mathematics and mathematics pedagogy."

The report can be downloaded from the NCE-MSTL website at www.nce-mstl.ie (www.nce-mstl.ie/files/Out-of-field%20teaching%20in%20post-primary%20Maths%20Education.pdf.)

*****

Dropping science subjects - not a smart move

A report in the *Irish Independent* (24/2/10) based on a survey of 210 of the 730 second-level schools revealed some disturbing trends. 31 (1 in 7) of schools said they were dropping or considering dropping LC Chemistry and 42 (1 in 5) said they were dropping or considering dropping LC Physics. A few schools had dropped the Transition Year or were considering dropping it. This supports earlier anecdotal evidence and if applied to the whole country would mean 108 schools dropping LC Chemistry and 146 schools dropping LC Physics. This amounts to a loss of between 20-25% of the total number of schools offering these subjects and would result in a major loss of numbers studying the subjects. This would have a major knock-on effect at third level for a wide range of courses and would seriously affect the career choices of many students. The Editorial in the paper headed 'Science teaching failing pupils' said this: *"It is impossible to escape the conclusion that the education of our young people is being dangerously subverted. Whether this is by accident or design, by indifference or purely by economic necessity is immaterial. .What is to happen to the gifted child who might have been set on a wonderful voyage of discovery that might have led to a career in the sciences and an important contribution to the life of the country?"* These cut-backs due to the loss of teachers by retirement, who cannot now be replaced, could have been predicted and shows that if you want a smart economy you have think smarter in advance and think through the implications of cutbacks. The loss of many senior and middle management in schools is also set to have a major impact on the running of schools, coupled with more militant action by teacher unions against the cuts. At the end of the day who suffers? Students, their families and in the long-term the country.

*****

Cutting off our nose to spite our face

Eanna Ni Lamhna

Who would have thought that the cutbacks that have been introduced by the Government would be so far reaching that they cut off forever any chance our country has of recovering economically. Yet that is exactly the effect current cutbacks to post primary schools will have, unless their impact is quickly realised and reversed. These cut backs mean that a considerable number of schools have now ceased offering Physics or Chemistry as science subjects to their pupils as pupil /teacher ratios worsen.

So we will soon have even fewer Leaving Cert students who have studied either Physics or Chemistry, fewer Science graduates, and fewer doing post graduate research or working as scientists in industry. And all at a time when the new European Commissioner for Research, Innovation and Science is our own Maire Geoghegan Quinn! Ireland is never going to be in a position to compete with Asia for manufacturing jobs. We are hardly a financial or banking centre. No, our great and wonderful value as a nation was always considered to be our extremely well educated work force. A very considerable portion of our school leavers go on to third level. We pride ourselves on attracting jobs to this country that need a highly skilled and educated workforce. This was true once, but not anymore.

Fewer and fewer secondary school pupils are opting for physics or chemistry in fifth year. Schools now find themselves with perhaps only five or six in a class and so cannot any longer, because of cut backs, afford a teacher for that small number. The subject may be taught to a group of fifth and sixth years together in the one group or indeed dropped entirely. Why are fewer pupils choosing these subjects? They see them as too hard to get high points in and so they select what they consider to be easier subjects. To them the Leaving cert is all about getting points rather than an education. And yet to be a scientist you only need two attributes – being able to notice things and being curious enough to ask questions. Children start out with the ability to do both. Our primary school curriculum has been upgraded since 1999 to include science as one of the core subjects on the curriculum. Primary teachers have been given much professional development in this area and the pupils study it with gusto – particularly boys.

It is when they go to post primary school that things change. Science, which comprises Physics, Chemistry and Biology is all just one subject up to Junior Cert and the enthusiasm with which it is taught depends on the qualifications of the teachers. A teacher with a degree in Physics will have the pupils loving it and picking it for Leaving Cert. The teacher who just did physics in first year in college and has a degree in a biological subject, may very well not teach physics with the same passion and so fewer pick it as a Leaving Cert choice. Our science teachers are certainly all qualified to teach, but more professional development, more teacher-training in subject content and knowledge is needed to improve this situation.

The situation is not helped by the fact that these practical science subjects have - quite properly- compulsory laboratory experiments as part of the syllabus and yet no school has a lab technician unless they pay for one out of their own resources. So imagine the chemistry teacher, with 24 pupils per class, who is timetabled for six classes in a row in the same lab with different groups. Who lays out the material for the experimental work? Who clears away after one group and sets out a different experiment for the next group to carry out? The teachers do the best they can in very under resourced circumstances. If we were really serious about producing potential scientists from our second level schools, we would ensure that they had lab technicians as they do in the other European countries. Just writing up the experiment in the book is not the same as doing it properly in the lab.

It is only since the advent of free education at second level in the mid 1960's that education became available for all. Environmental studies in Primary School and Biology as a secondary school subject were only first introduced in 1971. So we have a very stratified population in this country. People born before 1960 did no science at primary level and even if they went to secondary school, they learned very little science – particularly if they were women, as physics and chemistry were not widely taught in girls' schools. The situation improved for those born after 1960 when the sciences were more widely taught. But investment in science education has not kept up and so science is now being seen by today's students as too hard. So where are tomorrow's logical thinkers going to come from? How can we think clearly and develop problem solving skills if we have no training in science. How will we understand how the world works and the long term changes that are happening if we know no science? How can we see the importance of it and demand that resources be put into the teaching of it if we do not value it ourselves?

Craig Barrett, the former chairman of Intel, had harsh words to say about the results of our educational system. "If you look at the people who are interested in mathematics and technology and science and the performance of the country in that area, it's not wonderful." Sectors named as growth prospect in a recent EU study are nanotechnology, biotech, alternative energy, photonics and new materials. These sectors share a basis in science and technology. With our attitude to the supporting of teaching of science at second level we are not even at the races in producing people educated in these areas.

And it wasn't always so. The work done in Maynooth University is part of the Irish contribution to European space probes and to the International Committee on Climate change. Research at Cork University has recently produced a vaccine for prostate cancer. Those of us fired up with enthusiasm for science are as good as the best anywhere. We need to continue to have centres of scientific excellence in our third level colleges. But we won't have them with wishful thinking. We need investment and more importantly, students, who can see that a career in science is financially as well as intellectually worthwhile – something that is very much not the case at the moment. So forcing post primary schools into a situation where they can no longer offer Physics and Chemistry as Leaving Cert options is really cutting off our nose to spite our face, - sheer folly!

□

Eanna Ni Lamhna is a well-known writer and broadcaster on environmental topics and immediate past-President of An Taisce. This article first appeared in the Irish Daily Mail.

Celebrating 30 years of *Chemistry in Action!*

A number of people were asked to write articles looking back over 30 years, 1980-2010, since *Chemistry in Action!* was started. A lot has changed since 1980 and Ireland is unrecognisable in many ways. I would like to thank all these contributors for their willingness to write their retrospective overviews. Their varied contributions are given below, starting with some messages of support.

Chemistry in Action! Celebrates 30 Years

I am delighted to congratulate *Chemistry in Action!* on reaching its 30th year and 90th edition since it was launched at the Institute of Chemistry of Ireland's Annual Congress in 1980. This milestone was achieved through dedicated involvement of many and with the leadership and guidance of *Chemistry In Action*'s Editor, Dr. Peter Childs, who has been the driving force behind bringing this wonderful publication to such a wide audience.

Chemistry in Action! is a vital resource for Chemistry teachers and its extensive circulation around Ireland and the United Kingdom is testament to its quality. We are very proud that it is produced on the University of Limerick campus and distributed free of charge to Chemistry teachers around the country. This publication focuses on the critical need to stimulate interest in science as a key enabler of our future development, particularly as we seek to compete and succeed in the Knowledge Economy.

The University of Limerick is the largest provider of teacher education at secondary level in the country. Each year, we graduate the next generation of educators and it is our aim that they go into the schools and teach in a way that promotes understanding while inspiring and exciting students. Publications like this are vital in providing a collaborative forum which shares best practice, evidence-based research, teaching news and industry trends to benefit second- and third-level educators and their students.

As a reader of *Chemistry in Action!*, I look forward continued topical debate and excellent news items and would like to wish the contributors and editors many more years of success.

Keep up the good work,

Professor Don Barry,
President
University of Limerick

Congratulations to *Chemistry in Action!*: 30 years a Growing

A lot has been written and debated about how to advise young people in their choice of subjects for study. We read a lot about the national need for more Science and Engineering graduates. However, before any student can choose for a career in Science or Engineering they must first have an interest in the subject. Self evident perhaps, but often overlooked. In my experience, interest in their subject is the key ingredient for a successful times studying at 3rd level and for a successful career. It's difficult to get an interesting job if you have no interests yourself.

In the past 30 years *Chemistry in Action!* has played a vital role in Ireland in stimulating young people's interests in Chemistry. The infectious enthusiasm of Dr Peter Childs has been central to this effort but of course many other colleagues have been involved in these efforts also. Several generations of Science and Chemistry teachers have got inspiration from *Chemistry in Action!* with its wealth of interesting material. Who knows how many countless young people have been stimulated to take an interest in chemistry and a career based on the subject in the academic or industrial world as a result of this publication? These things are always difficult if not impossible to quantify, but we immediately get an impression of the influence of *Chemistry in Action!* on the scene in Ireland by mentioning it to **any** Science teacher.

If we are to grow as a modern nation, our young people, and those not so young, must embrace scientific knowledge as part of our culture in the same way that music, sport and language are integral parts of who we are. I look forward to many more years of *Chemistry in Action!* making a vital contribution to this mission.

Professor Kieran Hodnett
Dean, Faculty of Science and Engiuneering
University of Limerick

Best wishes from the Institute of Chemistry of Ireland

On behalf of the Institute of Chemistry of Ireland I am pleased to congratulate those associated with *Chemistry in Action!* on the publication of the 90th issue and its 30th birthday. The publication has become an invaluable resource for Chemistry teaching both within Ireland and overseas. The trojan work put in by the founding Editor, Dr. Peter Childs, in compiling 90 issues is a huge personal achievement. However, it is the use made of it and the widespread use as a teaching resource throughout schools in Ireland and beyond that is the ultimate reward for his efforts.

The first publication was launched at the Institute of Chemistry of Ireland's Annual Congress in Sligo in May 1980. It also featured a photograph of the presentation of the Medal to the top Leaving Certificate student in Chemistry. This Medal presentation continues to be an annual Institute event. In 2008 the medal was awarded to five students who scored equal top marks.

The Institute of Chemistry has an active interest in the quality of Chemistry programmes in the Universities and Institutes of Technology. The graduates of these recognised courses qualify for entry to Graduate Membership of the Institute (GradICI). These courses are regularly reviewed.

Despite the gloom associated with the current recession the performance of the Chemical, Pharmaceutical and related industries continue to prosper. The shedding of jobs which happened in many areas of the economy did not take place in this sector. It would be very unfortunate if one of the consequences of the current cutbacks would be that schools would be forced to drop Chemistry.

In approaching 2011, which is designated by UNESCO as International Year of Chemistry, we can be proud of the achievement of Irish Chemistry. The quality of teaching and the quality of our graduates are world class. Despite the number of subjects and the broad curriculum in school, where Chemistry is one subject of at least five other subjects, we perform well on an international level. This is a credit to the teachers at second-level who teach chemistry, often without adequate resources.

Anyone interested in the work of the Institute should visit our website at http://www.instituteofchemistry.org.

Professor Paraic James,
President, Institute of Chemistry of Ireland 2009-2011

Congratulations from the ISTA

My goodness me! Thirty years in publication leads me to recall first receiving an edition from Peter so many years ago. Following in the footsteps of the ISTA Journal *Science, Chemistry in Action!* became the second educational journal for Chemistry teachers in Ireland. In *Chemistry in Action!* I received my first encouragement to publish with a positive reference from the editor to a piece I wrote on Leaving Certificate Chemistry Assessment.

Like so many others I still look forward to receiving each issue with wonder what is happening in Chemistry both nationally and internationally. *Chemistry in Action!* continues to give teachers a voice in Chemistry matters and an insight into contemporary reports, issues and research. Above all it continues to acknowledge the professionalism of teaching and makes a wonderful contribution to the continuing professional development of teachers in Ireland.

Today in education there is an increasing emphasis on lifelong learning, the necessity to up the bar to higher order learning skills of analysis and synthesis, problem solving and careers in science and mathematics. What a resource *Chemistry in Action!* provides for us in all of these areas of development.

Well done Peter and to all in *Chemistry in Action!* On behalf of the Irish Science Teachers Association, I congratulate and thank you, your team and your sponsors on past issues and on this issue that marks 30 years of production. Long may *Chemistry in Action!* continue serving and supporting Chemistry Teachers in Ireland.

John Lucey,
Outgoing Chairman, ISTA.

Thirty Years of Science Communication and Popularisation in Ireland

William Reville
Dept. of Biochemistry, University College Cork, Cork w.reville@ucc.ie

Until relatively recent times science communication to the general public by scientists was somewhat frowned on in academic circles. If you wrote popular articles about your work or about science in general you risked being categorised by your colleagues as a 'mere populariser'. Happily that is all behind us today and scientists are both encouraged and expected to promote science on the public stage.

Most of the pressure nowadays on scientists to communicate with the public comes from Government through the science funding agencies. The Government is interested in promoting science for economic reasons. It has lately been converted to the realisation that the world runs on science-based technology and that Ireland's future economic prospects are entirely dependent on this technology. The Government's plan is to develop a 'smart economy' in Ireland, ie. an economy running on science-based innovation. Hence the generous funding of science and technology over the last 15 years and the emphasis on science promotion.

Science Promotion in the Print Media in Ireland

Roy Johnston

Roy Johnston wrote a science column in The Irish Times from 1970 to 1976 and I remember reading it when I was a student at UCD. Roy was Industrial Liaison Officer at TCD at the time and his column analysed science in a social and economic context.

The Chernobyl nuclear accident occurred on 26th April 1986 and 7 days later the radioactive fallout reached Ireland, on 3rd May. The Nuclear Energy Board (NEB) was responsible for monitoring radiation nationally, but it was not adequately equipped to deal with such an emergency. The Board asked the universities to help out by each monitoring the fallout in their own areas. I was asked to do this in Cork city and I set about monitoring radioactivity in air, water and milk with the assistance of a colleague, Professor Jim Heffron. The NEB asked me to publicise our findings through the media. And, so, for several weeks I contributed bulletins to *The Cork Examiner*.

This sensitised me to science in the newspapers and I noted that no Irish daily newspaper carried a science column and only rarely carried any science news. I proposed to the Editor of *The Cork Examiner*, Fergus O' Callaghan, that I would write a science column. He agreed and I began a fortnightly column in February 1987 and continued until Autumn 1994.

At that stage I wanted to write a weekly column to command more presence in the newspaper, but *The Cork Examiner* wanted to stay fortnightly. So, I approached *The Irish Times* and proposed writing a weekly column for them. The Editor, Conor Brady, agreed right away and I began writing my Science Today column for *The Irish Times* in January 1995. I have been happily writing this weekly column ever since.

My Science Today column was popular right from the start. This encouraged *The Irish Times* to broaden their coverage of science. In December 1997 they expanded coverage to devote an entire weekly page to science under the editorship of Dick Ahlstrom. My column now sits on this page.

Dick Ahlstrom, Science Editor, The Irish Times.

Dick also covers science stories elsewhere in the paper throughout the week. To this day, *The Irish Times* remains the only national daily newspaper in Ireland to provide regular science coverage and to devote professional in-house expertise to science.

The magazine *Technology Ireland* is published bimonthly by Enterprise Ireland and celebrates its fortieth birthday this year. It aims to encourage innovation and is targeted at technology managers, researchers, entrepreneurs and a general scientific readership.

Several interesting books that present science to the general public have been published in Ireland in recent years. In 1999 I published a collection of my *Irish Times* science columns (*Science Today: Understanding the Natural World* – Irish Times Books). Mary Mulvihill published *Ingenious Ireland: A County by County exploration of the Mysteries and Marvels of the Ingenious Irish* (Simon and Schuster, 2003) – a tour of the country's natural wonders, clever inventions and historic sites. In 2006, Dick Ahlstrom published an attractive collection of his Irish Times pieces on various aspects of the researches of Irish scientists – Flashes of Brilliance: The Cutting Edge of Irish Science (Royal Irish Academy 2006).

The lives and contributions of famous Irish scientists are described in outline in three books edited by Charles Mollan, William Davis and Brendan Finucane - *Some People and Places in Irish Science and Technology* (Royal Irish Academy 1985), *More People and Places in Irish Science and Technology* (Royal Irish Academy 1990), and *Irish Innovators in Science and Technology* (Royal Irish Academy, 2002). And the lives and works of famous Irish scientists in the physical sciences have been described by Charles Mollan in two magnificent volumes – *It's Part of What We Are*, Vol.1 and Vol.2 (Royal Dublin Society 2007). I prepared a wall poster entitled Super Irish Scientists, published by *The Irish Times* in association with Barry's Tea, distributed with the newspaper on 22nd January 2008, and sent to all Irish secondary schools. And, finally, Norman McMillan edited *Prometheus's Fire – A History of Scientific and Technological Education in Ireland* (2000) ISBN 0 952597403.

Super Irish Scientists poster

Communication of Science on Radio and TV

Relatively little home-produced science programming appeared on Irish radio or TV until the 1970s/1980s. Irish listeners and viewers mainly had to content themselves with UK programming such as *Bellamy on Botany*, David Attenborough's nature programmes, Patrick Moore's *Sky at Night*, and so on. A rare exception on TV was John Feighan's award-winning programme called *Exploring the Landscape* in 1988 on RTE1.

Peter Mooney has produced numerous science programmes on RTE Radio 1 since the early 1990s, including *Future* Tense (2001), The Human Genome Project (2004) and *Debating Darwin* (2008-2009). His namesake Derek Mooney has produced and presented the popular nature programme '*Mooney Goes Wild'* on RTE Radio 1 since the mid 1990s, featuring well known science broadcaster/presenters Eanna Ní Lamhna and Richard Collins.

RTE television has regularly featured science programmes over the past decade. The *Scope TV* programme featuring science, engineering and technology was screened annually from 2003 to 2007. A series of 4 programmes in the series *Science Friction* was screened in 2008. Both *Scope* and *Science Friction* were sponsored by Discover Science and Engineering (see next section).

Government Promotion of Science and Engineering

Discover Science and Engineering (www.science.ie)

The Government-appointed Task Force on the Physical Sciences reported in 2002. One of its key recommendations was the establishment of an integrated national science awareness programme. As a result, an organisation called Discover Science and Engineering (DSE) was set up by the Department of Enterprise, Trade and Employment within Forfás in 2003. The objectives of DSE were to raise awareness of the physical sciences, to improve student uptake of these subjects, to promote positive attitudes towards science, engineering and technology and to promote public understanding of science.

The main programmes operated by DSE are My Science Career (resources for finding out about science careers), Discover Primary Science (training and resources to help teachers in primary level science), Science Week Ireland (general organisation of the biggest annual promotion of science to the general public – 2nd week in November), Greenwave (mass science experiment in primary level schools – examination of how Spring arrives), and Discover Sensors (supports use of sensor technology by Junior Science students).

STEPS to Engineering (www.steps.ie)

STEPS to Engineering was established in 2000 to encourage first and second level students to explore the world of science and engineering and is now a core element of the national Discover Science and Engineering programme. STEPS is managed by Engineers Ireland. In 2008, over 85,000 students all over Ireland participated in STEPS organised events. STEPS aims to encourage students to consider engineering as a career choice.

Science Centres and Museums

Another recommendation of the Task Force on the Physical Sciences in 2002 was the establishment of a National Interactive Science Centre. Nothing much has happened on this front unfortunately. There was talk of the Government establishing such a centre in Dublin with outlying branches in Cork, Galway and Limerick, but this plan remains to be realised. Nevertheless a number of smaller science centres have been established around the country.

Science Gallery TCD (www.sciencegallery.tcd.ie)

The Science Gallery at Pearse Street, Dublin, occupies the first and second floors of The Naughton Institute. The Science Gallery invites everybody to engage with science and technology and its impacts on our everyday lives. Shows, debates, discussion, music, drama and comedy all stimulate scientific conversation across the whole community.

Museum of Natural History, Dublin (www.museum.ie/en/intro/natural-history.aspx)

The Natural History Museum, located at the Merrion Street side of Leinster House, houses the state collections in the disciplines of zoology and geology. The museum holds approximately 2 million specimens. About half of all the specimens are in the insect collection. There is much material from outside Ireland, a legacy of the 19th century British Empire, when Irish citizens and scientists in the British Navy sailed on various expeditions to faraway places.

Natural History Museum Dublin

Ireland's Historic Science Centre, Birr, Co. Offaly (www.birrcastle.com)

Birr is most famously associated with the Leviathan, the great telescope, then the largest in the world, designed and built at Birr during the 1840s by the Third Earl of Rosse. Lord Rosse used this 72-inch reflecting telescope to study immensely distant stellar objects and to provide evidence that many of these mysterious nebulae were actually galaxies located far outside our own.

The giant telescope has been carefully restored and is the principal item of attraction at Birr Castle Demesne. The Demesne also hosts a Historic Science Centre, housing astronomical instruments, cameras, photographs and photographic equipment used by the Third and Fourth Earls of Rosse and Mary Countess of Rosse in the middle and late 1800s Electrical and engineering equipment originally belonging to Charles Parsons, inventor of the steam turbine, and used in his experiments, is also on display.

Science and Discovery Room at National Wax Museum (www.waxmuseumplus.ie)

This new science museum was opened in October 2009. It is located in Foster Place, just off College Green, Dublin. The museum showcases world-class Irish Scientists whose work would not be familiar to the Irish public, e.g. John Holland (inventor of the submarine), Ernest Walton (who split the atom), Charles Parsons (inventor of the steam turbine) and John Tyndall (who first explained the greenhouse effect).

The Crawford Observatory at UCC (http://astro.ucc.ie/obs/index.html)

The Crawford Observatory at UCC

In 1878 Howard Grubb, of Thomas and Howard Grubb, the famous Dublin makers of telescopes, built a complete observatory at Queen's College Cork (now University College Cork), including the telescope dome, three major astronomical instruments and ancillary equipment. The observatory is unique in Ireland for the remarkable state of preservation of the instruments and the original condition of the buildings. The building is in the ecclesiastical style of the original UCC buildings, with Gothic architectural features. The instruments and the building were recently restored and are used to host various exhibitions and are on view to visitors by arrangement.

Blackrock Castle Observatory, Cork (www.bco.ie)

This observatory is a Cork City Council / Cork Institute of Technology partnership. The observatory aims to foster interest in science, engineering and technology through the medium of astronomy.

Lifetime Lab, Lee Road, Cork (www.lifetimelab.ie)

This initiative of Cork City Council is situated in the former Waterworks on the Lee Road. This is a unique attraction for visitors of all ages, with a modern interactive exhibition, schools resource centre, conference theatre, themed playground and beautiful restored buildings and equipment telling the story of how water was supplied to Cork City from the site since 1760.

BT Young Scientists and Technology Exhibition

This major event has been running annually since 1965. The Young Scientist competition is open to all second level students in Ireland and over 1500 science projects are now routinely entered annually. All entries are screened to select about 500 projects that go through to the competition held at the RDS, Dublin. The exhibition attracts over 37,000 people, making it one of the largest events of its kind in the world.

Richard O'Shea, 18 year old sixth year student from Scoil Mhuire Gan Smal, Blarney, Co Cork, winner of the BT Young Scientist & Technology Exhibition 2010 with his project entitled, "A biomass fired cooking stove for developing countries"

The first ever winner of the Young Scientist competition, John Monaghan, recently retired at Chief Executive Officer of Avigen, a US biotech company.

Training Postgraduate Students in Science Communication

Convinced of the importance of communicating with the public, several third level institutions have instituted programmes to train and encourage postgraduate students in the art of science communication. For example, at UCC we offer a module an Outreach and Communications to science, engineering and technology postgraduate students. The module incorporates the *Science for All* competition which has been running at UCC for the past 6 years. *Science for All* is a competition in which postgraduate students present the results of their PhD researches in a manner easily understandable to the general public. The students make 10 minute presentations, illustrated with PowerPoint slides, to a general audience. The presentations are judged by a panel of lay judges and the UCC winner goes forward to an All-Ireland version of *Science for All*, called *Science Speak*, held at the RDS and chaired by Pat Kenny of RTE. All seven Irish universities participate in *Science Speak*. UCC has won the *Science Speak* competition for the past two years running – Suzanne McEndoo in 2008 and Julie O'Donovan in 2009.

Julie O'Donovan, UCC. Winner of *Science Speak* 2009

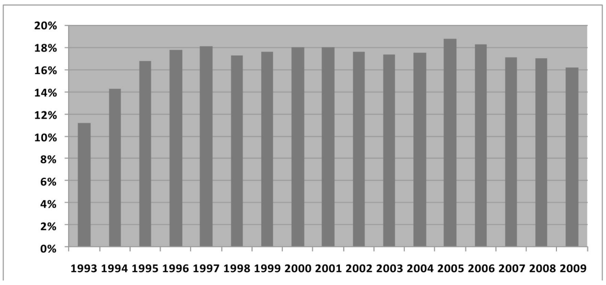
Science in Primary Schools

Probably the most significant development in science education in Ireland for decades was the formal introduction of science into the primary school curriculum in 2003/2004. There are 4 strands in the curriculum: Living Things; Energy and Forces; Materials; Environmental Awareness/Care. The curriculum supports children in working scientifically and in designing and making things.

Introducing science into children's consciousness at this early stage could have a revolutionary effect. It is to be hoped that this will foster an appreciation of science and a love of the subject in many children and that this will feed into a much better uptake of science subjects at second and third levels.

Poor Uptake of Science and Higher Level Mathematics

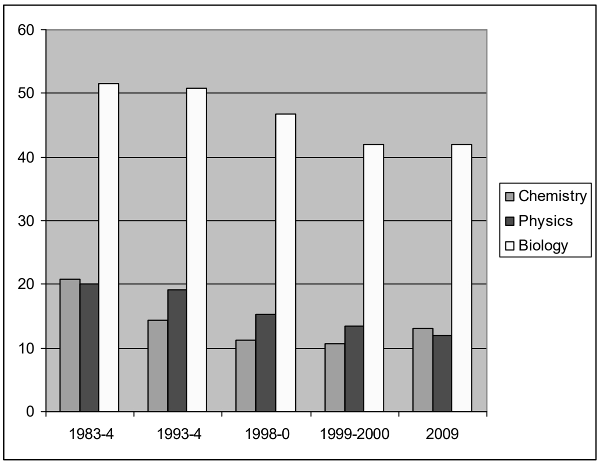
The uptake of physics and chemistry as Leaving Certificate subjects has significantly declined since the 1980s. Also, higher levels maths and applied maths uptake is very disappointing – in 2009 only 16.1% of the Leaving Certificate cohort took higher level maths. Biology is the only science subject that has retained a high level of popularity over the years.



Percentage of Leaving Cert. Cohort taking Higher Level Mathematics

The poor uptake of science and mathematics at second level feeds on into third level. The points requirements for many science and engineering course have dropped to worrying levels and alarming dropout rates of up to 39% have been reported recently for some university science courses.

And all of this despite the huge resources that have been mobilised in recent times to promote science. There remains a strong public perception that jobs in science are neither plentiful nor prestigious, which contrasts sharply with the perception of highly paid prestigious careers in medicine, law and business areas. It seems to me that science will never attract its deserved quota of the brightest students until the public perception of science is radically changed.



Percentage of Leaving Cert. Cohort taking Chemistry, Physics and Biology

William Reville, UCC and The Irish Times

William Reville is Associate Professor of Biochemistry and Public Awareness of Science Officer at University College Cork. He also writes the weekly Science Today column in The Irish Times. He wrote the book Science Today: Understanding the Natural World (Irish Times Books, 1999) and prepared the wall-poster 'Super Irish Scientists' published by the Irish Times, 2008. His research interest is the mechanism of protein turnover in skeletal muscle. He was a Fulbright Scholar at Iowa State University (1973-1976) and was awarded the Fulbright Medal of Honour by The Irish Fulbright Association in 2007..

□

Science Education and Sustainability

Roger Downer
President Emeritus, University of Limerick, Limerick roger.downer@ul.ie

Anniversaries provide for reflection and as *Chemistry in Action!* celebrates thirty years of publication, it is humbling to consider the changes that have taken place within that relatively short time frame, which comprises less than half of my life. Advances in telecommunications ensure that a wealth of knowledge is readily accessible in our homes; as we sit on a train, we can read e-mails from around the world and we can communicate more or less instantly with just about anyone with whom we wish to speak. We have sequenced the human genome and that of a number of other species and we have made considerable progress in our understanding and treatment of many major diseases. Chemistry has played an important role in the myriad of scientific advances that have occurred during the past thirty years and it will be pivotal as we embark upon the next three decades.

In pondering the challenges and opportunities of the next thirty years, the issues that come immediately to mind include energy, environment, food, health and the omnipresent problem of climate change. These are challenges that must be addressed by the concerted efforts of scientists from many disciplines with chemists forming an integral part of the effort. At the outset, it will be important to identify and understand the scale and nature of the problem. Sadly, much of the debate on these topics has been seized by opportunistic politicians and aspirant laureates who preach the rhetoric of change without careful analysis of the underlying causes or any real understanding of the scientific basis of the issues. They perform a useful service in using their celebrity status to raise awareness of the problems, but do a grave disservice by focussing on single issues and advocating simplistic solutions that do not address the totality of the situation.

A central concept in many of the issues that we will face in the coming years is sustainability. This is a word that has entered the lexicon of politicians and well-meaning activists in recent years and there is unanimity in its proclamation as a desirable goal. Unfortunately, few commentators bother to define or even think about the nature of the sustainability that they are promoting. They espouse the catchphrase, "sustainable development", which is often described as an integration of economics and environment. However, as Professor David Lavigne of the International Fund for Animal Welfare has pointed out, economic sustainability and environmental sustainability are different entities. Professor Lavigne illustrates this dichotomy by reference to the Mediterranean Monk Seal, which is now almost certainly extinct but around which there is a booming tourism economy in Sardinia with souvenirs, T-shirts and boat trips to the caves where the seals once thrived. Environmental sustainability has been lost but economic sustainability flourishes

The nature and magnitude of our global environmental problem can be appreciated if we think of the Earth as a spaceship with a finite supply of resources to sustain the diversity of animal and plant species on board. A delicate balance must be maintained between these life forms in order that they continue to co-exist. Unfortunately, one of the species, *Homo sapiens,* is undergoing a massive population explosion which is upsetting that delicate balance and threatening the survival of life on Planet Earth. At the time of the launch of *Chemistry in Action!* in 1980, the population of the earth was 4.4 billion. Today it is 6.8 billion and each day the human population increases by about a quarter of a million individuals; in other words our spaceship is taking on extra passengers in numbers equivalent to the population of Ireland every 20 days. Each of these individuals is a consumer of resources, a producer of wastes, and contributes to the loss of productive soils, destruction of forests, over-exploitation of fisheries, depletion of fossil fuels and climate change. As a result, the changes currently taking place on our planet are the most devastating since the end of the Mesozoic period 65 million years ago. Our spaceship is taking on additional passengers but no more supplies. Clearly, this situation is not sustainable.

A further illustration of the dilemma derives from consideration of the concept of ecological footprint. The ecological footprint of a nation or population is defined as the area of land or water required on a continual basis to produce the resources consumed and to assimilate the wastes produced. In the United States, the ecological footprint is about 12 hectares per individual but the available biocapacity is only about 6.7 hectares per individual. In Ireland and the United Kingdom the ratio is about 5.3:1.7 and even in an impoverished country like Bangladesh, the ecological footprint is 0.5 hectares per individual whereas the available capacity is only 0.3hectares per individual. The world is living in deficit and unless something changes, we are heading for a major environmental catastrophe.

Our global economic sustainability is also problematic for a number of reasons including the considerable disparity in wealth distribution. The combined GDP of the 41 poorest countries in the world is less than that of the 7 richest individuals. Over 3 billion people live on less than US$2 per day and there are 100 million children in the world who never enter primary school. It has been estimated that for US$15 billion, it would be possible to provide water, sanitation and basic education for every person in the world. This amount is not made available yet in the USA, the annual spend on cosmetics and perfume is US$20 billion and in Europe we spend US$150 billion on cigarettes and alcohol. Such massive disparities are not morally acceptable and will lead eventually to serious unrest and social disorder.

These elements of a non-sustainable global society have been recognised for a long time. Indeed, in the early part of the 19th century, the English political economist, Thomas Malthus warned of the danger of populations increasing at a faster rate than the food supplies available to them. In 1972, a think-tank called "The Club of Rome" published a report titled *Limits to Growth*, which stated that economic growth could not continue indefinitely because of the limited availability of natural resources and advocated zero population and economic growth.

Perhaps the most publicised attempt to address the dilemma emanated in 1987 from the World Commission on Environment and Development (WCED) chaired by the former Prime Minister of Norway, Mrs Gro Harlem Brundtland. This report recognised the importance of environment, economy and social equity in order to ensure a stable global society and proposed a series of recommendations which have been characterised as "sustainable development".

Among the recommendations included in the WCED report are:

- Increase in gross world industrial activity limited to 5-10X over the next century
- Raise the standard of living of poor nations to that of developed world
- Ensure environmental sustainability and preserve ecological base.

Consideration of the facts presented in the previous paragraphs will demonstrate compellingly that the noble intentions of the report are simply not possible. The planet cannot sustain a 5-10 fold increase in gross industrial activity and the lesser developed nations cannot achieve the standard of living currently enjoyed by wealthier nations because there is not adequate biocapacity to absorb such an enormous increase in the global ecological footprint. For these reasons, the term "sustainable development" as defined by the WCED Report is an oxymoron. Indeed, it is a fraudulent excuse to allow wealthy nations to continue to enjoy their current, comfortable lifestyle, take no serious remedial action and so jeopardise the future of our children and subsequent generations.

Supporters of the WCED concept of sustainable development dismiss the challenges of opponents and claim that there are vast untapped reserves awaiting discovery, that new technologies will resolve the problems, that major wars or plagues will eliminate large percentages of the population. None of these counter arguments are persuasive and most certainly do not justify a "full steam ahead and damn the torpedoes" approach. We must to begin to address our future in an environmentally, economically and socially responsible manner and, although I cannot state what actions need to be taken or even what actions can be taken, I will offer some thoughts based on three basic premises.

Premise 1 states that there are only two major global realms with the power and influence to effect major change and to reverse the deteriorating situation that I have described. These are nation states and multi-national corporations and both realms must assume leadership in effecting the required change.

Premise 2 states that both governments and multi-national corporations are influenced by public opinion. Increasingly governments are ruling more by consensus than by conviction as they focus their primary efforts on the path to re-election. Business also is driven by consumer/client demand, behaviour and corporate image. Noam Chomsky has described public opinion as the second major super-power and if it can be mobilised in support of environmental, economic and social change, government and business will listen and act.

Premise 3 states that efforts to reduce global poverty should be directed to the encouragement and facilitation of economic independence rather than the provision of direct aid. Furthermore, in that there cannot be a massive global expansion of economic activity, the wealthier nations will have to accept the transfer of some such activity to lesser developed nations. We must help these fellow travellers on Spaceship Planet Earth to improve their standard of living and attain economic independence and in order to achieve this goal we must all be willing to make some sacrifices.

The readership of *Chemistry in Action!* is privileged by education, scientific awareness, socio-economic status and, for most at any rate, the goodwill that the Irish enjoy globally. You are able to understand the issues and have the ability to influence decision makers. It would be a splendid legacy to the next thirty years if you could look back and claim to have used your knowledge and talent to bring about change and so helped to create a better, more sustainable planet.

□

Professor Roger Downer was President of the University of Limerick from 1998 to 2006. He was professor of Biology and Chemistry at the University of Waterloo from 1970-96 and from 1989-96, served also as Vice-President, University Relations. In 1996 he moved to Thailand as President and CEO of the Asian Institute of Technology, Bangkok.

Professor Downer was born in Belfast, Northern Ireland and graduated from Queen's University Belfast, with a bachelor of science in 1964 and a master of science in 1967. He earned a PhD at the University of Western Ontario in 1970 and in 1984, he was awarded the degree of Doctor of Science from Queen's University, Belfast. He also holds the honorary degrees of Doctor of Science (University of Waterloo) and Doctor of Laws (Queens University Belfast) and is an elected Fellow of the Royal Society of Canada and Member of the Royal Irish Academy.

Downer's research interests include insect physiology and biochemistry and he served as consultant to a number of multi-national corporations in the development of environmentally friendly strategies for suppression of pest insects.

He is currently Chair of the boards of the Milton and Ethel Harris Research Institute Toronto, Hunt Museum Limerick, IRFU Education and Player Welfare Committee, a member of the boards of Shannon Development and the Limerick Enterprise Development Project and he is a member of the Northern Ireland Higher Education Strategy board and member of review boards for several European Universities.

*****

Chemiscellany

10²³ HOMEOPATHY THERE'S NOTHING IN IT

Avogadro's number is everywhere!

A campaign was launched in 2009 to expose the unscientific nature of homeopathy. The 10:23 campaign's logo (see www.**1023**.org.uk) is shown above and it held a protest around the UK at 10.23 am on Jan. 30th. 2010. The protestors then overdosed on homeopathic remedies but they were OK as they were only drinking expensive water.

Any chemist will recognize the source of the logo - it is derived from Avogadro's number, 6.203 x 10^{23}, the number of particles in a mole of substance. Thus 18 mL of water contains 6.023 x 10^{23} molecules of water. Homeopathy is based on the premise that water remembers the 'signature' of substances that have been dissolved in it and if you select substances that have effects similar to a disease, then diluting a solution down and down until there is nothing left will cure you of the disease. The degree of dilution recommended, together with vigorous stirring, is a factor of 10^{60} (100 fold dilution done 30 times). This means that in the final solution there is only a 1 in 10^{37} chance of there being any molecules of the solute left i.e. so vanishingly small as to be nothing. The many blind studies that have done comparing homeopathy with placebo solutions have shown it is no better than a placebo and any effect is due to the placebo effect i.e. if you believe something is going to do you good then it will do so.

*****

30 Years of the Chemical industry in Ireland

Matt Moran
Director, PharmaChemical Ireland, Confederation House, IBEC, 84-86 Lr. Baggott Street, Dublin 2 matt.moran@ibec.ie

Introduction

To really trace the development of the chemical industry in Ireland it is necessary to go back a little further than the last 30 years. In reality the wave that drove the sector to being one of the largest in the world really started at the end of the 1960's with the establishment of a Citric Acid manufacturing facility at Ringaskiddy Co. Cork. It would be remiss of me to not mention the establishment of 2 major facilities before that date - the Danish based LeoPharma in 1957 and Squibb-Linson (now Bristol-Myers Squibb) in 1963. Now for a little more detail on these the growth phases of the sector in Ireland.

1960s

In 1957 Leo Laboratories, the Danish pharmaceutical company, established a facility in Dublin, mainly to supply the UK and home markets. This was followed by the establishment of Loftus Bryan Chemicals Limited by two German entrepreneurs at Rathdrum in Co Wicklow in 1960-61. Loftus Bryan manufactured active ingredients for generic medicines at the Co Wicklow site until it was taken over in January 1981 by the US based Schering Plough Corporation who renamed the company, Avondale Chemical Company, after the nearby birthplace of Charles Stewart Parnell, Rathdrum's most famous son.[1]

In 1963 the Government appointed Commission of Industrial Organisation which was charged with the task of examining the difficulties that possible entry into the Common Market might create for existing Irish industry. This Commission produced a detailed report on the Irish chemical industry. The report concluded that at the time there essentially was no basic chemical industry apart from four plants manufacturing sulphuric acid for the fertiliser industry. This was attributed to lack of native raw materials and lack of capital available for such investment. What the survey did identify was a secondary chemical industry producing paints, inks, pharmaceuticals, soaps and detergents for the consumer market employing approximately 2,800 people and generating about £6 million per annum of production. The report noted that out of the 2,800 employed in the secondary chemical industry only 52 were chemists reflecting a very low level of development work carried out in the industry at the time. Exports were negligible and the industry operated in a highly protected home market providing products nearly exclusively for domestic consumption.

In the same year Squibb Linson established a pharmaceutical manufacturing plant at Swords, Co Dublin. 1965 saw the start up of the Nitrigin Eireann Teoranta (NET) plant at Arklow to manufacture calcium ammonium nitrate and ammonium sulphate fertilisers. Plants to manufacture sulphuric acid, ammonia and phosphoric acid as raw materials for fertilisers were also started up at the Arklow site. This allowed the manufacture of complete combined fertiliser (N, P, K) at the plant.

1979 saw the establishment of combined ammonia and urea plant at Marino Point at Cork using the natural gas from the Kinsale Field. In the early 1980s the Arklow plant changed from making CAN and CCF fertilisers to just making CAN which necessitated the shutting down of phosphoric acid, sulphuric acid and CCF plants at the Wicklow site. NET ceased to make ammonia at the Arklow site in 1980.

1969 to 1989

The twenty-year period between 1969 and 1989 saw a rapid expansion of the pharmaceutical and chemical industry in Ireland and it is the investment that took place in this period, which is responsible for the strength of the sector in Ireland today. During this period the Industrial Development Authority of Ireland (IDA) specifically targeted those industries which would benefit most from the type of incentive package that they could offer in terms of grant aid and tax incentives. The type of industry which the IDA needed to attract was one that did not depend greatly on a convenient source of raw materials or was not too dependent on transportation to get their product to market. This resulted in the IDA identifying fine chemicals and pharmaceuticals as being one of the key sectors for development along with electronics, information technology and instrumentation. The basic or bulk industry with its high level of capital investment and recourse to scale was deemed unsuitable.

The IDA proceeded to aggressively market Ireland as an investment location for these types of industries, one of the prime targets for the IDA executives being the United States of America. The results of the IDA's strategy are plainly evident today. The expansion of the sector was extraordinary and a cursory glance at one or two key indicators will clearly demonstrate this. For instance, between 1973 and 1995 exports grew from £79 million to over £5 billion which represents an overall growth rate of 6,373% (See Table). Ireland became a net exporter of pharmaceutical and chemical products. The so-called Balance of Payments figure increased by 2,200% from the figure of £110 million in 1982 to a figure of £2.457 billion in 1995 .Currently there are some 220 companies or distribution outlets engaged in pharmaceutical, chemical associated product manufacture and distribution. In value terms in 1995 the sector was the second most important to the Irish economy counting for some 18% of total exports from this State. At this stage it should be noted that during this period of rapid development Ireland's mainly indigenous fertiliser industry contracted. The availability of cheaper raw materials from the UK heralded the eventual closure of such major manufacturing concerns as Gouldings Fertiliser Company.[2]

Development of the Irish PharmaChem Sector

As already mentioned there was some development of the pharmaceutical and fine chemical companies taking place in the 1960s but the real inflow of companies commenced probably in 1969 with the establishment of citric acid manufacturing plant by Pfizer Pharmaceuticals Production Corporation in Ringaskiddy. The IDA identified two development areas for the industry in Cork, one at Little Island and the other in Ringaskiddy. In 1972 Pfizer also established a pharmaceutical production facility at their Ringaskiddy site. Pfizer were followed into Ringaskiddy by Penn Chemicals, now GlaxoSmithKline, in 1975. Quest Biocon the Dutch parent company established their food ingredient plant in Carrigaline in 1976. In the early 1980s Angus Fine Chemicals developed a chemical synthesis plant, now owned by Hovione, just across the harbour from Pfizer in Ringaskiddy. Major investment in Ringaskiddy culminated with the announcement by Sandoz, now Novartis, in 1989 that it was to establish a major pharmaceutical chemical synthesis facility there.

Meanwhile Irish Fher now Irotec, Henkel, Gaeleo (Pfizer Pharmaceuticals), Mitsui Denman, FMC International, Plaistow, Cara Partners, Janssen Pharmaceuticals were all establishing sites at Little Island, not to mention Eli Lilly, then Elanco who established their facility outside Kinsale in 1981 and Schering Plough who took over the Chembiotica, antibiotic plant at Innishannon in 1983 to manufacture biotechnology products such as Interferon-A.

Site facilities were being established at Tipperary by Merck Sharp & Dohme in 1976, Sterling Drug (now GlaxoSmithKline) in Dungarvan and in Dublin where Warner Lambert, now Pfizer, Organon,now Merck, Armour Pharmaceuticals, now Reheis (since closed), and Loctite, all established facilities. Meanwhile in the Mid-West in the early 1980s Syntex, SIFA, PGP, Devcon and Aughinish Alumina all established facilities in or close to the Shannon development area.

From the 1990s to today’s Industry

The first wave of investment was dominated by fine chemical synthesis- much of it in the pharmaceutical sector in the manufacture of active pharmaceutical ingredients (APIs). Inevitably the flow of investment did slow but the nature of this investment did start to shift forward into the manufacture of pharmaceutical finished products. Helsinn Birex, Organon and Rottapharm established facilities in Dublin, interestingly enough these were all companies headquartered in Continental Europe as opposed to the US or Japan. Grelan (now Takeda) set up in Bray , Co. Wicklow and Wyeth Medica (now Pfizer) established a major tableting facility in Newbridge, outside Dublin.

The mid to late 1990s witnessed the emergence of biotechnology in the area of health research with huge advances occurring in genetic research with the entire human genome being characterized by the turn of the century. Government were strongly lobbied by the industry to prioritize this area in the context of industrial development and investment in research. Government did respond and Science Foundation Ireland was established in the late 90s, listing one of its major research priorities as being biotechnology or life sciences. Meanwhile Wyeth (now Pfizer) announced that it was going to establish one of the largest biomanufacturing plants in the world at Grangecastle, Co. Dublin. The company was prepared to invest close to €2 Billion in this project where it would manufacture Enbrel, a lead product used to treat rheumatoid arthritis. This heralded a new wave of investment in biotechnology with Centocor (Johnson & Johnson), Eli-Lilly and Pfizer following suit. (See Tables 1 and 2 below).

Table 1 Plant expansions (1999-2007)

	Euro Millions	Empl-oyment
Pfizer Ireland	432	250
Merck Sharp & Dohme	171.41	50
Organon Ireland (Merck Sharp & Dohme)	25.39	170
GlaxoSmithKline	317.43	100
Wyeth Medica (Pfizer)	57.14	170
Elan	35	120
Janssen Pharmaceuticals	100	60+
GE Life Sciences	34.15	150
Servier	69	112
Fujisawa(Astellas)	17	n/a

Table 2 Greenfield (new investments) (1999-2007)

	Euro millions	Empl-oyment
Wyeth BioPharma(Pfizer)	1270	1300
Bristol-Myers Squibb	381	250
Genzyme	320	480
Alza	152	80
Abbot	400	200
Gerard Laboratories	40	380
Altana Pharma	70	150
Taro Pharma	N/a	300
Recordati	28	60
Centocor	650	330
Takeda	80	60
Amgen	820	1100
Gilead	60	80
Eli-Lilly	400	200
Merck Sharp and Dohme	100	120
Servier	115	155

Industry at a Crossroads

At the time of writing this piece the entire sector is valued at €44.17 billion in exports and employs around 24,500 people directly, accounting for at least this number again in the sub-supply sector. So in value terms, over 50% of the nation's exports arise from this sector (Table 3 below traces the growth of the sector over the last 35 years). The sector contributes over €1 Billion in Corporation Tax alone each year so it has become a vital cog in the country's industrial machinery. This is very positive news for the country and indeed for those who choose to study science as the industry is an important employer of science graduates with 50% of its employees holding a third level qualification of some type.

Table 3 Exports 1973-2008
(Source: Central Statistics Office)

1973	€100.31 million
1995	€6.40 billion
1998	€18.03 billion
1999	€21.08 billion
2000	€27.22 billion
2001	€32.25 billion
2003	€35.7 billion
2008	€44.17 billion*

*51.2% of total exports in 2008

However, the global picture in the pharmaceutical industry is radically different, with the sector here dominated by the global pharmaceutical industry this is bound to impact the sector here. Globally the industry faces two major challenges:

- The impending expiry of many patents on major blockbuster drugs
- Research pipelines that are drying up

Once a chemical or biological entity is filed for patent on the basis of it having therapeutic activity undergoes a range of tests for safety and toxicity then entering a prolonged regime of clinical trials. Experts estimate that only 1 in 100,000 of these entities actually ends up in the marketplace (see Figure 1 below)! Typically the whole process takes around 12 years to complete and costs anything up to € 1 billion. The total patent life of a medicine is 20 years so the company is afforded 8 years in which to recover the cost of this process and also to generate funds to drive its research programmes. Once the patent expires the market is open to generic competition, prices are driven down, which may benefit the patient, but most companies will record a 60% fall in revenues in the first year after patent expiry. Over the next 3-4 years around €100 billion worth of so-called blockbusters will come off patent (see Figure 2). Many of these are manufactured in Ireland, hence the industry is facing a very challenging period.

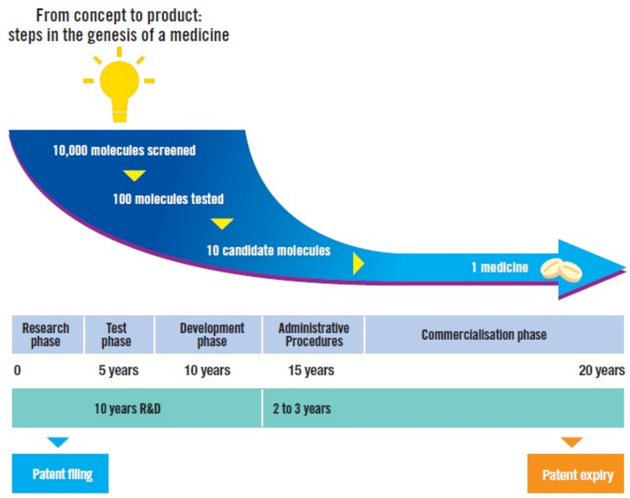


Figure 1 From concept to product (Source: LEEM)

In recent years companies would have had drugs in development to replace the blockbusters as they came off patent. This no longer the case, it is becoming more difficult to identify new therapies as the diseases left are much more difficult to cure. This has driven a raft of mergers and acquisitions such as Pfizer and Wyeth or Merck and Schering-Plough.

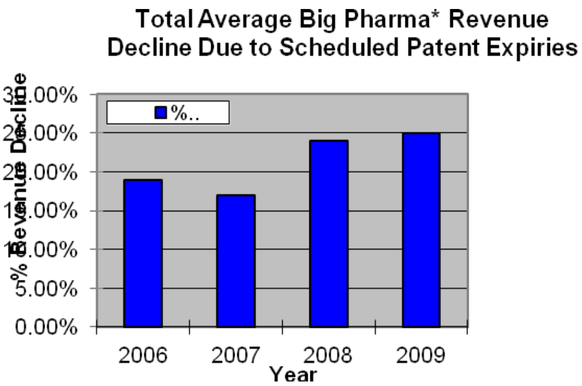


Figure 2 Effect of patent expiry on revenue
(*Big Pharma average includes J&J, Novartis, Merck & Co., Abbott, Eli Lilly, Glaxo SmithKline, Pfizer, Sanofi, Bristol Myer Squibb and Roche. Source: Moody's FM)

Industry Response

The industry through its representative body, PharmaChemical Ireland (PCI) has just launched a strategy document outlining how it can respond in order to secure the long term future of the sector in Ireland.[3] It makes a number of recommendations to the industry, to Government and to the research community. In short it suggests that unless companies change their mandate in this country their long-term future is no longer secure or certain. PCI proposes that companies here expand their mandate to include development as well as manufacturing - the so called D+M Model. Looking at Figure 3 below that traces the discovery to launch of a new product, Ireland currently dominates the launch and manufacture space - now companies need to work back towards the clinical trial space to cover taking the drug from the clinic to manufacture and back further to proof of concept stage if possible. Time to market is a key issue for the industry and reducing the time here could potentially save the industry a lot of money. IBM estimated that if the top 30 pharmaceutical companies shaved just 16% of their cost of goods they could potentially save $10 Billion.[4] Adopting the D+M model also brings companies closer to research and allows them to develop local intellectual property and skills hence increasing their relevance. It also opens up opportunities for local industry to provide specialist services and supports.

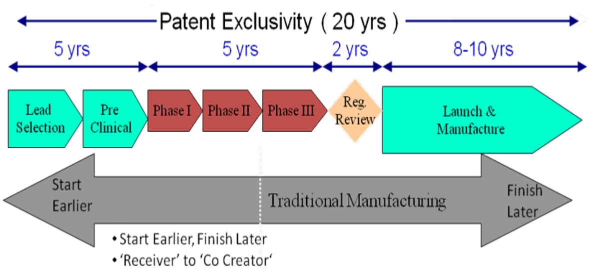


Figure 3 Achieving success in drug discovery - development + manufacturing

It is important that Government buys into this concept and plays a role by ensuring that tax incentives for conducting R&D and protecting intellectual property are best in class. This model provides an opportunity for the research community to work more closely with companies and to develop new skills and research teams. This in turn will provide career opportunities for science graduates at all levels including PhDs.

So is the industry responding to this challenge? There are a number of examples of companies in Ireland investing in process development centres, notably Merck, Sharp and Dohme , Pfizer and Genzyme. Some of the more recent investments appear in Table 4 below. These reflect a positive and emerging trend within the sector which is likely to continue. There is now little doubt that the face of the sector in this country will change radically over the next 5 years. Those companies that adapt to a new harsher reality will survive and prosper, and the industry has the opportunity to move to a higher more secure plane.

Table 4 Recently Announced Investments (as of April 2009)

Company	Invest-ment	Employment	Products	Location
Merck,Sharp & Dohme	€200m	170	Vaccines	Carlow
Merck,Sharp & Dohme	€100m	120	Development	Ballydine, Tipperary
Teva	€65m	165	Generics	Waterford
Eli-Lilly	€400m	200	Biotech	Cork
Wyeth(Pfizer)	€24m	20	Development-Solid dosage	Newbridge
Genzyme	€130m	170	Biotech-Manufacturing	Waterford
Genzyme	€20m	18	Development	Waterford
Pfizer	€109m	100	Biotech-Development	Cork
Gilead Sciences	€75m	100	Solid Dosage	Cork
Glaxo SmithKline Beecham	€250m	150	Active Pharmaceutical Ingredient	Cork
Servier	€115m	155	Active Pharmaceutical Ingredient	Belview,Kilkenny
Servier	€58m	115	Solid dosage	Arklow
Glaxo SmithKline Beecham	€53m	50	Solid Dosage	Dungarvan, Waterford

Education

From an educational perspective the study of science is of primary concern to the sector. Typically companies employ graduates from the physical and life sciences and across the range of engineering disciplines. The industry remains disappointed at the lack of response by Government to the O'Hare Report (Task Force on Physical Sciences, 2002)[5] as it thought that a lot of work had been dedicated to coming up with a set of sensible recommendations. The industry has supported the Irish Science Teachers Association in their request to Government to fund the provision of technicians to secondary level laboratories and it believes that investment in the laboratory infrastructure is required as recommended by O'Hare.

It is interesting to note the recent uplift in interest in the sciences at third level by second level students. Though this is no doubt driven by current economic conditions, nonetheless it is encouraging.

One outcome of the industry going down the D+M route will be an increase in opportunities for PhDs which should benefit the universities and institutes of technology. Still the industry will remains a good employer for science and engineering graduates across the board. It is supportive of the recommendations outlined in the recent report published by the Advisory Council for Science on the role of PhDs in the smart economy. Ongoing engagement between the enterprise sector and the educational sector can only be a good thing.

Conclusion

The Chemical sector in Ireland is quite unique in that it has developed along different lines to the more traditional hubs for this industry such as Germany, the UK and the USA. It is here as the result of enlightened Government policy back in the 1960s. It has not grown but it has been implanted- the real challenge for the industry here is to grow its roots now. Roots which come from knowledge, come from brainpower come from ability. Ireland has proved that it could hold and grow a very successful sector over the last 40 years what it has to do is anchor and root it in the country so that it will continue to grow from a firmer more embedded base for next 140 years and beyond.

References

1. O'Brien C, 2001, Chemistry in Ireland : Avondale Chemical Company, *Chemistry in Action!*, Autumn, 1991.

2. W & H N Goulding Ltd, 1956, Dublin Ireland *1856 - 1956 - A short history of the firm.*

3. PharmaChemical Ireland, 2010, *Innovation and Excellence PharmaChemical Ireland Strategic Plan*

4. IBM Business Consulting Services, 2005, *The Metamorphosis of Manufacturing From Art to Science*

5. Task Force on the Physical Sciences, 2002, *Report and Recommendations*

Matt Moran is the Director of PharmaChemical Ireland (PCI), which is part of IBEC, and PCI is the body that represents the pharmaceutical and chemical industry in Ireland. In March 2009 he took over as President of the Irish Science Teacher's Association at their annual meeting in Limerick.
*www.**pharmachemicalireland**.ie/*

Diary

2010

20th Symposium on Chemical and Science Education, University of Bremen
May **27-29th**
ingo.eilks@uni-bremen.de

4th. Chemistry Demonstration Workshop
June 14-17
University of Limerick
Peter.childs@ul.ie

10th. **European Conference on Research in Chemical Education**
July 4-9
Krakow Poland
http://ecrice2010.ap.krakow.pl

21st International **Conference on Chemical Education**
Jul. 28-Aug. 2
Taipei, Taiwan
Dr. Mei-Hung Chiu
(mhchiu@ntnu.edu.tw)

21st. Biennial Conference on Chemical Education (BCCE)
August 1-5
University of North Texas in Denton, USA
http://www.bcce2010.org/home/home.php

Variety in Chemistry Education (ViCE)
Sept. 2-3
Loughborough University, Loughborough, Leicestershire
http://www.heacademy.ac.uk/physsci/events/detail/2010/vice_2010

SMEC10
Inquiry-based learning: Facilitating authentic learning experiences in science and mathematics
Sept. 16-17th
Dublin, DCU
http://www.dcu.ie/smec/2010/index.shtml

29th. ChemEd-Ireland
October 9th
Dublin, DIT
Claire.mcdonnell@dit.ie

National Science Week
Nov. 7 -14th

2011

The Contribution of the ISTA to Science Education in Ireland

Declan Kennedy
Department of Education, University College, Cork d.kennedy@ucc.ie

My introduction to the ISTA

I am delighted to have been asked to contribute an article on the Irish Science Teachers' Association for this 30th anniversary issue of *Chemistry in Action!* I have every issue of *Chemistry in Action!* published to date and I still remember the excitement of receiving the first issue. Thirty years ago I was at the beginning of my career as a chemistry teacher in Colaiste Muire Cobh. Having completed my BSc in UCC in 1976, I joined the Cork branch of the ISTA as a student member during my HDipEd year as I really needed help. The principal of the school, Brother Bede, a chemistry teacher, put a supreme act of faith in me and asked me to take over the teaching of his Leaving Certificate chemistry class. Realising the great responsibility put on my shoulders, I headed off to my first meeting of the Cork branch of the ISTA and received a particularly warm welcome from two of the branch officers, Sr Mercedes and Michael O'Mahony. I had walked into a room full of strangers and by the end of the evening I had a room full of friends. It was clear to me that if I were to become a successful science teacher, the best training I could receive was from the ISTA members. I was so impressed by the dedication of this group of teachers that I became immediately "hooked" on the ISTA and immersed myself in ISTA activities from that time onwards. The outstanding support and help received from the ISTA is nicely summarised by Randal Henly:

"I joined the ISTA and never looked back. Without the opportunities provided by, and the backing of, the ISTA in those early years, I know I would never have achieved what I have." (Henly, 1986).

The early days of the ISTA

The Irish Science Teachers' Association, Eol Oidí na hÉireann, was founded on 3rd January 1961 at a meeting held in the Chemistry Department UCD. The meeting coincided with an Institute of Chemistry of Ireland Refresher Course for science teachers and Mr George Lodge, one of the driving forces behind the setting up of the ISTA, was elected as the first ISTA Hon. Secretary. The other officers elected were Professor T.S. Wheeler (President), Fr. D. McGinley (Chairman), Mr A.V. Henry (Treasurer) and Mr W Broderick (Editor). When discussing the establishment of the ISTA, Dr A.E. Somerfield describes how the meeting was a small scale version of the present ISTA Annual Conferences in that the Institute of Chemistry of Ireland course involved lectures and displays of scientific apparatus and books (Somerfield, 1982). The first Annual General Meeting of the ISTA was held in UCD in April 1962 and the first Presidential Address entitled "Billard Balls and Hard Water" was given by Professor T.S. Wheeler, UCD. The first issue of the ISTA journal *SCIENCE* was published in 1962 and continues to the present time thanks to the hard work and dedication of many Editors, among whom were William Broderick, Fr. Lee, George Lodge, Norah Kelly, Diarmuid McCann, Randal Henly and the present Editor Rory Geoghegan.

Whilst the ISTA was initially Dublin based, it did not take long for a branch network to be established. In 1962 a group of science teachers in Cork established the "Cork Secondary Teachers' Science Society" which in 1964 became the Cork Branch of the Irish Science Teachers' Association. The launching of Sputnik by the Soviet Union in 1957 and subsequent feelings of technological inferiority among many other countries, meant that the 1960's were a time of great change in science education throughout the world. This era is described by William Broderick, a founder member of the ISTA, who explains that that launching of Sputnik really accelerated change in the classrooms of Ireland (Kelly and Broderick, 1982). These changes were influenced by work being done in the USA by the Physical Science Study Committee, the American Chemical Society and the Biological Sciences Curriculum Study and also by the Nuffield Science schemes in the UK. The concerns of the science teachers in the classrooms of the 1960s was reflected in the rapid growth of the ISTA during this time, with an Athlone branch formed in 1966 and by 1968, branches had been established in Monaghan, Clare, Sligo, Waterford, Mayo, Wexford and Kilkenny. It is clear that the growth of the ISTA was greatly facilitated by the Department of Education. Somerfield (1982) describes how, during the time of great change in science education in the 1960s, the Department of Education sponsored many in-service courses for teachers in various parts of the country. The local ISTA branch organised the venue and speakers in co-operation with the Department of Education, which funded the costs involved in running the in-service courses.

Figure 1 Mr Randal Henly is one of the recipients of the Lodge Award, named in honour of one of the founders of the ISTA. It was awarded to him in recognition of outstanding contribution to science education in Ireland. In this photograph Randal is presenting his Science is Fun lecture at a meeting of the Cork branch of the ISTA.

In 1968 the seventh Annual Meeting was held in Cork and this meeting initiated the setting up of a new constitution involving a Council, Executive Committee and branch representatives as part of the structural organisation of the ISTA. Thus, the ISTA was well established and had a good structural organisation for the challenges that lay ahead.

ISTA Activities

Whilst various amendments to the ISTA constitution have taken place over the years, the initial aims of the ISTA have generally remained unchanged since its foundation. A study of these aims helps us to understand more clearly the role of the ISTA in science education in Ireland (see Table 1 below.)

Aims of ISTA

- To provide leadership in promoting science education.
- To promote the teaching of science at both primary and secondary level.
- To promote co-operation between science teachers.
- To continue to promote, and be involved in, curriculum development.
- To continually review the structure and organisation of the Association in order to keep in touch with the changing demands of its members.
- To improve (a) the funding of the Association's activities, (b) the quality of the Association's publications, (c) the public image of the Association.

Table 1. Aims of the Irish Science Teachers' Association.

In order to achieve the above aims, the ISTA engages in various activities related to science education. For example, the ISTA has always been actively involved in organising in-service courses for its members through regular branch meetings. These meetings are usually held in a local Education Centre, school or third level institution. Not only do these branch meetings deal with issues related to science education, but they also serve as a social occasion in that they allow science teachers to meet each other in an informal and relaxed setting. In addition, the branch meetings help to keep teachers in touch with all events related to science education, e.g. ChemEd-Ireland conferences, updates on syllabus reform, launching of new science equipment and textbooks, assessment issues, etc. The ISTA branch meetings also help to nurture a close and co-operative relationship between the ISTA and the local Education Centres, local industries and third level institutions.

In addition to the local branch meetings, the ISTA Annual Conference is organised every year by one of the local branches. This is the highlight of the

ISTA calendar and is usually attended by large numbers of science teachers from all over Ireland. Speakers at the conference are drawn from Ireland and also from abroad. One of the most memorable speakers over the past thirty years has been Professor Hubert Alyea, Princeton University USA who received three standing ovations at his lecture demonstration at the ISTA Annual Conference held in Cork in 1982.

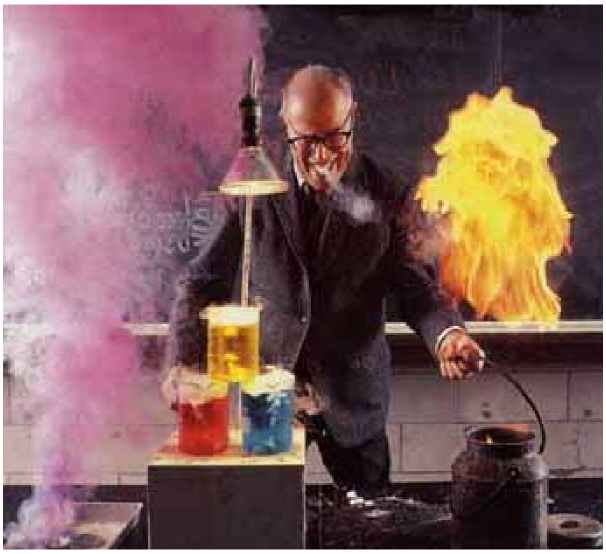


Figure 2 The world famous Professor Hubert Alyea who delivered the demonstration lecture "Lucky Accidents, Great Discoveries and the Prepared Mind" at the ISTA Annual Conference held in UCC in 1982

Having attended every ISTA Annual Conference since 1977, there is no doubt in my mind that this event plays a key role in science education in Ireland. The great value of this conference is that it brings hundreds of science teachers together for renewal and refreshment over a weekend that is packed with science-related activities. Science teachers have the opportunity to attend top class presentations, participate in workshops, view the latest equipment and textbooks on offer and meet with their fellow science teachers. In addition, the ISTA bookshop facilitates the dissemination of resource materials and policy documents produced by the ISTA sub-committees.

ISTA and Department of Education and Science

On researching the history of the ISTA, it is clear that there has always been close collaboration between the ISTA and the Department of Education and Science.

When discussing the early years of the ISTA, Somerfield (1982) points out that many of the branches of the ISTA grew out of in-service courses sponsored by the Department of Education. This point is echoed in contributions by some of the founder members of the ISTA (Kelly and Broderick, 1982; Somerfield et al, 2001) who paid tribute to Dr. Liam Mulcahy and Sean O Nuallain of the Department of Education, for their support in obtaining funding for courses in the early years of the ISTA. Fortunately, the work of the above two inspectors was carried on by the next generation of inspectors, among whom were Mr. Seán Ó Donnabháin and Dr. Carl O'Daly. Many ISTA members (including this author) had the pleasure of working closely with both of these inspectors over many years in the areas of providing in-service courses for science teachers in various venues around Ireland. These in-service courses were generally organised in co-operation with the local branch of the ISTA and were held in the evenings and at weekends. In addition, for many years the Department of Education also organised summer in-service courses of one week duration in Kevin Street College of Technology, Dublin. In 1985 the Department of Education initiated very successful Intervention Projects in Physics and Chemistry (Porter, 1997) and many ISTA members were closely involved in these projects. In more recent times, the great sense of collaboration between the ISTA and the Department of Education and Science has been strengthened by the setting up of the Teacher Professional Networks (TPN) system for funding the professional development of teachers. This is one of the most innovative schemes ever established by the Department of Education and Science, as it provides funding to the subject associations to assist in the provision of continuing professional development for teachers.

International and Industrial links

One of the great father figures of science education in Ireland is Dr. Oliver Ryan, recently retired as senior lecturer in science education from NUIG. Oliver has always been actively involved in the ISTA throughout his lifetime of teaching and has been instrumental in establishing international links for the ISTA. For example, in 1973 Oliver represented the ISTA at a meeting in the University of Maryland, USA, to establish the International Council of Associations for Science Education (ICASE). This is the professional body representing science teachers' associations throughout the world. Since that time, the ISTA has been closely involved with ICASE. The ISTA currently holds the position of European Representative of ICASE and will be represented at the Third World Conference on Science and Technology Education in Estonia in June 2010. In addition to ICASE, the ISTA has close links with our fellow science teachers in ASE England, ASE Scotland and ASE Northern Ireland. The first delegation to the ASE Annual Meeting in the University of Lancaster took place in 1969 and the ISTA was represented by Mr. Randal Henly and Mr. Michael Shields. Since that time, the ISTA has been represented each year at the above three ASE conferences and representatives from ASE are also invited to attend the ISTA Annual Conference.

In addition to his work on the international stage, over 20 years ago Oliver conceived the idea of setting up the Science Educator of the Year to honour and to recognise outstanding achievement in the area of science education. Each year Oliver organises the entire process by obtaining nominations from the various ISTA branches. Then he organises the selection of the winner, whom he announces in his own unique style during the banquet at the ISTA conference.

Figure 3 Dr Oliver Ryan presenting the Science Educator of the Year Award 2009 to Mary Lee in honour of her outstanding contribution to science education in Ireland. Also shown is Matt Moran, Director of PharmaChemical Ireland and President ISTA.

In the early years of the Association, the role of President was usually filled by academics from third level institutions but, as the ISTA expanded, this role has also been filled by representatives from industry. Links between the ISTA and industry were strengthened in the 1990s when Karla Lawless of BASF generously provided sponsorship for various ISTA activities, e.g. sponsorship of the ISTA Annual Conference and sponsorship of training workshops for the BASF Minilab using microscale apparatus. One of my earliest memories of involvement in an Industry-Education initiative was organising a symposium in 1995 on behalf of the ISTA at at an international conference entitled *Partners in Chemical Education,* which took place at the University of York, England. One of the main speakers at the symposium was Dr. Cashel Riordan, ISTA President and Director of Quality Assurance at Pfizer Pharmaceuticals. In recent years, industry-education links have been strengthened with many industries becoming corporate members of the ISTA, the establishment of the PharmaChemical Ireland Science Quiz, and the sponsorship of the Science Educator of the Year Award by PharmaChemical Ireland. In addition, the Pfizer Foundation USA in collaboration with local ISTA branches has kindly sponsored several workshops on Forensic Science, Biotechnology and Green Mathematics. The current ISTA President is Matt Moran, Director of PharmaChemical Ireland.

Figure 4 Karla Lawless, BASF, outgoing ISTA President, handing over the chain of office to incoming President, Matt Moran, PharmaChemical Ireland at the 2009 AGM in Limerick.

Curriculum Development

One of the most important tasks performed by the ISTA is to represent the views of its members on all NCCA Course Committees. Due to the fact that each science subject has a corresponding ISTA sub-committee, which meets regularly and reports to ISTA Council, the ISTA is in an ideal position to keep its members informed of progress being made on the development of new science syllabi. The local branch meetings, the journal *SCIENCE* and the ISTA member's area of the new ISTA website, greatly facilitate the flow of information to ISTA members and from ISTA members to their representatives. In recent years the important role of the ISTA was underlined when it initiated a successful campaign to convince the NCCA to publish adequate Teacher Guidelines, outlining the depth of treatment required for the Junior Certificate Science syllabus.

Conclusion

I hope that this article has succeeded in showing that the ISTA is at the very heart of science education in Ireland. Since the foundation of the ISTA almost 50 years ago, it continues to make an enormous contribution to every aspect of science education in Ireland - particularly the professional development of science teachers. One of the great strengths of the ISTA is that it is a voluntary organisation. All work in the area of the provision of inservice courses, production of resource materials, submissions on curriculum reform, drawing up of science education policy documents, etc. is all done in some ISTA member's spare time. Congratulations to Dr Peter Childs on 30 years of Chemistry In Action! We hope that this publication will, in the same way as the ISTA, continue to go from strength to strength.

Acknowledgments

Sincere thanks to Randal Henly, Sr. Mercedes Desmond, Rory Geoghegan and Noel Brett for supplying much useful information needed when researching this article.

References

Henly, R (1986), 'Early Days of the Association', *Science* 21 (2), 5 – 7.

Kelly, N and Broderick, W (1982), 'Some Memories of the Early Years', *Science* 17 (2), 12 – 18.

Lodge, G (1962), 'Eol Oidi na hEireann Its Origin and Activities', *Science* 1 (1), 7 – 9.

Porter, G (1997), 'Intervention Projects in Physics and Chemistry', *Science* 32 (2), 22 – 26.

Somerfield, A (1982), 'Early Days of the Association', *Science* 17(2), 8 – 9.

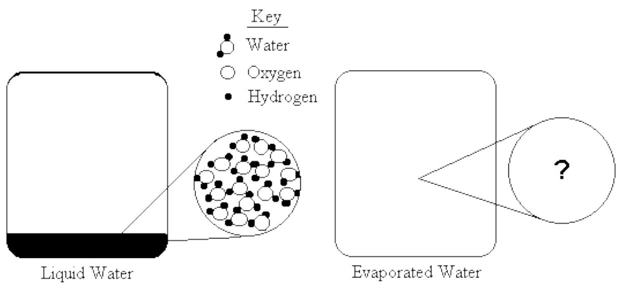
Somerfield, A., Scott, A., Kelly N., Richardson, B., Browne P., Allen B., Loughman, J., Renehan, H., (2001), .Early Days of the Association., *Science* 36(2) 12 – 22.

□

Dr. Declan Kennedy is currently Senior Lecturer in Science Education in the Department of Education, University College Cork. He joined UCC as a full time lecturer in 1998 after 23 years teaching science in Colaiste Muire, Cobh, Co Cork. He is currently the membership secretary of the ISTA and a member of the ISTA Leaving Certificate Chemistry and Junior Science committees.

<u>Correction</u>: In issue #89 p. the following diagram did not print and is given below. It was meant to illustrate the type of diagnostic question used by Maria Sheehan in her intervention project.

Sample Question: The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water evaporates?

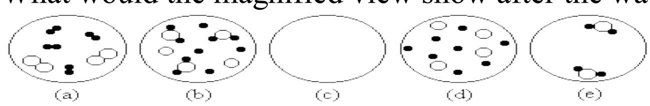


Figure 19 Sample question testing understanding of the particulate nature of matter

Proceedings 28th. ChemEd-Ireland

October 17th. 2009, University of Limerick.

This issue contains the papers given at the 28th. ChemEd-Ireland conference, except for that given by Brendan Duane. The conference was held in the University of Limerick on October 17th., 2009. It was organised by a team from the National Centre of Excellence for Mathematics and Science Teaching and Learning (NCE-MSTL). The conference marked the return of ChemEd-Ireland to Limerick, where the conference ran for 25 years from 1982 to 2006, and the conference now rotates between four centres: University of Limerick UL), University College Cork UCC), Dublin City University (DCU), and Dublin Institute of Technology (DIT). It is intended that it will alternate between the East and West coast, to try and make it accessible to as many chemistry teachers as possible. The theme of this year's programme was "*Preparing for the Future: the Importance of CPD for the Chemistry Teacher*", and this was addressed in a number of ways. The programme is given below. One session dealt with ICT resources for teaching Chemistry and this was supplemented by an opportunity to see and try the software over lunch.

The 2009 year conference was well attended with ~80 participants and the teachers who came seemed to enjoy what was on offer. Most of the papers from the conference are given below in the Proceedings and you can access PowerPoint files for the talks at the NCE-MSTL website: http://www.nce-mstl.ie/files/ChemEd09/.

The conference was supported financially by the Second Level Support Service (SLSS), the Institute of Chemistry of Ireland (ICI), the Ireland section of the Society for Chemical Industry (SCI), and the Ireland Region of the Royal Society of chemistry's Education Division. Their help in keeping the fees low is greatly appreciated.

The 2010 conference will be held on Saturday October 9th. in DIT and will be organised by Dr. Claire McDonnell. Email Claire.mcdonnell@dit.ie for details.

ChemEd-Ireland 2010

Conference Programme

Preparing for the Future: the Importance of CPD for the Chemistry Teacher

9.00 a.m. - 4.30 p.m.
Registration – Tea/Coffee
Dr. George McClelland - Introduction to the National Centre for Excellence in Mathematics and Science Teaching and Learning
Plenary Lecture
Professor Norman Reid – A Scientific Approach to the Teaching of the Sciences
Break
Tim Harrison - How to get the most out of Chemical Practical Work
Dr. John O'Reilly - A Virtual Chemistry Laboratory for Irish Post-Primary Schools (VCLIPPS) to support the professional development of Irish chemistry teachers in the midst of curriculum change
Douglas McDonald - Colorimetry for all – hands-on demonstration of the Mystrica colorimeter
Lunch
Tim Harrison – Software demo
Brendan Duane – SLSS Chemistry ICT
Douglas McDonald - Demonstration
Plenary Lecture
Miranda Stephenson – Inspiring Better Teaching of Science: A UK-Wide Professional Development Programme
Brendan Duane – Resources in the Leaving Certificate Chemistry
Tea/Coffee – Display of Posters
Dr. Peter E. Childs - New TY Science Modules
Close of conference

A Scientific Approach to the Teaching of Chemistry: What do we know about how students learn chemistry and how can we make our teaching match this to maximise performance?

Norman Reid
Emeritus Professor of Science Education, University of Glasgow, Glasgow, Scotland
dr_n@btinternet.com

Introduction

Chemistry is an exciting subject to teach. The insights and understandings from research in chemistry enable the subject to be always on the move, with new discoveries taking place. The problem for the teacher is to keep up to date. However, there is another major problem. Chemistry is regarded as a difficult subject by many learners. This article seeks to explore *why* chemistry is difficult as well as what we can do about the difficulties in our teaching. The aim is that our students find chemistry exciting, challenging and useful, whether they pursue careers in the sciences or not. Although the focus here is on chemistry, much of this applies equally to physics and mathematics and to some areas of biology.

Background

The content of school chemistry curricula remained fairly static for decades to the late 1950s. At that time, there was quite a worldwide revolution in what was to be taught at school level and the order in which topics were presented. The content was updated and new insights from the atomic and molecular understandings of chemical phenomena were introduced early. The amount of organic chemistry was increased greatly and there was much less emphasis on the endless lists of '*preparations and properties*' so familiar to those educated before the 1960s.

Very quickly, reports started to circulate that school students were finding chemistry difficult. In a very early study on this, the following topics were found to be causing problems.

- Topics related to equations and the mole (e.g .volumetric and gravimetric work, Avogadro and the mole)
- Topics with some arithmetical content (e.g. much of thermochemistry and thermodynamics)
- Oxidation and Reduction (e.g. redox, E˚s and ion electron ideas);
- Organic topics (e.g. topics like esters, proteins, amines and carbonyls, aromaticity)

Parallel studies showed that certain themes in physics also caused problems. These included many areas of electricity, concepts like density and acceleration, wave motions. In biology, water transport phenomena and genetics showed the same high levels of difficulty. Although many studies were carried out to explore these areas of difficulty, the key thing is to find out *WHY* certain topics caused problems. Was it intrinsic to the nature of the sciences or was it related to the way humans learn in highly conceptual areas? It turns out to be both.

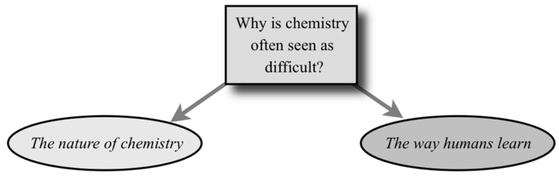


Figure 1 Why is Chemistry Difficult?

The danger is that we offer *descriptions* of the difficulties instead of exploring fundamental reasons. Thus, people started to describe chemistry as abstract or full of concepts. Such descriptions may well be true but they do not take us forward much. There are thousands of studies looking at the misconceptions which students were developing but almost no one asked *why* such misconceptions were being observed. There was even a tendency to blame others: primary school science, lack of mathematical abilities, or bad student attitudes None of that took us forward at all.

This article seeks to unfold the story from carefully conducted research studies. The word 'research' needs a little explanation. Most educational research never moves beyond attempts to *describe* what is happening in learning situations. In contrast, research in a science like chemistry moves well beyond this and seeks to understand the principles underpinning the chemistry and to explore the reasons *why* things happen in the way they do. Here, I am seeking to give a summary of some educational research related to the teaching and learning in the sciences, this research having a strong focus in pinpointing the underpinning principles and always asking the question '*why?*': why is chemistry difficult and what can we do about it as teachers?

Early Insights

Several observations from careful research started to offer the key insights to explain why chemistry is difficult although it took many years for these observations to be brought toegther. For example, experienced examiners had noticed that, in quite a few types of questions, candidates tended to gain very high marks or, more frequently, very low marks. Very few candidates gained marks in between the extremes. This was a strange observation.

Quite separately, in some work in medicine and in psychology, it was appreciated that human memory had a number of discrete '*components*' and two of them were labelled as '*short-term memory*' and '*long-term memory*'. Later, a major study looking at learning in organic chemistry found that students looked at structures and '*read*' them like they would read language. Thus, ethanoic acid was seen as C, hyphen, H, 3, hyphen, C, equals O, hyphen, O, hyphen H. Students managed to convert this 'reading' into the structure but, faced with a simple ester, their system of reading failed to lead to the correct structure. Esters contained too much information to be 'read' this way.

In this last study which was published in 1980, Kellett made the key insight when she grasped that it was the *amount* of information that learners faced which was critical in hindering success. Working with Johnstone, she started to consider the possible psychological explanations for this observation. The work of Miller (1956) was seen as important and gave the clue. Miller had found a simple way to measure the capacity of what he called 'short-term memory'. He found that adults, on average, were able to hold about 7 items of information *at the same time*. From his measurements, he realised that almost all adults have a short term memory capacity lying between 5 and 9. He described the item of information as a '*chunk*'.

The capacity of this part of the brain is fixed genetically and cannot be expanded. However, Miller found that people learned to group items of information together so that they were seen as one '*chunk*' and he described this skills as '*chunking*'.

Have you tried to remember a telephone number which has been just given to you. Unless there is some pattern in the sequence of numbers, it is almost impossible for most telephone numbers with many more than 7 digits. If I gave you the telephone number of my former research centre (01413306565), you would struggle to remember it, for it has 11 digits. However, if you appreciated that the first four digits are the Glasgow code, the second three are the university code, then the number looks like: 0141-330-6565. The first four are seen as *one* chunk of information, the second three digits are seen as *one* chunk of information and you have enough capacity in your working memory to hold the number, now seen as 6 chunks: area code, university code, four numbers for extension.

The Idea of Information Load

In some brilliant work, Johnstone and Elbanna measured the capacity of what they called the '*short-term memory*' of over 300 students, using two methods, now known to be highly reliable. They looked at the performance of these students in a range of assessment items. A group of experienced teachers had considered these items and agreed the likely information load of each item in the test. They described the information load of a test item in terms of the number of ideas which a student had to hold *at the same time* in order to succeed. The '*at the same time'* is critical for some questions can be broken down into a series of stages. They expected that, as the information load of the questions rose, the student success rate would fall. What they found was somewhat surprising.

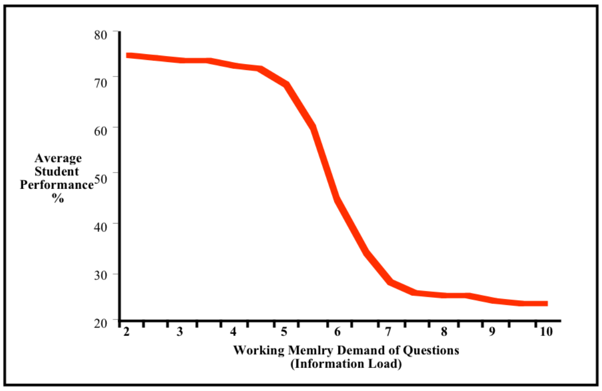


Figure 2 Information Load and Student Performance

The figure above is based on what they published but I have labelled the 'Information Load' as '*Working Memory Demand*'. We shall return to this later but, for the moment, we shall replace the phrase '*short-term memory*' by '*working memory*'. I shall explain that later. The real surprise was that the graph as not a straight line. There was a cataclysmic collapse in performance when the information load of the questions reached about 6.

They went further. They divided the whole student group into three roughly equal groups: those with above average working memory capacities, those with average working memory capacities, and those with below average working memory capacities. What they obtained is shown (in simplified form) in figure 3.

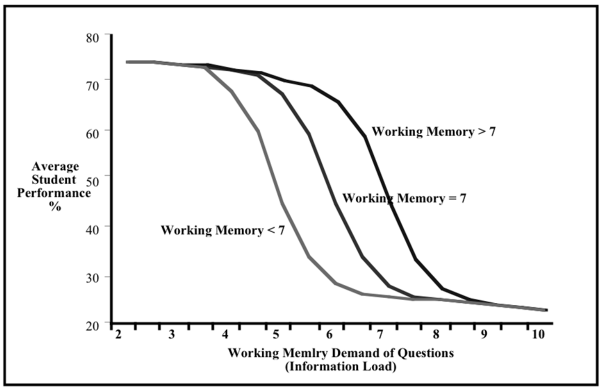


Figure 3 Information Load, Performance and Working Memory Capacity

This showed that it was the working memory capacity which was the factor controlling success. This was the key breakthrough and much research followed it. When they published their results, the neat quantitative nature of their findings was thought surprising and many repeated the experiment. Similar results were always obtained. Steadily the phrase '*short-term memory*' was replaced by '*working memory*'. This needs clarified. What is now known is that there is a part of the brain where we hold and process incoming information. When this part of the brain simply holds information, it can be seen as a '*short-term memory*'. When it holds information and *also* seeks to process it in some way, then the phrase '*working memory*' is more appropriate. It is now known that we cannot work right up to the limits of our working memory capacity and that partly explains why the performance collapse occurs at about 6. When we think of learning, the working memory is the part of the brain where we do our thinking, our understanding and our problem solving. The long-term memory is essentially a quite massive store. Ideas pass through our working memory and may be stored in the long-term memory for later use.

Working Memory is where we ….

Hold information temporarily.
Think and try to make sense of information.
Interpret and sort out our ideas.
Arrange for new ideas to be stored in long-term memory
Solve problems

Working Memory is …

Fixed in capacity.
Grows with age to about age 16.
Easily overloaded

Working Memory and Success

The capacity of working memory *controls* all our learning when seen as understanding. If we happen to have an above average working memory capacity, then we can handle more ideas at the same time and this leads to greater success in assessment tasks. It also leads to greater success when we are trying to understand in a subject like chemistry.

Further research also led to an important finding. While working memory capacity is fixed genetically, it grows with age to reach its maximum about the age of 16. Thus, while an average 16 year-old school student may have a working memory capacity of 7, the average 14 year-old only has 6 and the average 12 year-old has 5. This explains why certain topics cannot be introduced too early. The younger learner simply does not have enough capacity to handle the ideas. This reveals one of the key problems in a subject like chemistry. Very often the curriculum we are required to teach asks us to introduce topics too early. To understand such topics requires a working memory capacity which few pupils possess at a younger age. For example, concepts like energy are remarkably demanding on working memory while introducing ideas like ionic bonding too early will almost always cause problems. We are asking our pupils to grasp the 'molecular' understandings of chemistry before they have even got to grips with the descriptive aspects.

The limitations of working memory capacity also offers an explanation why so many pupils cannot do the mathematics in a chemistry classroom. The working memory can cope with the mathematics. The working memory can cope with the chemistry. It has insufficient to cope with both *at the same time*.

In some very recent research work, the relationship of working memory capacity with performance has been examined with many school subjects. In this study, Hindal found that the measured working memory capacity of very large numbers of school students, aged 13, did indeed relate to success in a wide range of school subjects. However, looking at many studies, it is clear that the science subjects and mathematics show the strongest relationships.

By their very nature, many topics in chemistry, physics and mathematics are highly conceptual. This means that, in order to understand the concept, the learner has to hold several ideas *at the same time* in their working memory. Examples where this is acute include the concepts of density, acceleration, quantisation, organic structures, the mole and Avogdro's number, ion-electron ideas, and, in biology, the whole area of genetics. The topic of genetics has been known for many years to be one of the most difficult in all biology. Working memory limitations explains why and a recent study has confirmed this.

It is possible to express the relationship between working memory capacity and performance in tests and examinations in terms of correlation. A correlation coefficient indicates, for a large group of students, the extent to which a value in one measurement tends to go along with a large value in another measurement. Correlation says nothing about *why* such a pattern exists and never indicates, on its own, any cause-and-effect in the relationship. Thus, for example, it was found many decades ago that there was a high correlation between cigarettes smoked and the incidence of certain heart and lung diseases. It took further research on the chemicals in cigarette smoke and their effects on human tissue to show that it was cause-and-effect: it was the smoking that tended to *cause* the diseases.

For working memory capacity, the research of Johnstone and Elbanna showed that there was a cause-and-effect relationship between working memory capacity and test performance. The table below shows a few of the results from the literature showing the extent of that relationship as a correlation coefficient. All of the results are high unlikely to have been caused by chance. Indeed, the possibility of any of these results being caused by chance is much less than 1 in a 1000.

Age	Country	Sample	Subject	Correlation
13-15	India	454	Science	0.34
13	Kuwait	641	Science	0.23
15	Greece	105	Chemistry	0.34
13	Taiwan	151	Physics	0.30
13	Taiwan	141	Biology	0.25
13	Taiwan	141	Genetics	0.62
16-17	The Emirates	349	Physics	0.32
16	Greece	90	Mathematics	0.40
11	Pakistan	150	Mathematics	0.69

Table 1 Some Correlations of Working Memory Capacity with Performance

The values of the correlation coefficient can be interpreted in terms of marks. In one very early study, the effect was shown to be very considerable, with a difference of 13% between those with above average working memory capacities and those with below average working memory capacities. Other studies have confirmed this. For example, in a study with Greek school students, it was found that having an above average working memory capacity gave a 16% advantage in Chemistry marks when compared to having a below average working memory capacity. This means that part of a student's success in chemistry depends on their working memory capacity, and this is fixed genetically and not open to expansion.

Now look at the following examination question: '*25ml samples of a solution containing Cu^{2+} were treated with excess potassium iodide and the iodine released titrated with 0.1M sodium thiosulphate solution using starch indicator, 8.25ml being required. Calculate the molarity of the original copper solution*' This is an example where working memory is likely to be be totally overloaded, even for many university students. However, there is a simple way to look at such a question which reduces the load quite dramatically. I shall show that later (see appendix). This leads to an important principle. The limitations of working memory capacity pose very real problems in learning a subject like chemistry. However, there are ways to reduce the problem considerably and we shall look at some of these.

Solving the Problem

It has been shown that working memory capacity will control our ability to understand in highly conceptual areas of the curriculum. Equally, the way we set test questions in chemistry may give a very unfair advantage to those who happen to have above average working memory capacities. It seems that the testing aspect can be resolved without too much difficulty. We need to design questions which do *not* give this unfair advantage to those who happen to have above average working memory capacities. One study in mathematics has shown that this is possible. The test was demanding but the results did *not* relate to measured working memory capacity. This is an important step that we can take in all our in-school assessments.

The simple way to do this is to look critically at our assessment questions and estimate how many piece of information and procedural skills our pupils will have to hold in their working memory *at the same time*, for any prospect of success. Ideally, this should be kept well below the average working memory capacity for the age of our pupils. This will make the question fair for all.

The other main area is to consider how we can *change* our teaching so that the limitations of working memory capacity do not hinder understanding. There are several studies which have now shown that this is possible and these will be discussed later. An interesting idea was published in 1999 which offers a very simple understanding of the problem. This model was based on extensive research and I find it helpful (Figure 4).

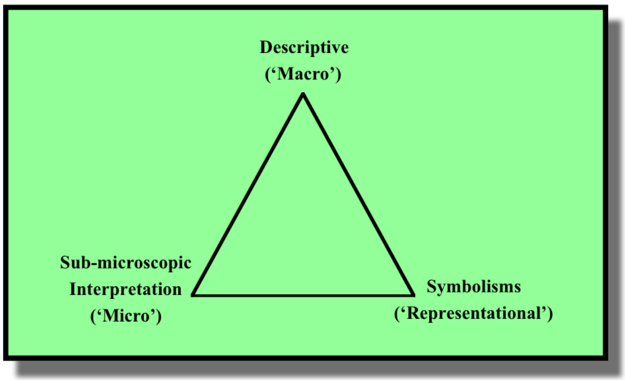


Figure 4 The Chemistry Triangle (Johnstone, 1999)

The point that Johnstone emphasised is that working at all three corners of the triangle *at the same time* creates the likelihood of considerable working memory overload. As chemistry teachers, we are experienced enough to be able to handle the descriptive and relate it to the sub-microscopic while using all kinds of symbolisms to represent what we understand. The novice learner cannot do this: there will be working memory overload. When some of the information is so familiar that it can be handled in an almost automatic way, then this leaves space in the working memory to take on more aspects. He argues that chemistry teaching must start with the descriptive. Only when that is well established can we introduce sub-microscopic understandings. The representational needs to be introduced very gently step by step. There is sound logic to his argument.

More About the Brain

Research throughout the last 30 years of the 20th century has shown that, in fact, there are three main parts of the brain which are important in understanding. These research studies have been published mainly in psychology and educational psychology papers and articles. They are all essentially the same although they can vary in the language they use. Figure 5 shows one diagrammatic representation which represents the research findings fairly well. The key point is to recognise that *everyone learns in essentially the same way*. There has been so much emphasis on variations between learners that this simple fact is often lost. The differences between learners involve minor but important variations *within* a way of learning that we *all* share.

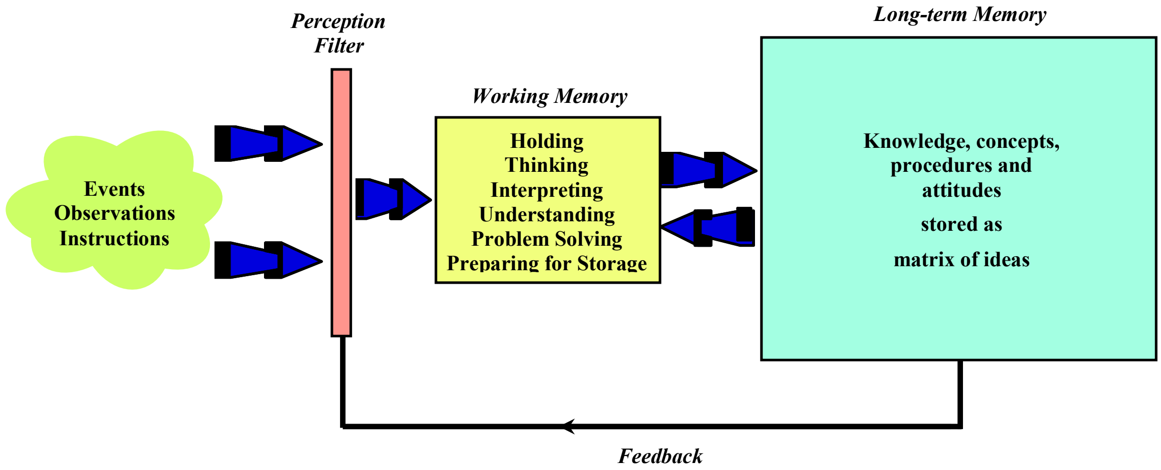


Figure 5 Information Processing

We are surrounded all our waking hours by an onslaught of information bombarding us continually. This comes at us through our senses, mainly our eyes and ears. On order to preserve some sanity, we select very heavily and ignore much of what comes at us. What is selected by the perception filter enters our working memory. It may be stored in long-term memory. Indeed, to understand new information coming at us, we may need to draw into working memory information already held in long-term memory.

The model thus shows the flow of information and this applies to all life, not just school learning. In essence, we take in selected information, process it and then, perhaps store it. The ideal is that we can re-access what we have understood at a later stage and then use it in a new situation, with some chance of success.

If the working memory is overloaded in the holding and processing of new information, then the possibility of understanding is highly remote. The best the learner can do is to memorise. Memorisation simply means we pass the information into the long-term memory where it is stored in an isolated fashion, unrelated to previous knowledge or ideas. Recalling memorised information is never easy at a later date. Think of how much chemistry you learned during your university degree. Much of it you memorised. How much can you recall today?

When faced with a question in a test paper, the information in the test question is taken into the working memory. This then 'looks' into the long-term memory to try to find relevant information and understandings held there which may offer ways to answer the test question. If, at any stage of this process, the working memory is overloaded, then success is almost impossible.

The model shown in figure 5 is supported by vast amounts of carefully conducted research. It makes sense of the nature of understanding and shows clearly why a subject like chemistry is so often difficult. The model is also of great predictive value and some of the predictions have been tested experimentally and shown to be correct. Let us look at some of these predictions.

A World of Predictions

Five predictions have been developed from the model and tested in various research studies. All have been found to be supported.

Predictions from Information Processing

- When selection filter works well, working memory overload is less likely: *better performance.*
- When selection filter is well informed by pre-learning, working memory overload is less likely: *better performance.*
- Chunking skills enable the working memory capacity to be used more efficiently: *better performance.*
- Working memory overload can force the learner to memorise: *attitudes deteriorate.*
- Ideas linked together extensively in long-term memory enable better recall: *problem solving skills enhanced.*

The perception filter selects what will enter the working memory from the world around. If the selection filter works efficiently, then only information of direct relevance to the task in hand will be selected, thus reducing the possibilities of working memory overload as the working memory tries to handle relevant along with spurious information. There is a straightforward test which is used to give a measure of the efficiency of selection and it has been shown again and again that those who have this skill always do better in assessment tasks.

Selection is based on previous knowledge, experience and attitudes. Several studies have show that highlighting key features in long-term memory influences the effectiveness of the next stage of learning. It is rather like drawing to the surface the key landmarks from previous knowledge. These then inform the perception filter and the selection process then tends only to draw in the relevant features of information in future learning. Test performance is found to improve quite markedly.

Working memory capacity cannot be altered. However, the working memory can be used more efficiently. One way of doing this is to enable learners to group information they already hold into 'chunks'. The working memory then handles the chunk of information *as one unit*, releasing more space for other information. This is almost certainly the explanation of the improved examination performance for *some* school pupils brought about by the use of CASE (Cognitive Acceleration in Science Education) materials. The materials give the pupils opportunities to automate procedures and ideas, thus reducing working memory overload. CASE materials do not work for all pupils and this is consistent with the observation that the way working memory can be used efficiently is highly idiosyncratic.

If working memory capacity is overloaded, then learning more or less ceases (except for rote memorisation). This has been found to be true. We humans have an enormous capacity for rote memorisation (and passing examinations using the skill) but this way of learning has consequences. For example, memorised knowledge can rarely be applied in novel situations. Thus, it is of limited value. Secondly, memorisation is not a process which reflects the natural way of learning. Attitudes towards the subject being memorised tend to deteriorate.

When information and ideas are linked up correctly in long-term memory, then they can be applied later. Indeed, research has shown that the more ideas are interlinked, the more these ideas can be used effectively in problem solving situations where the problems are of a novel nature.

Making Learning More Effective

These ideas have been applied in various areas of learning and the outcomes studied. We shall look at some of the research findings as they relate to chemistry teaching and learning. In doing this, I shall summarise a few experiments which have been carried out, some with school pupils and others with university students.

Lecture Type Learning

Although we associate lecturing more with university teaching and learning, it is amazing how much '*teacher-talk*' takes place in secondary teaching. This is inevitable. Information and understandings which are new to the school pupils have to be shared, directions have to be given, and advice and hints offered. School pupils only have an hour or two each week with their teacher in chemistry and it is unrealistic to expect them to discover, without strong direction from us, the insights and understandings which took the best brains in the history of the world centuries to unravel.

Look again at figure 5. The perception filter controls what enters the working memory. However, the perception filter is influenced by what we already know, held in long-term memory. In an amazing series of experiments with first year university students (around 200 each year, for six years), an attempt was made to explore how the efficiency of the perception filter might be enhanced. This was carried out using the idea of the pre-lecture. A pre-lecture involved a series of tasks to be undertaken by the students *before* they started the each formal lecture course, these tasks being based on what they should already have known from their studies at school. By undertaking these tasks, the landmarks of an area of chemistry were highlighted and this meant that, when they faced the new material, these landmarks could guide the students to see what was important. The hypothesis was that their working memories were less likely to be overloaded and understanding would be enhanced. The extent of understanding was assessed by careful scrutiny of examination scripts, analysis of examination performance, interviews and discussions.

Here, we are going to look only at the examination performance. For two years, pre-lectures were employed. With a change of course leader, these were then discontinued for three years. In the sixth and final year, a written form of pre-lecture was developed and offered to the students. Each year group was divided into two: those with better school grades in chemistry ('Upper Group'), and those with poorer grades in school chemistry ('Lower Group'). The university examination outcomes are shown in Table 2 below.

Year Group	Pre-Learning	Upper Group Average (%)	Lower Group Average (%)	Difference between Groups	Difference
1993-94	Pre-lectures	50.9	48.8	2.1	Not statistically significant
1994-95	Pre-lectures	49.2	49.0	0.2	Not statistically significant
1995-96	None	46.9	38.7	8.2	Statistically significant
1996-97	None	48.2	42.0	6.2	Statistically significant
1997-98	None	46.7	41.3	5.4	Statistically significant
1998-99	Paper-based	49.8	47.7	2.1	Not statistically significant

Table 2 The Effect of Pre-lectures

The examinations were very similar from year to year but not identical. The key point to note is that, when some form of pre-learning was used, the students with the less good qualifications from school did as well as as those with the better grades from school. The researchers deduced that preparing the mind for learning was of benefit to all but was of greatest benefit to those who were less well prepared on the basis of their previous learning.

The pre-learning activities brought to the surface of the minds of the learners the important landmarks of the subject matter. This enabled the selection filter to work more efficiently, making working memory overload less likely. A somewhat similar activity occurs in many school lessons when there is time of revision and recapitulation at the start of a lesson before the new material is introduced. This is an excellent practice but it can be used to highlight the landmarks from previous knowledge so that they can guide future learning. This can enable the working memory to function better.

Learning in the Laboratory

Numerous research students have shown consistently that school pupils enjoy laboratory work. However, there is considerable evidence that not too much learning actually occurs. Part of the problem is that some school curricula suggest purposes for laboratory work which are inappropriate. Thus, a simple analysis shows that the vast majority of school pupils who undertake courses in chemistry will *never* become practising chemists. Therefore, the specific practical skills associated with the laboratory are *not* very important. Of much greater importance is to see the laboratory in making chemistry real, in illustrating ideas and beginning to develop the important idea that chemistry, as a science, develops its ideas by means of experimental evidence. Perhaps, these outcomes are best left unassessed but that is another story.

Of course, chemistry laboratory work is expensive in terms of materials and time. It is important that the time is used effectively. In some early research work in the 1980s, it became very clear that laboratories are very demanding in terms of information. Our students face unfamiliar materials, equipment, surroundings. They have to come to terms with written and verbal instructions. Sequences of operations have to be carried out correctly and care is need to follow safety instructions and get 'right answers'. The potential for information overload is enormous and the working memory quickly is overwhelmed. The outcome is that the learners concentrate on following the essential instructions, with no working memory capacity left for thinking or understanding.

Some research in the 1980s and 1990s considered the need for pre-laboratory experiences. Here, in a matter of 15-20 minutes before the laboratory time, university students were given tasks which revised the underlying ideas in the experiment they were to face. As with pre-lectures, the key landmarks of the area of chemistry were highlighted. The students then could face the experiments with a clearer idea of the key ideas and their perception filters would select from all the information coming at them what was of greatest importance, thus reducing the possibility of working memory overload.

In one study in physics, the improvement in performance, in a test specifically designed to assess understanding of ideas and their application in novel situations, showed an average improvement of learning of 11%. In another study in chemistry, understanding was assessed by recording the numbers of questions asked by learners (only questions related to understanding). Working with a sample of about 500, those who had undertaken pre-laboratory tasks asked *less than half* the questions when compared to those who did not undertake pre-laboratory tasks.

We need to recognise that school laboratory experiences can be very variable. For many pupils. the laboratory time is an opportunity to 'rest their brains' and enjoy working informally with classmates, a break from teacher-centred activities! We also need to recognise that the aims for including laboratory work, as set out in curricula, may often be inappropriate. For myself, I see school labwork as a time to make the chemistry real (formula and equations are very abstract) and see how chemistry actually works. Of even greater importance, I see the chemistry laboratory as an opportunity, very gently, to introduce the way that chemistry works to obtain its insights. I would never assess laboratory work at school level and this distorts the learning processes. However, the laboratory is very often a place which is very high on information. Research has shown that working memory overload is common. The idea of preparing the mind for learning in the laboratory is, therefore, important. The pupil can then gain so much more.

Changing our Teaching

In a high concept subject like chemistry, the possibility of working memory overload is very considerable. There are a few research studies which have deliberately re-designed the teaching to reduce the possibility of working memory overload. In these studies, the material to be taught was *not* changed, the time was *not* changed and known areas of learning difficulties were *not* avoided. Indeed, in none of the studies was there any teacher re-training. All that was done was to re-cast the written materials (which provided information input and also directed the tasks the pupils undertook), taking into account the limitations of working memory capacity.

What was done was that the teaching order was sometimes altered and known complex areas were broken down. Graphics and dialogue boxes were used with great care, always seeking to minimise working memory demand. Ideas were sequenced carefully so that new ideas could be built on to ideas which had already been grasped.

In the first study, a sample of over 200 Greek school pupils aged about 15 were divided into two groups. One group were taught by the traditional approaches while the other group had their textbook replaced by new teaching materials. Danili, the researcher, designed these specifically to reduce the load on working memory. At the end of the period of work, the pupils were tested and she found that the group using the new materials performed markedly better than the group following the traditional approach.

In the second study, 800 pupils from the Emirates, drawn from two age groups of older secondary school pupils, were involved. Four very large sections of their curriculum were completely re-cast by Hussein (the researcher), the aim again being to reduce the likelihood of working memory overload. The curriculum was *not* altered in any way but the way it was presented was changed radically. The outcomes were quite remarkable (Table 3).

The table below shows considerable statistical detail. However, the key point is that, in every case, the group using the new teaching materials performed *very much* better than the group following the traditional approach. The researcher used a t-test and this compares the mean marks of two groups to see if one group is performing better than the other. In fact, the t-values are very high and, therefore, the probability that the results happened by chance are extremely low (much less than 1 in 1000: $p < 0.001$).

Group	N	Mean (%)	Standard Deviation	Gain (in Mean Marks)	t Value	Probability
Periodic Table (Year 10)						
Experimental Group	200	79.2	4.8	18.2	26.2	$p < 0.001$
Control Group	200	61.0	2.2			
Chemical Equations (Year 10)						
Experimental Group	200	80.2	9.0	9.2	9.7	$p < 0.001$
Control Group	200	71.0	10.1			
Organic (Year 11)						
Experimental Group	200	71.0	6.7	14.0	19.7	$p < 0.001$
Control Group	200	57.0	7.4			
Acids and Alkalis (Year 11)						
Experimental Group	200	75.0	6.5	10.7	15.1	$p < 0.001$
Control Group	200	64.3	7.5			

Table 3 Improvement in Marks

A third study took place in Taiwan and this did not involve chemistry. Working with younger secondary school pupils, Chu re-cast the entire curriculum in genetics, specifically to reduce possibilities of working memory overload. She found the same pattern of outcomes: a vast improvement in test performance when considering understanding.

These three studies took place in *different* countries, with *different* curricula, *different* ages, and *different* teachers. Nonetheless, they all showed the same pattern of outcomes. Thus, it is possible to re-think the way we teach in the sciences so that the limited working memory capacities of our students is less likely to be overwhelmed. This does NOT mean changing the topics to be taught or complex re-training of teachers. Chemistry, by its very nature makes high demands on limited working memory capacity. As teachers of chemistry, we have shown some measure of success in the study of chemistry. However, the majority of our pupils will see the subject as difficult simply because of its intrinsic high working memory demand. Nonetheless, it is not too difficult to re-think our teaching approach to reduce this demand, making the subject much more accessible to many more school students.

Attitudes to Chemistry

Some have asserted that our pupils cannot do chemistry because they have poor attitudes towards chemistry. Others express the opinion that the poor attitudes towards chemistry are caused by lack of success. It has to be stated that there is no research evidence to support either view. What is found universally is that the students who have less success tend also to have poorer attitudes. There is *no evidence* to show that the lack of success causes the attitudes or vice versa. It seems that lack of success and poor attitudes simply tend to go together, each feeding of the other. However, these kinds of studies do not really help us at all. Indeed, the methods used to measure attitudes in the majority of studies are highly flawed and are not able to give clear answers, but that is another story.

The real question is to ask why so many students are '*turned off*' by chemistry. Is there anything we can do about it? The study by Hussein in the Emirates also looked at attitudes related to studies in chemistry and found something rather amazing. The school students who had experienced the new teaching materials were found to have *dramatically* more positive attitudes related to studies in chemistry when compared to a parallel group of students who had not used the new approach. However, was this cause and effect? Remember that the new materials were deliberately designed to reduce the demand on limited working memory capacity. However, the new materials were also well designed, pupil-friendly and attractive. A later study by Jung in South Korea started to throw some light on the area of attitudes and has offered some key pointers. However, before looking at this study, it is possible to bring together some findings from many previous studies and point out the implications for the sciences. Much of the research has been done in relation to physics while some has looked at chemistry. Biology has rarely been studied in terms of attitudes. Overall, the patterns shown in table 4 are widely supported.

Research Finding	Implication
Interest develops early (by about age 14)	Expend our effort and energy with younger pupils.
Boys and girls are equally interested but areas of interest vary.	Ensure that themes and topics contain a balance of themes to interest both genders.
School teachers have a very critical role	Expend our effort and energy in supporting and resourcing teachers.
Things outside the school have almost no impact	Science Centres, one off events and network TV may be fun. They have very limited lasting impact.
There is a successful curriculum approach	This is based on the concept of applications-led curricula (discussed later)
Integrated science courses are disasters	Chemistry needs to be taught by chemists, physics by physicists and biology by biologists at all secondary levels.
Career potential must be perceived	The considerable career openings for those with school qualifications in the sciences needs to be made explicit.

Table 4 Key Research Findings related to Attitudes

The implications from the research evidence summarised in table 4, on its own, could all be implemented easily. It would generate much more positive attitudes towards subjects like chemistry and physics.

Now let us return to the work of Jung in South Korea. In this study, over 700 school students aged 12-15 were involved. They were following an integrated science course and the Koreans were concerned about the rate of drop out as the pupils chose *NOT* to study the sciences at later stages. Incidentally, this almost always seems to happen when science is taught in an integrated fashion. However, the unusual, maybe unique, nature of this study was that it looked at working memory capacity. You will remember that the capacity of individual pupils is easy to measure. This was done for all 714 students in the study. The measured working memory capacity was then related to the way the pupils saw their studies. Let us look at a few of her findings. Two age groups were involved: ages 12-13 and 14-15.

Sample = 714, Aged 12-15 South Korea	Kendall's Tau-b Correlation
I am enjoying studying science	0.17
Science is interesting	0.13
Sciences is an important subject for my	0.16

Table 5 Interest and Enjoyment related to Working Memory

The pupil responses to various questions was related to their measured working memory

capacity using a statistic called Kendall's Tau-b correlation. In simple terms, what table 5 shows is that there is a slight, but highly significant tendency for those with *higher* measured working memory capacities to say they are enjoying studying science, they find it interesting and that it is an important subject for them. The statistic does *not* tell us if this is a cause and effect relationship.
However, the study went to divide each age group into three groups: those with above average working memory capacities (high), those with average working memory capacities (mid), and those with below average working memory capacities (low). The pupils were asked to say whether they were interested in science or not. Table 6 shows what was found.

Table 6 shows those with *below* average working memory capacities were *much more likely* to say that they were *NOT* interested in science. Again, this does not indicate '*cause and effect*' but the study went on to ask another question which suggested strongly that we were, indeed, looking at cause and effect.
The study asked then how they preferred to study in science.

Are you interested in science?	Age 12-13			Age 14-15		
	High (N = 100)	*Mid (N = 166)*	*Low (N = 98)*	*High (N = 95)*	*Mid (N = 172)*	*Low (N = 83)*
YES	66%	55%	39%	48%	36%	22%
NO	33%	42%	57%	53%	64%	78%

Table 6 Interest in Science and Working Memory

	Age 12-13			Age 14-15		
	High (N = 100)	*Mid (N = 166)*	*Low (N = 98)*	*High (N = 95)*	*Mid (N = 172)*	*Low (N = 83)*
I have tried to understand science	71%	54%	50%	70%	61%	37%
I have tried to memorise science	24%	34%	39%	21%	35%	45%

Table 7 Ways of Learning Science and Working Memory

Table 7 shows how their perceived preferred way of work relates to measured working memory capacity. Although a few pupils did not want to categorise themselves in this neat way, nonetheless the pattern is very clear. There is a strong tendency for those with *lower* working memory capacities to depend more on *memorisation*.
This result has to be seen in the context of some very early work in psychology which showed clearly that the natural way for young people to learn was to try *to make sense of* the world around them. Thus, memorisation is *not* the natural way to try to learn. Pupils actually *want* to understand. However, perhaps they are being forced to memorise in an attempt to pass examinations which possess great power in South Korea.

This reveals the problem. The natural way is to try to understand. However, even when the limitations of working memory capacity make that impossible, the pupils still have to pass examinations. They resort to memorisation to gain success. I suspect we all did a large measure of this when we were studying for our degrees in chemistry. We had to pass, understanding was too demanding, and memorisation offered a way out.

It is possible to see all this as a simple hypothesis as shown in Figure 4.

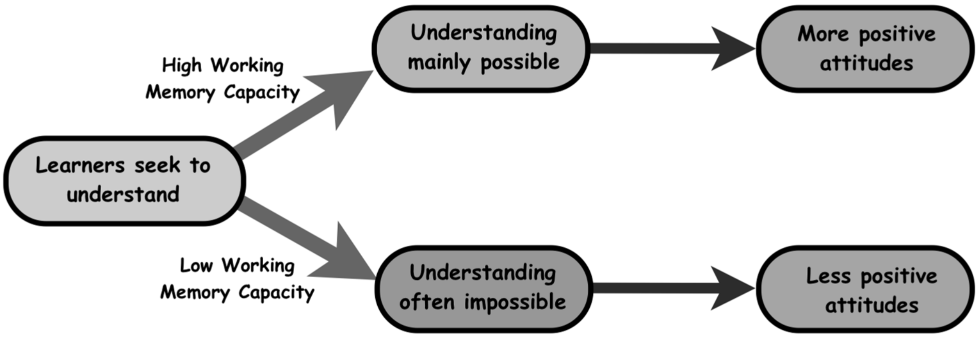


Figure 4 Working Memory and Attitudes

Research has shown that the enjoyment of learning does *not* relate simply to some perception of how easy the subject is seen. Indeed, there are studies which show that more difficult tasks are *more* enjoyable. Enjoyment comes when the learner can be successful in understanding: *making sense of the ideas of chemistry as they relate to their world*. If understanding is not possible because of limitations in working memory capacity, then satisfaction drops rapidly and the pupils attitudes towards their studies in chemistry deteriorate.

You may have noticed that an extra phrase was slipped into the last paragraph: *as they relate to their world.* This comes from many observations which have pointed to what is now called an '*applications-led curriculum*' and this is our final area of discussion.

The Application-led Curriculum

This concept arose from a major study relating to attitudes to physics, carried out by Elena Skryabina in Scotland and encompassing ages 10 to 20. In most countries, attitudes towards physics seem to deteriorate with age but, in Scotland she observed an unexpected pattern. In her work, she used extensive surveys and interviews.

As expected from ages 12-14, attitudes plummetted. In Scotland, pupils follow an integrated science syllabus over this age range and this outcome is in line with what is observed elsewhere. Studies have shown that attitudes towards all subjects tend to deteriorate during this age range, probably due to the onslaught of adolescence. However, the sciences fare much worse than other subjects, almost certainly as a direct consequence of teachers having to teach outside their area of commitment and confidence.

In Scotland, all pupils must take at least one science subject from age 14-16. What was strange was that, for those who chose physics, their attitudes became *markedly more positive* over the two year course from age 14-16. Interviews started to throw light on what was happening. The physics curriculum for ages 14-16 was not built around the traditional topics of physics. The themes studied are shown in Table 8.

Themes Studied
Telecommunications
Using Electricity
Health Physics
Electronics
Transport
Energy Matters
Leisure
Space Physics

Table 8 An Applications-led Physics Curriculum

Looking at the curriculum overall, the same physics was covered as in a traditional curriculum. In other words, the destination was the same; the route to get there was utterly different. Step by step, the physics was unpacked to make sense of aspects of the world around. Much was the world of direct relevance to young people aged 14-16. It was an interesting observation that, when this curriculum was first introduced (late 1980s), teachers often saw it as a dilution of physics. Evidence has now shown that the course laid an excellent basis for further studies in physics and, indeed, the proportion *wishing* to go on with physics (including the girls) was found to be the highest for any elective subject in the Scottish curriculum. In simple terms, there is rigour but also the young people were being '*turned on*' by the physics.

It is very easy to confuse this type of curriculum with curricula that are known that have titles like, '*chemistry in context*'. These curricula seek to *illustrate* traditional chemistry by using appropriate contexts. This is good but we need to remember that the curriculum is still fixed by the logic of the discipline and the contexts may or may not be those of direct relevance and interest to the pupils.

The Applications-led Curriculum

- The chemistry to be taught and its teaching order is determined by the learners: their needs and what is perceived by them to be related to their context and lifestyle.
- In an applications-led curriculum, the destination is the same as the traditional curriculum.
- In an applications-led curriculum, the route to get to the destination is totally different

In an applications-led curriculum, the actual curriculum is *determined* by the applications. Thus, in an applications-led curriculum, the chemistry to be taught and its teaching order is determined by the learners - their needs, what is perceived by them to be related to their context and lifestyle. Chemistry lends itself to this approach and there are exemplars in the literature. One paper, written over a decade ago, advocated themes like:
clothes, washing and dyeing; food and drink; cooking; cleaning; cosmetics and cleanliness; drugs and medicine; colour, decoration; consumer choice, analysis; resources. Another paper, written about the same time, considered it further and, after considerable analysis, suggested the following curriculum structure (perhaps for 14-17 year olds), using five headings:

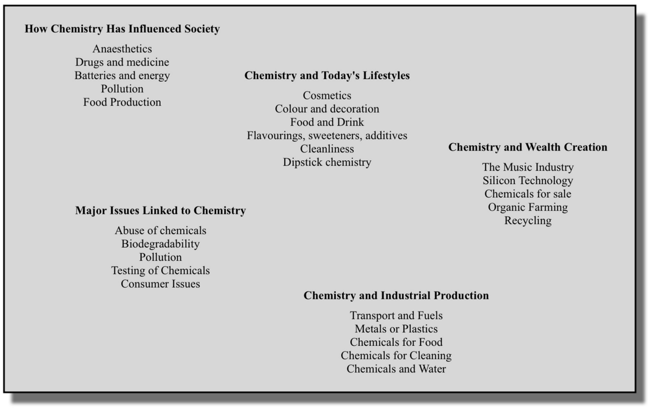


Figure 6 Application Areas of Chemistry

Figure 6 shows a very different way of considering chemistry at school level. An actual example, for a younger age group, is described in the paper:
'A number of years ago, in one school with a mixed social intake, a syllabus that reflected some of the ideas in this paper was introduced. Some five teachers were involved. The course was the first real chemistry that the pupils had met and their age was about 13. The idea of the elements was presented as "building blocks", analogous to the letters in a alphabet that could form an apparently endless array of words. The periodic table was seen simply as a device to display these elements. Over the year, the pupils started to look at their world (the air, water, the sea, rocks and minerals, the atmosphere) with a simple agenda: what elements could be found and what was mankind doing with what was there? Many fundamental chemical ideas just arose naturally, eg. the concept of bonding, reactivity, physical properties of matter, energy and bonds, states of matter. The course was descriptive, based on the world around, applications-orientated, and it avoided quantitative aspects. The effect on the pupils was remarkable. At the end of the year, *every* pupil who was of sufficient ability, *without exception*, opted to take the chemistry course for the ensuing two years.'

Bringing it All Together

A considerable amount of research has been described in this article. The aim is to suggest that we need to base our curriculum development and our teaching on the evidence which has been available through research. I have tried hard to avoid showing my opinions!
Here is a summary to help us as teachers in our work:
(a) We need to recognise that the difficulties for our pupils when they learn chemistry lie in the nature of chemistry itself and in the way we all learn. Chemistry can be highly conceptual and this makes great demands on limited working memory space, often making understanding not easily accessible.
(b) We need continually to challenge our teaching in order to present chemistry in ways which minimise working memory overload. This can achieved, for example, by re-thinking teaching order, by breaking down some areas in parts, by sequencing ideas so that one idea builds on other ideas.

(c) We need to check all our assessment questions to ensure that we are not placing excessive loads on limited working memory capacity. We can look at each question and ask how many things the pupil has to hold and manipulate at the same time in order to get an answer.
(d) Wherever possible, we need to employ pre-learning experiences. Before new topics are introduced, it is important to make sure that the underlying ideas are revised and used as landmarks in learning. Before each laboratory experience, make sure that the key underpinning ideas are revised and brought to the surface.
(e) Always aim at understanding and check regularly to see if this is happening. Make sure that the 'understanding' message is consistent by ensuring that our classroom questions and formal test and examination questions are actually testing understanding.
(f) Relate chemistry continually to the real world experience of our pupils. We may not be able to change the curriculum to be applications-led but we can adapt our teaching to make applications have a dominant focus.

Chemistry learning should be exciting. By its very nature, an understanding of chemistry contributes considerably to our understanding of the world around and how it works. Also, by its nature, chemistry is making discoveries every day. Our aim is to develop the next generation so that they can see something of the contribution of chemistry to our lifestyles and our culture. Of course, a few of them may go on to make their own contributions to new understandings in the world of chemistry.

Acknowledgements

This talk was based on the RSC's 2007 Nyholm lecture which can be found at online free: http://www.rsc.org/Publishing/Journals/RP/article.asp?doi=b801297k
The article here has also drawn heavily from the journal: *Research in Science and Technological Education*, 2009, Volume 27, issue 2. This entire issue is devoted to the theme of Working Memory.
References can be found for the research quoted in one of these sources (mainly the first) and is duly acknowledged.

The Author

Norman Reid is an experienced teacher at both school and university levels. He is Emeritus Professor of Science Education at the University of Glasgow and Honorary Professor of Science Education at the University of Dundee, and is currently President of the Education Division of the Royal Society of Chemistry. He can be contacted at: dr_n@btinternet.com

For More Information

The aim of this article is to offer a readable account of a considerable amount of clear research evidence relating to teaching and learning. Much more can be found in academic papers in various journals but you may not have easy access to these. The following further reading should be more accessible:

The journals entitled *University Chemistry Education* and *Chemistry Education Research and Practice in Europe* combined to form *Chemistry Education Research and Practice.* This RSC journal (including the older titles) is online free: http://www.rsc.org/Publishing/Journals/RP/index.asp

To gain an overview of the whole area, read:

Johnstone, A.H. (2000) Teaching of Chemistry – Logical or Psychological? *Chemistry Education Research and Practice in Europe*, 1(1), 9-15.
Reid, N. (2008) A Scientific Approach to the Teaching of Chemistry, (The Royal Society of Chemistry Nyholm Lecture, 2006-2007), *Chemistry Education Research and Practice*, 9(1), 51-59.

One complete issue [volume 8(2)] of *Chemistry Education Research and Practice* was devoted to laboratory work.

One complete issue [27(2)] of the journal *Research in Science and Technological Education* was devoted to papers on working memory. Your library may be able to get hold of this for you. This issue contains:

The Concept of Working Memory, *Research in Science and Technological Education,* 2009, 27(2), 131-138.
Working Memory and Difficulties in School Chemistry, *Research in Science and Technological Education,* 2009, 27(2), 161-186
Working Memory, Performance and Learner Characteristics, *Research in Science and Technological Education,* 2009, 27(2), 187-204.
Working Memory and Attitudes, *Research in Science and Technological Education,* 2009, 27(2), 205-224.
Working Memory and Science Education, *Research in Science and Technological Education,* 2009, 27(2), 245-250.

Specific papers published in *Chemistry Education Research and Practice:*

Johnstone, A.H. and Selepeng, D. (2001) A language problem revisited, 2(1),19-29.
Johnstone, A.H. and Ambusaidi, A. (2001) Fixed response questions with a difference, 2(3), 313-327.

Danili, E. and Reid, N. (2005) Assessment Formats: do they make a difference? 6(4), 198-206.
Danili, E. and Reid, N. (2006) Some potential factors affecting pupils' performance, 7(2), 64-83

Two papers in University Chemistry Education can be found at:
http://www.rsc.org/images/Vol_5_No2_tcm18-7041.pdf
Johnstone, A.H. and Al-Shuaili, A. (2001) Learning in the laboratory; some thoughts from the literature, 5(2), 42-51
Sirhan, G and Reid, N. (2001) Preparing the Mind of the Learner - Part 2, 5(2) , 52-58

Appendix: Introducing the Concept of Power

The ability of an acid to neutralise a base can be thought of as depending on three factors:

- the volume used
- its molarity
- its 'power'.

For simple acidimetry, *power* is defined as the number of hydrogen ions produced or absorbed by one molecule of the acid or base. Thus, hydrochloric acid and sodium hydroxide had a power of ONE while sulfuric acid and calcium hydroxide had a power of TWO. [The molecule was defined in terms of the written formula.].

This leads to the relationship:

$V_1 \times M_1 \times P_1 = V_2 \times M_2 \times P_2$

(acid) *(base)*

The usefulness of such a relationship in obtaining 'correct' answers is obvious. The argument against using such a relationship is that it could be seen as removing the necessity to *understand* the chemistry of the reaction. However, this is not true in that the reaction has to be understood *BEFORE* using the concept of 'power'.

Consider the following problem:

"Calculate the molarity of potassium hydroxide if 25 mL is exactly neutralised by 10 mL of 0.1 M sulphuric acid."

The student needs to know the formula of the acid and base and, hence, deduce the 'power' of the acid as 2 and the 'power' of the alkali as 1. The rest is easy. If an acid like ethanoic (acetic) is used, the student has to understand the reaction and that only one hydrogen is involved in the formation of water. The method has the great advantages in that it gathers all the variables into one easily remembered relationship which can be applied in a straightforward fashion. This generates confidence for the first-time learner, so important for future success.

Power in Redox Reactions

However, there is another even greater advantage. The same relationship applies to redox reactions as well. Power is now defined in terms of the *electrons lost or gained per molecule or ion of reactant*.

Consider the following analysis.

"If 20 mL of 0.02 M potassium permanganate is acidified and treated with excess potassium iodide solution, iodine is released. When this iodine is titrated against 0.1 M sodium thiosulfate solution, using starch indicator, what volume of thiosulfate would be used ?"

Ion electron equations have to be developed and balanced:

$Mn0_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

$2I^- \rightarrow I_2 + 2e^-$

$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^-$

From these, the relevant values for "power" are easily observed under these conditions:

Power of permanganate ion = 5
Power of iodine molecule = 2
Power of thiosulfate ion = 1

(note: electrons per molecule or ion)
The whole calculation can be done easily:

V x M x P = V x M x P = V x M x P
(permanganate) *(iodine)* *(thiosulfate)*

The student can see easily that all that is need is the the permanganate-thiosulfate relationship, the iodine not being relevant. The calculation reduces to:

V x M x P = V x M x P
(permanganate) *(thiosulfate)*
20 x 0.02 x 5 = V x 0.1 x 1

giving the volume of thiosulfate as 20 mL.

The relationship can be extended to another useful application for technicians. For example, in finding the volume to be added to 900 mL of 0.585 M sulphuric acid to obtain exactly 0.500M acid:

V x M x P = V x M x P
(original acid) *(desired acid)*
900 x 0.585 x 2 = V x 0.500 x 2

This gives the required volume as 1053 mL and the 900 mL must be diluted to 1053 mL.
In passing, the product, VMP, is meaningful and, in the units used above, is the number of millimoles of the reactant. Thus, the method could be extended to calculations where masses are also involved.

Now, give yourself a challenge and try it out on the question given earlier:
'*25 mL samples of a solution containing Cu^{2+} were treated with excess potassium iodide and the iodine released titrated with 0.1 M sodium thiosulphate solution using starch indicator, 8.25 mL being required. Calculate the molarity of the original copper solution*'

You should obtain a value of 0.033M.

Can you see how the formula acts as a chunking device bringing together many pieces of information into one relationship, which then requires only 1 'chunk' of space in the working memory? However, the pupil has to *understand* the chemistry: the reduction of Cu(II) to Cu(I) and the thiosulfate reaction.
Have fun.

******

IT in Chemistry Teaching

How to Get the Most Out of Chemistry Practical Work

T.G. Harrison and W.J. Heslop
Bristol ChemLabS, School of Chemistry, University of Bristol, Bristol
t.g.harrison@bristol.ac and bill.heslop@learnsci.co.uk

Introduction

Bristol Chemical Laboratory Sciences (Bristol ChemLabS) is one of the few Centres for Excellence in Teaching and Learning (CETLs) in science in the UK. It was funded by the Higher Education Funding Council for England (HEFCE) with the aims of raising standards in the teaching and learning of practical chemistry to create a major national resource for the teaching and learning of practical experimental science and also to engage with, and enthuse, students of all ages. The philosophy behind this project is that practical work must form an essential part of teaching and learning in chemistry.

Through Bristol ChemLabS we wished to transform the student experience of practical chemistry, setting a new standard for laboratory-based learning. This was done through (a) the development of state-of-the-art professional-standard teaching laboratories equipped with research-grade instrumentation (b) the creation of e-learning and e-assessment, as well as more conventional teaching methods to improve student experience and (c) establishment of a wide-ranging programme of outreach and public engagement regionally, nationally and internationally.

Traditional chemistry labs at undergraduate level are often considered boring, repetitive and may not be relevant to 21st Century. There is a strong need to enthuse modern students, sometimes called the 'Wii Generation', by making the practical experience fun, more enjoyable and interesting.

Many chemistry teachers will remember their own undergraduate practical classes as perhaps often arriving at the laboratory without a clear idea of the practical techniques to be used and it was only after the laboratory, during the lengthy write up, that the point of the practical was understood and at the same time wishing that a fundamental question had been asked of the demonstrator at the time or realising that a critical dilution had been missed out!

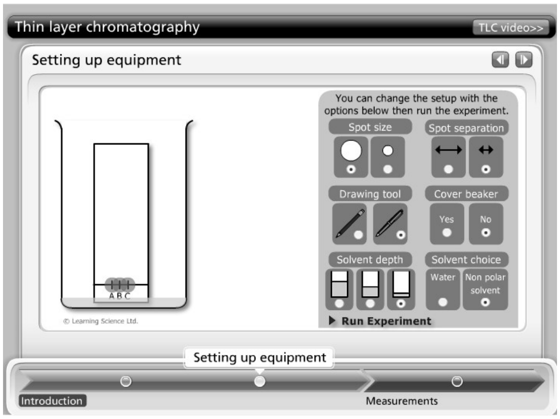


Figure 1 A screenshot of the Thin Layer Chromatography (TLC) simulation

It is clear that trainee chemists will clearly get much more from the laboratory experience if they know what they are doing in advance of entering the laboratory. One of the main ideas in Bristol ChemLabS has been to shift the balance of work outside the laboratory to *before* rather than *after* the practical class, so that students are much better informed and more confident and that practical skills are developed and assessed *in situ*. This makes for better use of valuable lab time. All this work is supported by an e-learning tool called the Dynamic Laboratory Manual (DLM). This concept has been applied to pre-university level chemistry practical work in a software package called A Level Chemistry LabSkills.

LabSkills software contains the full range of practical techniques and skills required of 'A' level chemistry, IB and other pre-university courses (see Table 1). Each of the techniques contains a brief introduction to the technique, a simulation intended to allow students to rehearse practical skills and to find out what is the correct way to set up or use apparatus with error messages explaining the error of students' ways. In this way students can break as much virtual glassware as they like. Once the student has mastered the simulation, there is the opportunity to see video clips of the state-of-the-art apparatus being used, which are broken down to bite-sized pieces, each with the sort of comments that a teacher or demonstrator would give. Following on from this is an interactive section on safety. Just to check the students have been through the whole section there are a few multiple choice/multiple completion questions that the students can print out and hand in to the teacher already marked or uploaded to the school's virtual learning environment. If the school has not got a virtual learning environment an alternative version is available (see breaking news).

Reflux	Titration
Recrystallisation	Titration curves
Filtration	Collection of a gas
Distillation	Enthalpy change of combustion
Solvent extraction	Enthalpy change in solution
Melting point	Colorimetry
Thin layer chromatography	Electrochemical cells

Table 1 Preparation, Purification and Quantitative analysis

The resource includes fourteen self-contained modules covering the main lab techniques commonly used at this level. Each module contains a mix of simulations, videos, safety resources and multiple choice tests (Table 1). Sixteen additional modules consider core laboratory competencies covering basic skills, lab calculations, and chemical tests. Each module contains structured questions with hints and feedback and multiple choice tests (Table 2).

Tests and Observations	Basic skills
Tests for inorganic compounds	Weights and measures
Tests for organic compounds	Preparing solutions
Transition metal compounds	Heating

Table 2 Tests and Basic Laboratory Skills

Five tutorials on laboratory calculations and 5 tutorials on instrumental analysis (Table 3) are included. Each of the latter is explained using simulation of the techniques and photo-tours of the instrumentation. There are twenty widely performed experiments at Post 16 covering preparative, qualitative and quantitative practicals common to most exam boards.

Lab calculations	Instrumental techniques
Stoichiometry and yield	Mass spectrometry
Quantities and concentration	IR spectroscopy
Errors and significant figures	NMR spectroscopy
Reaction rates	GC analysis
Equilibrium constants	HPLC analysis

Table 3 Laboratory calculations and instrumental techniques

These support teachers' own practical scripts (Table 4). There are also drop down reference resources: Equipment glossary with descriptions of commonly used equipment, reagent glossary of descriptions of reagents commonly used at this level, lab health and safety comments, a scientific calculator and of course a Periodic Table.

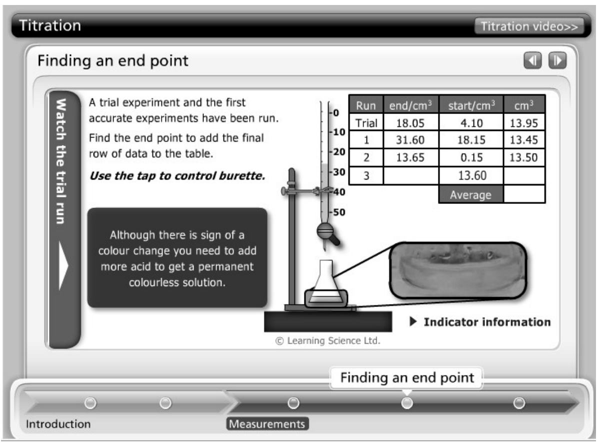


Figure 2 A screenshot of the titration simulation

Oxidation of alcohols	Enthalpy of hydration (Hess's Law)	Enthalpy change of neutralisation
Enthalpy change of combustion	Preparation of an ester	Multi-stage synthesis – aspirin
Preparation of an alkene	Hydrolysis of an ester	Investigating reaction equilibria
Nitration of an aromatic	Preparation of a halogenoalkane	Preparation of chrome alum
Acid / base titration	Iron (II) / permanganate titration	RMM of a volatile liquid
Reaction of iodine and propanone	Iodine / thiosulfate titration	Iodine clock
Identification of an unknown	Preparation of an organic acid	

Table 4 The twenty experiments outlined in the software

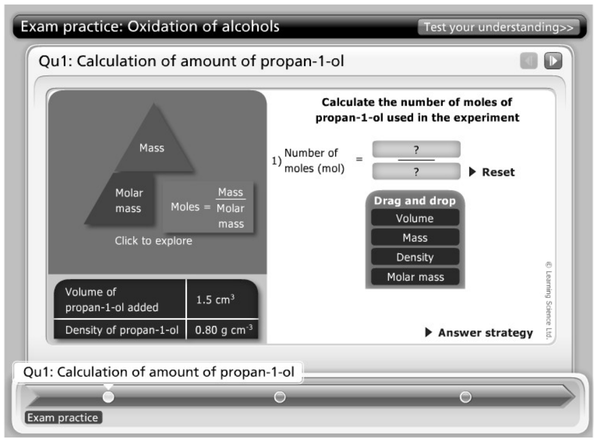


Figure 3 A screenshot of one of the chemical calculation tutorials

Using this resource

How can this resource be used? Several opportunities have been identified. The originally-intended use is that students should be directed to work through specific sections in the lead up to a practical class or assessed practical work. This supported self-study may be used as homework, with the students submitting printed test results. A second use is in the demonstrating of techniques on a white board during class time with the interactive elements being used for whole class review and group discussion. This may be more desirable in schools without virtual learning environments (VLEs) or Management Learning System (MLS). Any lab with computer access during the practical session can run the software as an *aide memoire,* with the glossaries on equipment and common chemicals likely to be of assistance. The resource can also be used as an effective way for students to actively revise practical work away from the laboratory or when repeating a missed practical session is not an option.

The resource is not intended as an e-text book or to replace practical work. This is a software tool, which promises to revolutionise the way pre university practical chemistry is taught, it can enable chemistry students, trainee and newly qualified teachers to carry-out pre-work ahead of practical classes, so maximising the quality of the time they spend in the laboratory. It is an effective leaning resource as it requires students to actively participate in their own learning process. The high level of interactivity requires the students to continually test their understanding of the science and learn from their successes and their mistakes. Instant feedback is given to at every stage which supports students, whatever their level of knowledge and understanding. It has already been hailed as ‘A groundbreaking computer program’ by the *Times Educational Supplement* (TES).

A Level LabSkills for schools and colleges is now the extended course that replaces the AS Chemistry LabSkills previously reported in this journal (Harrison & Shallcross, 2008; Harrison *et al*, 2009). Chemistry LabSkills software is not just having an impact on UK schools in supporting A level and International Baccalaureate (IB) chemistry. Firstly the Royal Society of Chemistry is working with Pfizer on the Discover Chemistry initiative, which centres on the skills needed to ensure the chemical industry continues to thrive in the UK. As part of this initiative Discover LabSkills has seen around 1100 trainee chemistry teachers presented with either AS Chemistry or A Level chemistry LabSkills over the last two years, to support their teaching development during their PGCE courses. Secondly, universities in Australia, Canada, South Africa and the Far East are either already using or are about to use a version of the software ‘’Foundation Chemistry LabSkills. They are very interested in using it as they have large numbers of first year undergraduates whose starting point for practical skills development is at a similar point to Post 16 UK students.

Breaking News

As a consequence of discussing Chemistry LabSkills with teachers at the conference in Limerick in 2009 it was decided to produce a version of the software resource that does not rely on a school having a virtual learning environment available. Instead the Chemistry LabSkills Teacher Edition has been produced, where the software runs from a memory stick allowing teachers to use the resource in a whiteboard mode. For more information please see www.labskills.co.uk web site.

A practical skills revision version for students, the LabSkills Student Edition, which has reduced functionality, is available through www.amazon.co.uk.

References

T.G. Harrison, D.E. Shallcross, W.J. Heslop, J.R. Eastman & A.J. Baldwin ‘Transferring Best Practice From Undergraduate Practical Teaching To Secondary Schools: The Dynamic Laboratory Manual’, Acta Didactica Napocensia, March 2009, **2**(1), pp1-8. Also available at: http://adn.teaching.ro/v2n1.htm (last accessed December 2009).

T.G. Harrison and D.E. Shallcross**,** 'A Chemistry Dynamic Laboratory Manual for Schools’, Chemistry in Action, **86**, Winter 2008, pp20-22. Also available at http://www.chemlabs.bris.ac.uk/CinA86Winter2008p20-22.pdf (last accessed December 2009).

Contact information:

Timothy G. Harrison, Bristol ChemLabS, School of Chemistry University of Bristol, UK t.g.harrison@bristol.ac and corresponding author, William J. Heslop, Learning Science Ltd, Bristol, UK bill.heslop@learnsci.co.uk

□

A practical response to the promotion of inquiry in chemistry in Irish secondary schools

John O'Reilly
Department of Educational and Professional Studies, University of Limerick, Limerick
john.oreilly@ul.ie

Introduction

Chemistry education in Ireland stands at a crossroads, with a variety of forces acting on future developments. The number of students taking chemistry through into higher education remains low, despite the recent increases in CAO applications for science courses. Various stakeholders have highlighted the urgent need to address this. The government, through the Strategy for Science, Technology and Innovation (2006, p.10) proposes a focus on investigative approaches and assessment of practical work.

"The strategy proposes to increase participation rates in the science subjects by:- i) reforming the science curricula for leaving certificate, ii) investment in continuous professional development and networks for teachers, iii) awareness promotion and the provision of guidance materials, iv) rebalancing the content of the science curriculum in the direction of problem solving and v) revisiting the issue of technical assistance for schools to facilitate practical coursework."

The necessity of developing a project-based, hands-on investigative approach and an ability to assess practical work is emphasised. The National Council for Curriculum and Assessment (NCCA) is in the process of responding to this by developing a revised senior cycle curriculum with a focus on key skills and in the context of the science syllabi is placing a strong focus on inquiry-based teaching and learning.

This action in Ireland is very much in keeping with ongoing efforts in Europe which are guided by the Rocard Report (2007) that recommends (p.7) a *"reversal of school science teaching pedagogy from mainly deductive to inquiry-based methods"*. Significant funding has been devoted to this and currently the Fibonacci network is coordinating the dissemination of inquiry-based resources in primary and secondary schools across 21 member states. Fibonacci builds on the successes of the Pollen (primary schools) and SINUS-TRANSFER (secondary schools) networks.

The common denominator here is change, which presents significant professional development challenges in the areas of teaching, learning and assessment for teachers, who will be tasked with realising these (potentially) radical reforms.

What is Inquiry-Based Science Education (IBSE)?

Traditionally science is taught in a deductive way ("top-down") – the teacher presents concepts, their logical implications and helps students to apply these ideas. IBSE proposes an inductive approach ("bottom-up"), where students are involved in Problem-Based Learning (PBL) through inquiry. Inquiry is defined (Linn, Davis, & Bell, 2004, cited in Rocard, 2007) as the

"process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments"

PBL is based on problem solving to drive learning, where new knowledge must be gained in order to solve the problem and students evaluate and critique their own arguments and findings.

While there is uniform agreement amongst policy makers of the need to develop teaching approaches that promote IBSE across Europe, there is also the recognition that inquiry is not precisely defined and that different countries and cultures may value some aspects of inquiry over others. It is difficult to be precise and detailed as to what exactly IBSE would look like in practice.

Educational Change

This "fuzziness" in interpretation has been addressed by the dissemination of IBSE resources and Continuing Professional Development (CPD) for teachers in the Pollen and SINUS-TRANSFER networks. It is critical that these resources be developed by and for teachers in a manner that mirrors the "bottom-up" approach advocated by IBSE itself – no professional group appreciates change being foisted upon their members.

An approach to IBSE must recognise the realities of the nature of teachers' work including time constraints, the pressure of exams, resource limitations and the upheaval that can be caused by a shift in teaching, learning and assessment. Fundamentally change must not assume that teachers will accept directives on faith because someone else has worked it out. Fullan (2007) recognises the all-encompassing nature of educational change and the critical role played by teachers:

"Reform is not just putting into place the latest policy. It means changing the cultures of classrooms, schools, districts, universities/ and so on."(p.7)

"Educational change depends on what teachers do and think – it's as simple and as complex as that" (p.129)

Teachers then must be given the opportunity to contribute to reforms themselves, decide on their worth and then allow time for the majority to make sense and meaning of changes in working practice, to order to decide whether innovations are worthwhile. Even when such provisions are made, reforms more often than not fail. An analysis of the literature on educational change would indicate that some of the causal factors that affect failure are:

- Lack of curricular alignment: the new approaches to teaching and learning are not adopted because the assessment system does not evaluate them.
- Lack of engagement with policy makers: most educational research focused on change does not engage with policy makers at all.
- Lack of understanding of objectives of change: the rationale for changes in teaching approaches is unclear. As a result the pedagogical basis for change is unclear.
- Lack of ownership: there is a sense that change must be accepted as a matter of faith and that research is "done" to teachers with no practical advantage to them.
- Lack of funding: often change is undermined simply because funding cannot be made available to support infrastructure development, training and sustainability.

Penuel (2009) describes an interesting case study, where reform failed despite significant investment of resources to promote the GLOBE project, a respected international program for environmental science. Multiple schools were involved and alignment maps were provided during significant in-service workshops, that described how teaching, learning and assessment were linked and integrated. The workshops involved hands-on experience and provision of mentors and equipment. Despite this (p.657)

"Teachers using reform-oriented curriculum materials enact them either to a limited extent or in ways that do not reflect the intentions of designers."

It is suggested that a lack of ownership and clear understanding of the objectives of change were the principle causes of failure. In order for change to occur Fullan (2007) argues it is necessary to develop a "bias for action" and that beliefs change as a function of action i.e. we need to act in new ways in order to gain insights and that through this a shared vision and ownership can emerge.

What kind of infrastructure can provide a platform for this "bias for action" and how can it address the issues above?

A Virtual Chemistry Laboratory for Irish Post-Primary Schools (VCLIPPS)

VCLIPPS is a "Virtual" chemistry laboratory, that is, a functional laboratory space (in 2D) within which you can perform experiments and get results (including "messy" data), that would be in keeping with what you would expect in the real world. It is built on an existing virtual laboratory developed by Carnegie-Mellon University

(CMU), which provides an open environment with a strong focus on stoichiometry and acid-base chemistry. You can access it (freely) here at http://www.chemcollective.org/ through the "Run Virtual Lab" link on the left hand side. The interface is quite intuitive and easy to use. An example of VCLIPPS in action illustrating both functionality and how it can exemplify IBSE is described below.

We are testing this laboratory in the Irish context and adapting it on the basis of feedback from all stakeholders, with a particular focus on teachers and students. This research is predominantly being conducted by Dermot Donnelly, a research student who is funded through an Irish Research Council for Science, Engineering and Technology (IRCSET) Embark Fellowship. Dermot has interviewed all major stakeholders in the development of Chemistry education in Ireland to ascertain their opinions relating to IBSE and how VCLIPPS might serve a useful role in teaching, learning and assessment. He is currently working with a cohort of teachers who have kindly agreed to trial the virtual lab in teaching sessions that are observed and discussed. Students are also consulted at the same time and it is hoped that further student input will be gained through this year's SciFest. VCLIPPS is also being tested with trainee teachers in Initial Teacher Education, to determine its impact on student teachers' confidence, understanding of the nature of science and IBSE. Finally, an experiment is underway to compare VCLIPPS to the real laboratory and determine what differences in learning exist (if any) between the two approaches.

Funding is being sought to adapt the software according to feedback received from stakeholders, improve the interface and add the capacity to incorporate real-time graphing, gas phase reactions and kinetics. The latter will allow for the simulation of synthesis experiments.

It is intended that VCLIPPS will be housed in a Virtual Learning Environment (VLE) like Moodle, to enable ready access to IBSE problems across the entire syllabus and to allow teachers to design and contribute new problems. This will allow for a high level of ownership, placing teachers in the role of curriculum makers (Moonie-Simmie, 2007).

VCLIPPS is addressing the factors identified in the research background above as follows:

Lack of curricular alignment: A virtual lab provides an ideal infrastructure for the assessment of inquiry. We aim to embed VCLIPPS into the revised leaving certificate assessment, where students would download and solve authentic chemistry problems several times over the senior cycle. Students will first write an experimental plan, explaining their reasoning and everything they manipulate will be recorded in the lab. Their plan can be altered in response to their results and a conclusion written. Examiners would therefore have a unique insight into the students' process thinking and would assess their work using an inquiry rubric. The fact that grade is being awarded for this effort will then encourage changes in approaches to learning and therefore teaching.

Lack of engagement with policy makers: We are working strongly with the National Council for Curriculum and Assessment (NCCA), who support the basis of this work and our research methodology, in particular the potential of VCLIPPS to serve as an assessment instrument. The Second Level Support Services have also indicated their willingness to support the dissemination of VCLIPPS. We are also in communication with the Inspectorate and the State Examinations Commission (SEC), who we wish to work with to ensure maximum reliability and validity of the assessment of inquiry-based learning. Interviews have also been conducted with those who inform policy makers, to include key figures in chemistry education and industry.

Lack of understanding of the objectives of change: VCLIPPS will allow for the development of a critical mass of high quality, inquiry-based chemistry problems that will be incorporated in a VLE, that will include teacher and student interviews, classroom video of use, discussion forums (where problems can be discussed and new ones added) and a description of how the teacher's Pedagogical Content Knowledge (PCK) has changed through engagement with VCLIPPS. This will therefore make teaching through inquiry very "visible" and accessible and facilitate teachers "giving it a go" in their classrooms. Early data indicates that students take very quickly and enthusiastically to this approach.

Lack of ownership: This work is being developed by Irish teachers, for Irish teachers. We are trying to develop structures that support teachers to interpret and adapt to new ways of teaching, to develop a bias for action and to become curriculum makers. It is important that the feedback we receive from teachers regarding changes they would like to see in the lab is acted upon.

Lack of funding: Many schools are hampered by a lack of equipment and time to conduct experiments which promotes demonstrations and/or a recipe approach to science. VCLIPPS could provide a ready solution to this although it is important to note that it does not seek to replace practical laboratory work but to support it through an emphasis on process. VCLIPPS would also minimise the costs associated with assessing practical work.

It is critical to note that VCLIPPS does not seek to replace real, practical work but to support it by allowing for thought experiments to be conducted virtually, to alter say the variables from a previous experiment (concentration, species, temperature, etc.) and see what effect they would have.

Example of VCLIPPS in use

This example is focused on a relatively simple problem relating to the concept of density, which offers a good illustration of how students can be challenged to consider factors that are normally decided for them e.g. quantities of substances to use. Here the student is presented with a problem: s/he has three jars of metal powder from which the labels have been removed. S/he is given a table listing the densities of the likely metals contained in the bottles. The student starts by producing a plan shown in Figure 1.

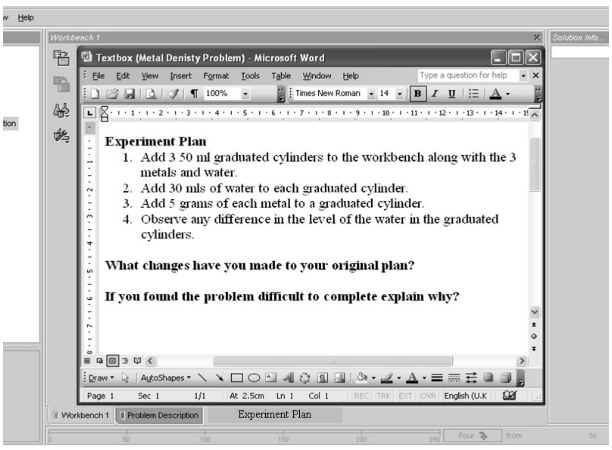


Figure 1 The Student Plan

In the final version of VCLIPPS the planning software will be integrated into the software and we are considering the possibility of including a hints system, so that students can use it to make a start even if completely stuck. Here the student has understood that s/he can determine the density by measuring the mass and volume of water that the metal displaces (= volume of metal) and compare these values to the table to identify the metals. The student has also decided to use a graduated cylinder and on the appropriate amount of water and metal. In Figure 2 the experiment is under way.

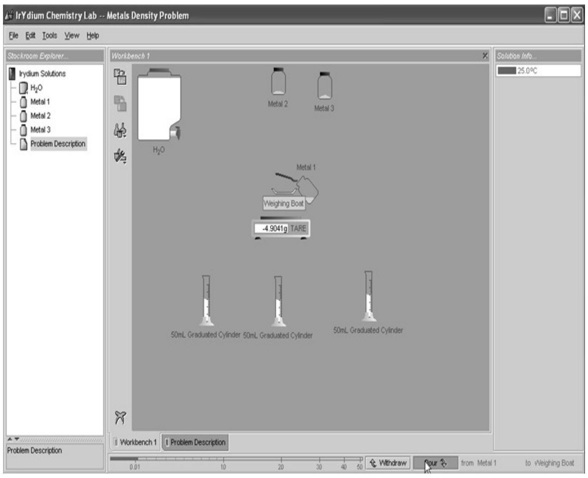


Figure 2 Conducting the experiment

Note that the data is "messy" and each use of the spatula withdraws a different amount of metal – the bar on the bottom can serve as a rough indicator.

Figure 3 shows a zoomed-in view of the experiment after the metals have been added to the graduated cylinders, where the volumes have only marginally increased from their initial levels. Note the student had used different initial volumes in each cylinder. The small volume change makes it very difficult to determine an accurate density reading.

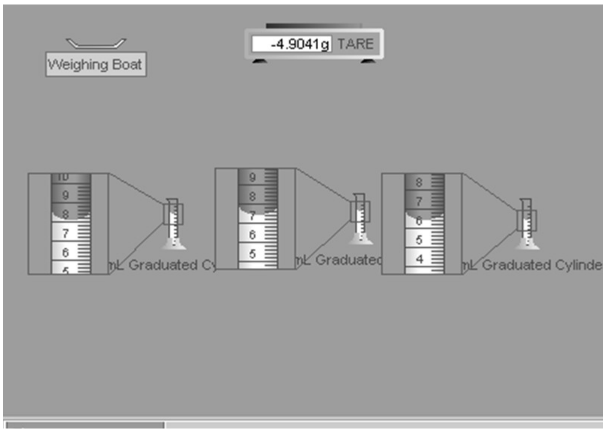


Figure 3 The zoomed-in view

In Figure 4 the student has revised his/her plan to add much more metal, perhaps recognising that a much larger quantity is required to see a visible displacement (since the densities are of the order of 20 g/ml) or perhaps through trial and error. In both cases there is useful learning that can be expanded upon by the classroom teacher.

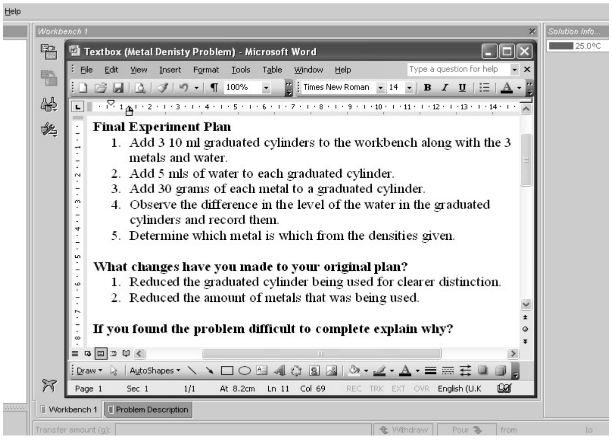


Figure 4 The revised plan

Note the error – the amount of metal has actually been increased!

Hopefully this serves as a useful illustration of how VCLIPPS can give insight into student thinking to the teacher, how it can provide a scaffold for inquiry (with an appropriate level of challenge) and how it might be used (with an appropriate rubric) for assessment. It can be used in a one computer classroom or in a computer lab. Many more sophisticated problems exist to include a wide selection of acid-base and equilibrium problems and challenging, application-driven problems that, for example, task students with trying to develop a cheap but reliable approach to determining the concentration of arsenic in drinking water in Bangladesh.

If sufficient problems can be developed by teachers to encompass the whole syllabus and therefore enable an inquiry-based approach, it is hoped that this will greatly facilitate teacher engagement with IBSE and encourage the community to continue to develop and add problems to VCLIPPS.

Conclusion

VCLIPPS has the potential to address the goals outlined in the SSTI, through giving teachers the opportunity to critically engage with and shape the change process. If adopted in practice it has the potential to continually evolve through the input of problems designed by teachers. In this way an understanding of IBSE unique to the Irish context will be developed. Both Fullan (2007, p.92) recognises that

"To achieve large scale reform you cannot depend on people's capacity to bring about substantial change in the short run so you need to propel the process with high quality teaching and training materials (print, video, electronic)."

and Penuel (2009, p.659) also states that

"Sustained, content-focused professional development is key to helping teachers gain practical knowledge of specific curricular activities and develop an understanding of what classroom instruction with the materials should look like."

They recognise the critical need to make the change process visible and explicit in action and it is hoped that in this way VCLIPPS can act as a scaffold and be of significant service to Irish teachers.

Collaborators in this work include Carnegie-Mellon University, University of Pittsburgh, the Digital Enterprise Research Institute (NUIG), Dr. Declan Kennedy and Dr. Odilla Finlayson.

The author would like to thank Dr. Peter Childs for the opportunity to present this work at Chem Ed-Ireland 2009 and wish him a happy and active retirement. Thanks also to those teachers who became involved at that time. Anyone interested in participating or getting further information can contact the author at John.oreilly@ul.ie

References

Fullan, Michael (2007), *The New Meaning of Educational Change*, 4th edition. Teacher's College Press'

Moonie-Simmie, G. (2007), 'Teacher Design Teams (TDTs) – building capacity for innovation, learning and curriculum implementation in the continuing professional development of in-career teachers', *Irish Educational Studies*, 26(2), 163-176

NCCA Science Reform, accessed 18th February 2010 http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Senior_Cycle/Senior_Cycle_Developments/Science/Science.html

Penuel, W., Fishman, B., Gallagher, L., Korbak, C., Bladimir, L-P. (2009), 'Is Alignment Enough? Investigating the Effects of State Policies and Professional Development on Science Curriculum Implementation'. *Science Education*, 93(4), 656-677

Rocard Report (2007), *Science Education Now: A renewed pedagogy for Europe*, accessed 18th February 2010 http://ec.europa.eu/research/science-society/index.cfm?fuseaction=public.topic&id=1100

Strategy for Science, Technology and Innovation, (2006), Department of Enterprise Trade and Employment, accessed 18th February 2010 http://www.entemp.ie/science/technology/sciencestrategy.htm

□

Dr. John O'Reilly is a Lecturer in the Department of Educational and professional Studies at the University of Limerick. He has a first degree and a PhD in Chemistry. This paper describes the development of a Virtual Chemistry Laboratory for Irish Post-Primary Schools (VCLIPPS) that will begin testing in the context of the NCCA trials of the revised chemistry syllabus. VCLIPPS aims to support the teaching, learning and assessment of inquiry-based approaches to chemistry education and is engaging with all stakeholders including state agencies, teachers and students.

Colorimetry made easy – the Mystrica colorimeter

Douglas Macdonald
Mystrica, 39 Charterhall Road, Edinburgh EH9 3HS, Scotland, UK
mystrica@blueyonder.co.uk http://www.mystrica.com

Anything involving colours and colour changes is of interest to students. The results of experiments are directly observable, unlike some changes than can only be detected through the intermediary of instrumentation. With a colorimeter the effects can be measured and the changes quantified creating an immediate and relevant link between observation and measurement. Colorimetry can create opportunities for students across the secondary age range and be an exceptionally useful tool in the development of the vital scientific skills of observation, accurate measurement and the analysis of numerical data.

The Mystrica colorimeter (Figure 1) has been developed by practicing teachers as a small, versatile, accurate and affordable instrument. Class sets could be used by small groups of students of any age and ability and it is ideal for more advanced work such as individual student projects. Stand-alone it is easy to operate and it can also be connected through a USB link to a computer running the simple software that is free to download.

Figure 1 The Mystrica colorimeter

The colorimeter uses three LEDs as its light source, red (~630nm), green (~525nm) and blue (~465nm). Either absorbance or transmittance can be selected. The four button keypad controls power on, the selection of colour, selection of absorbance/transmittance and calibration which sets the value of the blank (usually water) to 0.000A or 100.0%T. Samples are placed in standard glass or plastic cuvettes with a maximum volume of 4cm3. The minimum volume that can be used with accuracy is 1cm3. Its small size and robust construction mean that it needs little storage space and can withstand normal classroom environments.

Accuracy and reliability

The Mystrica colorimeter gives a linear response throughout the range of 0-2A (1-100%T). This is determined using strips of neutral density filter as shown in Figure 1.

A comparison of ten units that had been in continuous use in a school for fifteen months showed all working perfectly and with a standard deviation of only 0.003A (standard solution with absorbance of approximately 0.4). SSERC (Scottish Schools Equipment Research Centre) tested the Mystrica colorimeter and concluded that ‘The Mystrica colorimeter represents excellent value for money as a simple, robust and reliable colorimeter for use in schools/colleges’ (SSERC Bulletin, summer 2009).

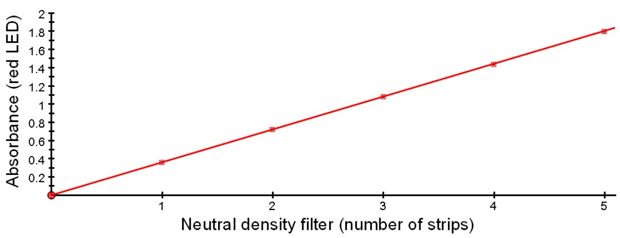


Figure 2. Linearity of response of the Mystrica colorimeter over the range 0 - 2A

Applications

Many of the potential uses of the colorimeter are described on the website www.mystrica.com and include the study of rates of reactions and reaction kinetics, the determination of concentrations of coloured ions and molecules, enzyme reactions and population growth. Preparation of a standard curve and measurement of chlorine in water is illustrated in Figure 3. The method described uses a little starch in the potassium iodide solution to generate the blue starch-iodine complex and increase sensitivity. The chlorine levels typically found in domestic tap water can easily be measured.

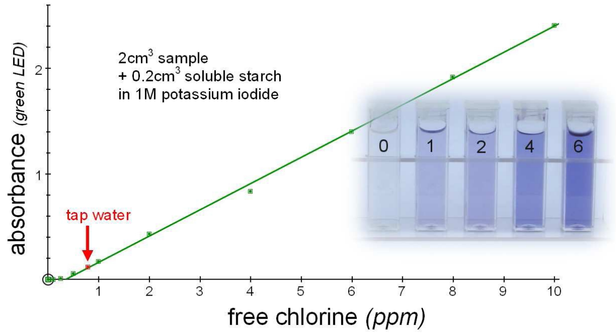


Figure 3 Measurement of chlorine in water samples (typical tap water values would lie within the range 0.3 - 3ppm)

Figure 4 shows an example of the results obtainable using the colorimeter linked to a computer. The graph of absorbance versus time for the iodination of propanone should give a straight line since the reaction is zero order with respect to iodine concentration. This graph appears in real time creating an eye-catching and easily understood visualisation. A class of students working in pairs could produce a complete set of reaction kinetics varying the concentrations of iodine, acid and propanone in a one hour lesson.

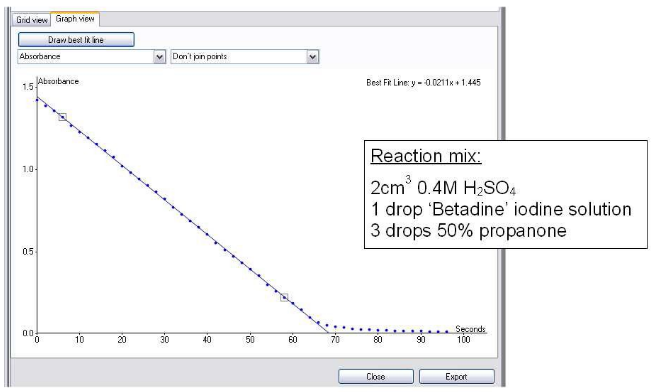


Figure 4 Iodination of propanone (screenshot from Mystrica software showing line of best fit through selected points).

Availability

The Mystrica colorimeter is available through most suppliers of scientific equipment to schools or from Mystrica Ltd, (www.mystrica.com). Priced at around €130, including cuvettes, cuvette stand, USB link and free software, it is a fraction of the cost of comparable stand alone instruments. There are some comparably priced datalogger colorimeters but these can only be used when connected to secondary devices (computers/dataloggers). The multifunctional nature of dataloggers means that their software is generally quite complicated. Many teachers have been put off their use for this reason. The Mystrica colorimeter is ready to go and its single purpose enables the software to be kept simple. With instruments such as this it should be possible to bring quality data collection within effective reach of students and teachers throughout the curriculum.

□

After obtaining a PhD in genetics from Edinburgh University, Douglas MacDonald has spent the last 25 years teaching science in a variety of schools in UK and overseas, most recently as Head of Science at the British International Schools in Jakarta and Cairo. Now back home in Scotland, he divides his time between teaching and the development of equipment and ideas to enhance practical science.

Subject-specific professional development at the National Science Learning Centre, York, UK

Miranda Stephenson
Programme Director, National Science Learning Centre, Heslington, York

Introduction

The National Science Learning Centre has been in operation since November 2005. Funding comes from the Department for Children, Schools and Families, the Wellcome Trust and a number of industries (Astra Zeneca, Astra Zeneca Science Teaching Trust, BAE systems, BP, General Electric Foundation, GlaxoSmithKline. Rolls-Royce, Vodafone and Vodafone Group Foundation).

Some of the reasons that the funders got behind the initiative are captured in reports such as the CBI Education and Skills Survey which indicated that 40% of employers prefer to recruit people with Science or Mathematics qualifications. Interestingly research shows that people holding these qualifications at A level are far more likely to command higher wages (whether or not their employer knows about the qualification!).

Additionally, at the beginning of 2000 the number of students opting to study the physical sciences, technology, engineering and mathematics at A level and in Higher Education was in decline, which was of real concern to the government as the UK economy relies upon STEM related industries.

"It is essential to have young people prepared to become the engineers, research scientists and doctors of the future. It is essential, but not enough. Developed countries also need a population who understand science, and are critically aware of its implications."
Sara Parkin, Forum for the Future

So the challenge was to make science education more attractive to encourage more to continue with their studies, but also to enable the larger population to also understand its relevance and importance to society's needs.

The national network of Science Learning Centres

The National Science Learning Centre and a network of regional Centres was set up to provide high quality professional development to teachers of science and school technicians from the primary and secondary sectors (including those teaching in Further Education, but not Higher Education).

The courses provide participants opportunities to explore

- pedagogical content knowledge (what does science education research tell us about young people's knowledge and skill and the implications for the classroom, how well do teachers know their subject and are they able to teach it to a range of learners),
- contemporary science (what are the big scientific ideas which young people should know about, how does science

research occur and what are the implications for the classroom)
- creativity and innovation (how can we increase young people's engagement in their learning with a view to encouraging more to take their studies further, or indeed to pursue careers in science-related areas)
- Leadership (teachers and technicians develop leadership skills to ensure their schools and departments aspire and achieve excellence in practice)

The network of Science Learning Centres covers the UK and Ireland through the work of the National Science Learning Centre.

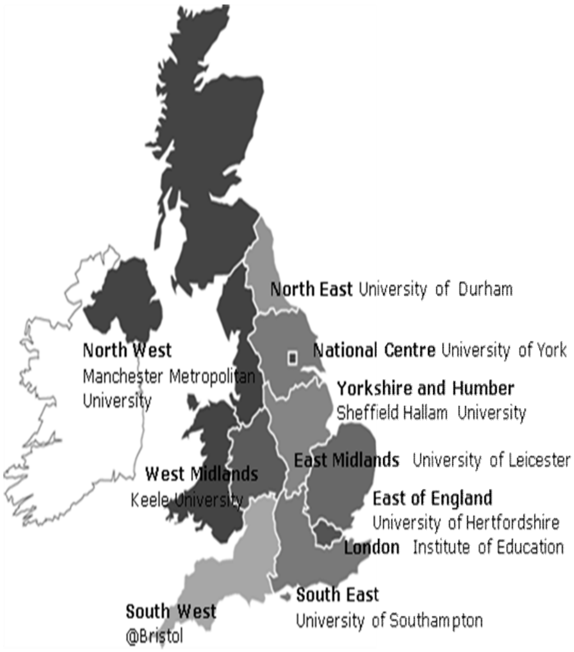


Figure 1 Location of Science Learning Centres

Thus teachers of science in Ireland are not only eligible to attend the courses at the National Centre; they are also eligible for a significant bursary known as the ENTHUSE Award. The Award covers the course fees, the costs associated with hospitality, and makes a contribution towards costs associated with travel, replacement teacher or cover costs and if anything is left over from the bursary the school can use this towards new science equipment (more details are on our portal).

The National Science Learning Centre will guarantee that participants on the courses receive professional development which is of exceptionally high quality, often connecting them with contemporary science and modelling leadership, and always providing new pedagogical ideas based on evidence from research, experience or good practice drawn from the teaching community.

So who is eligible to come? Courses are targeted at:

- Secondary and post-16 science teachers
- Secondary and post-16 heads of science
- Primary science teachers
- Primary science coordinators or subject leads
- Further Education lecturers
- School and college science technicians
- Other support staff in the science classroom

The courses cover all sectors (primary, secondary and post-16) are aimed at people at the start of their career to those who are experienced and/or in leadership. In 2009/10 we are offering over 90 instances of 70 different courses which can be found on our portal https://www.sciencelearningcentres.org.uk. Just click on any pink area of the map, then the course and events link, to see what is available till the end of this academic year. By the way, registration on the portal is quick and free and gives users access to many resources which are useful in science teaching.

The courses are led by a team of Professional Development Leaders, all of whom are experienced teachers. However, as the courses tend to be 4 – 5 days long, delivered over two residential periods these leaders draw upon contributions made by science education researchers, practicing scientists and engineers, excellent teachers and other specialists.

From April 2010, participants will be able to link their professional development experience to an opportunity to receive professional and/or academic recognition (but that's a story for a separate article!). If you are interested please do contact me.

Our internal monitoring of impact tells us that the percentage of participants who aim to:

- change their own teaching practice is 45%
- make improvements in pupils learning is 25%
- work with colleagues in improving practice across the department or school is 20%

- introduce new activities is 20%
- improve pupils' motivation is 10%
- improve leadership skills is 6%

> Ideas I obtained gained great responses from students back in school, who enjoyed more chances to discuss and articulate their thoughts. Mark Furneaux, who came on *New approaches to teaching Physics*

Most participants express a combination of these targets.

Because the courses have a second residential period, we ask the participants to share the impact their planned activities have had back in school or college.

Here are two brief studies to give you a picture of what we hear.

Lyndsey Cannell, Hawkley Hall High School
Science in an Engineering Context

Lyndsey was totally fired up and planned *"to incorporate engineering into everyday lessons and into her departments schemes of work".*
She's involved her department, her assistant head and the pupils have enjoyed an engineering week in school, which also looked at career opportunities.

Emma Hawkey, International School and Community College, Birmingham

Advanced skills for science technicians
Emma said *"I am now running local meetings for technicians and sharing with them the ideas I picked up on the National Science Learning Centre course.*

The staff and pupils at my college are pleased with the exciting range of demonstrations I've introduced them to."

Figure 2 In the picture, Emma is introducing her teaching colleagues to new demonstrations

Around 94% of our participants report to us that they have systematically worked on new activities, often with colleagues, to improve the quality of science teaching in their school or college.

The McKinsey report which looked at how countries achieve excellence in education stated: ***"****Above all, the top performing systems demonstrate that the quality of an education system depends ultimately on the quality of its teachers"*

As teachers we are constantly being creative, and giving enormous energy to ensure students are given our best. This takes its toll on us as individuals. The courses we offer give teachers and technicians time to step back and reflect on their practice. The courses are full of new ideas, which have been tried and tested in the classroom. It is an opportunity for teachers and technicians to gain professional development in a relaxed but inspiring environment.

An open invitation to participate is extended to all those who teach science in Ireland.

Contact details:

- Science Learning Centres website www.sciencelearningcentres.org.uk
- National Science Learning Centre Programme Director Miranda Stephenson m.stephenson@slcs.ac.uk

□

Miranda Stephenson taught chemistry for several years before becoming Director of the Chemical Industry Education Centre, based in the Chemistry Department in the University of York. When the National Science Learning Centre was set up in York she became Programme Director.

New Resources for TY Science

Introducing TY Science

In this section of the conference some new teaching materials and ideas were introduced. Brendan Duane (SLSS) talked about resources fro teaching LC Chemistry. Peter Childs then introduced the TY Science project, whose aim is to produce new teaching materials for the Transition Year Option. This has been running since 2003 and five modules, developed by trainee science teachers, have already been developed, trialled, revised and made available to teachers. In the 2008-9 academic year four more modules were developed and three of them, which are now available to buy and try, are described here. The modules each consist of a photocopiable student's handbook and a companion teachers' handbook. Each module costs €10 and additional copies of the Student's handbook can be bought for €5 each. The modules cover at least 8 week's work on a particular theme, and each brings in aspects of Biology, Chemistry and Physics, depending on the topic.

The previous TY Science titles are:

- Forensic Science
- Science of Sport
- Cosmetic Science
- Environmental Science
- Science of Survival

To date over 500 copies of the available titles have been sent out. To purchase copies email the project director, Peter Childs at: peter.childs@ul.ie. There is a postage charge if materials are ordered by post but none if they collected at UL or at conferences. Some additional resources are also available for teaching some of the topics e.g. UV lamps for use with thin layer chromatography.

Food Science

Anne O'Dwyer, Department of Chemical and Environmental Sciences, University of Limerick
anne.m.o'dwyer@ul.ie

This article introduces the new TY Science Module on Food Science. This was developed in the academic/school year 2008-9 and made available to teachers at the start of the 2009-10 school year. The module was developed and trialled as part of a Final Year Project, under the supervision of Dr. Peter E. Childs, and revised in the light of the author's own experience and the comments of other people who tried out the module.

Aims of the module

- To provide Transition Year teachers and pupils with a cheap and alternative resource for Science which is closely linked to the pupils' own lives and the real world.
- To build on the pupils' previously developed scientific knowledge from their experience of Junior Certificate Science and to provide a foundational knowledge of Biology, Chemistry and Physics for the Leaving Certificate.
- To develop the pupils' awareness of Science in their everyday lives, to appreciate the importance of Science and to encourage thinking like scientists.
- To encourage teachers and pupils to become more familiar with careers related to Science and the necessity of Science in the Food Industry in particular.

Why Food Science?

The topic of Food Science was chosen because food is a necessary part of every pupil's life, and it is a topic that all pupils will have some previous knowledge of, no matter how limited. Many of the experiments and investigations in the Food Science module involve tests on food samples. While laboratory materials are still needed for many of the classes, the use of cheap and widely available food materials helps teachers trying to source materials for use with a large Transition Year group. Because pupils prepare, cook, handle and eat food everyday, this opens a window of opportunities and possibilities of extended investigations and observations that the pupils can make outside the laboratory. This encourages the pupils to become independent learners. Through learning and developing a clearer understanding about food, food groups, food spoilage and preservation, cooking methods and how we taste food etc., it is the author's hope that pupils will be better able to make more informed and healthy decisions about the type of foods they eat.

Table 1.Outline of the Food Science module; 8 units of 3 lessons each.

Units	**Lessons**
1: **A Taste for more**	**Lesson 1**- Looking into Food **Lesson 2** – Our Source of Energy **Lesson 3**- Who's Diet?
2: **The Nutrients**	**Lesson 1**- The Nutrients **Lesson 2** – Let's 'C' all about Vitamins **Lesson 3**- Food Supplements
3: **Food Additives**	**Lesson 1** – Do you know what you are eating? **Lesson 2** – Can we take away the additives? **Lesson 3**- How influenced are you by labels?
4: **Food Processes**	**Lesson 1 -** From the farm to the shelf to the table… **Lesson 2 –** The basics about Baking **Lesson 3 –** Let's Agree to Disagree
5: **Food Spoilage**	**Lesson 1 –** Food Preservation **Lesson 2 –** Food Spoilage and how to prevent it **Lesson 3 –** Polar Pathogenic Perspectives
6: **Science of Cooking**	**Lesson 1 -** Safe Food Preparation **Lesson 2 –** How does cooking change food? **Lesson 3 –** Why heat what we eat?
7: **Mmm … Tasty**	**Lesson 1 –** Tasting the Difference **Lesson 2 –** Can you taste with *just* your mouth? **Lesson 3 –** Why taste at all?
8: **Milk It!**	**Lesson 1 –** Just Milk **Lesson 2 –** What can we make from milk? **Lesson 3 –** Taking a look at the Experts

Content of the module

The module is composed of 8 individual units each with an introductory single lesson, a double lesson (ideally in a laboratory) and an optional follow-up single lesson. Each of the units combine elements from the Biology, Chemistry and Physics Leaving Certificate courses and their links with food. The topics are introduced to the pupils within real life contexts. Such an approach facilitates the pupils' understanding and interest as the information is 'drip fed' to them on a need-to-know basis. Pilot & Bulte (2006) recommend using a constructivist approach to allow pupils to expand and broaden their existing knowledge from presviou science courses, in our case Junior Certificate Science. Through different activities such as debating, designing and presenting posters, as well as investigations and experiments, pupils will work independently as well as in small groups to take responsibility for their own learning.

Evaluation

A thorough analysis of both of the Pupil Questionnaires and Teacher Questionnaires from the implementation of the Food Science Module (Version 1.2) highlighted the improvements and alterations needed to be made before revising as Version 2.1, for dissemination to Transition Year Science teachers for the academic year 2009/2010.

References

Pilot, A., & Bulte, A.M.W., (2006), 'Why do you "need to know"? Context-based Education', *International Journal of Science Education,* 28(9), p.953 – 956.

Anne O'Dwyer graduated in 2009 from the University of Limerick with a BSc degree in Physical Education and Chemistry. In 2009 she won an IRCSET scholarship to do research in chemical education under the supervision of Dr. Peter E. Childs. She is part of the Chemistry Education Research Group at UL and is researching the problems in teaching and learning organic chemistry. The work described here was part of her Final Year Project.

□

Science and Medicine

Karen Murphy

This article introduces the new TY Science Module on Science and Medicine. This was developed in the academic/school year 2008-9 and made available to teachers at the start of the 2009-10 school year. The module was developed and trialled as part of a Final Year Project, under the supervision of Dr. Peter E. Childs, and revised in the light of the author's own experience and the comments of other people who tried out the module.

This module seeks to link the science already covered for the Junior Certificate and relate to ideas to be covered in later science coruses, particularly in Biology and Chemistry.

The module consts of 8 units, each one consisting of an introductory lesson, a double lesson (ideally in a laboratory, where most of the practical work is done) and an optional extension single lesson. Initaillay the module looks at some important classes fo medicine and how they work:

Initially the module looks at important classes of drugs used in medicine:

- Antibiotics
- Antiseptics
- Anaesthetics
- Antacids
- Analgesics

It then goes on to look at the synthesis and production of drugs, using aspirin as an example; the use of technology in medicine – X-rays, CT scans, radiogaphy; and finally a look at alternative medicine.

The topics covered in this unit are shown below:

- Unit 1: Action of antibiotics
- Unit 2: Antiseptics
- Unit 3: Blocking sensations - anaesthetics
- Unit 4: Antacids
- Unit 5: Analgesics & Pain
- Unit 6: Importance of medicines
- Unit 7: Science & Technology in Medicine
- Unit 8: Why not take the alternative route?

Structure of the units

Each unit contains an introductory single lesson, a double lesson and an optional further single lesson.

e.g. **Unit 1: Action of antibiotics**
Lesson 1. Antibiotics
Lesson 2. The Superbug
Lesson 3. A look further

Each unit develops the ideas and has a series of pupil activities and experiments.

In unit 1, for example, pupils look at the history of antibiotics, discuss resistance to antibiotics, how antibiotics are made industrially and make yoghurt as an illustration of fermentation; in the optional lesson they are asked to research and make presentations on different aspects of antibiotics.

It is hoped that the material covered will be of interest to pupils, will relate to their everyday life and will develop scientific literacy in this area.

□

Karen Murphy graduated with a BSc degree in Science Education (Biological Sciences) in 2009 from the University of Limerick and produced this material as part of her Final Year Project at UL in 2008-9 under the supervision of Dr. Peter E. Childs. The materials were revised in the light of the author's own experience on Teaching Practice and the comments of other people who tried out the module.

Issues in Science

Ciara Hayes
Department of Life Sciences, University of Limerick, Limerick ciara.hayes@ul.ie

This article introduces a new TY Science Module on Issues in Science. This was developed in the academic/school year 2008-9 and made available to teachers at the start of the 2009-10 school year. The module was developed and trialled as part of a Final Year Project, under the supervision of Dr. Peter E. Childs, and revised in the light of the comments of other people who tried out the module.

The aim of this study was to design, develop, implement and evaluate a Transition Year module on 'Issues in Science', which would introduce TY pupils to some of the controversial issues in modern science.
All of the topics in the module were chosen as they are topics that are currently in debate among the scientific community or in the public domain, and they all involved the concept of risk assessment and so therefore over the course of the modules pupils developed skills in order to be able to make a balanced decision given the evidence on each of the topics.

As well as learning about the science involved in understanding each issue, pupils were also encouraged to develop a range of skills, shown in Figure 1. Many of these are transferable or soft skills like presentation and debating, although more conventional skills like the use of ICT and laboratory skills were also covered.

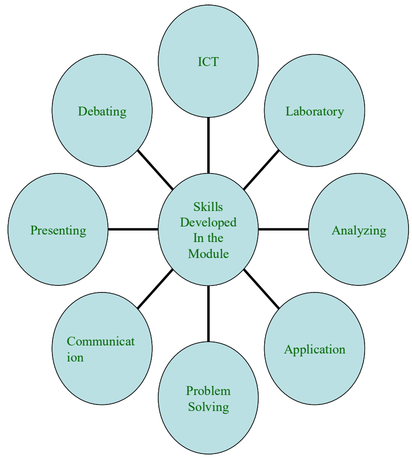


Figure 1 The skills developed in the module

This module called on teachers and pupils to experience different ways of teaching and learning, than would be traditionally used in the classroom.

This module was focused on researching topics, debating issues and carrying out activities other than experimental work, as most of topics e.g. nuclear power, are not suitable for simple laboratory experiments. The following topics were selected for discussion during this module:

- Risk assessment
- Genetically modified foods
- Stem cell research
- Biofuels
- DNA Identification
- Nuclear power
- Electromagnetic radiation
- Fluoridation of water supplies

Each unit consisted of an introductory single lesson, a double where the topic was developed and researched, often with some form of presentation and discussion of the issue, and an optional extension single lesson. At thend of the module the pupils should understand the science behind each issue, the debate for and against the topic, and have had opportunity to discuss, debate and make their own minds up on the issue. It is hoped that this module will help develop scientific literacy and produce more informed citizens, even for those pupils who not continue to study science. However, its is hoped that by being exposed to real issues that are under debate and appear frequently in the media, that pupils will see the relevance of studying science and be encouraged to study it further.

□

Ciara Hayes graduated with a BSc degree in Science Education (Biological Sciences) in 2009 from the University of Limerick produced this material as part of her Final Year Project at UL in 2008-9 under the supervision of Dr. Peter E. Childs. The materials were revised in the light of the comments of trainee teachers and science teachers who tried out the module during the 2008-9 school year. Ciara is now doing research in life sciences at the University of Limerick.

2011 has been designated by IUPAC and approved by UNESCO as the International Year of Chemistry. The Irish contribution is being coordinated by the President of the Institute of Chemistry of Ireland. You can check on international activities at the official website: http://www.chemistry2011.org/

"The International Year of Chemistry 2011 (IYC 2011) is a worldwide celebration of the achievements of chemistry and its contributions to the well-being of humankind. Under the unifying theme "***Chemistry—our life, our future***," IYC 2011 will offer a range of interactive, entertaining, and educational activities for all ages. The Year of Chemistry is intended to reach across the globe, with opportunities for public participation at the local, regional, and national level.

The goals of IYC2011 are to increase the public appreciation of chemistry in meeting world needs, to encourage interest in chemistry among young people, and to generate enthusiasm for the creative future of chemistry. The year 2011 will coincide with the 100th anniversary of the Nobel Prize awarded to Madame Marie Curie—an opportunity to celebrate the contributions of women to science. The year will also be the 100th anniversary of the founding of the International Association of Chemical Societies, providing a chance to highlight the benefits of international scientific collaboration.

IYC 2011 events will emphasize that chemistry is a creative science essential for sustainability and improvements to our way of life. Activities, such as lectures, exhibits, and hands-on experiments, will explore how chemical research is critical for solving our most vexing global problems involving food, water, health, energy, transportation, and more.

In addition, the Year of Chemistry will help enhance international cooperation by serving as a focal point or information source for activities by national chemical societies, educational institutions, industry, governmental, and non-governmental organizations."

Now is the time to start planning what you can do in your school or institution.
This is your chance to promote Chemistry as a subject and as a career to your students.

□