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Cover photo: Teachers at work in a workshop on organic chemistry at ChemEd-Ireland 2013 (Photo: P.E. Childs)

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Editorial #101

Eurovariety 2013

In this issue we print the plenary talks given at Eurovariety 2013, which was held 3-5 July in the University of Limerick. Although the conference was aimed at university lecturers in chemistry, it also included academics involved in training chemistry teachers. The training of chemistry teachers was a major theme of the conference. Although the focus of the talks is not directly relevant to teaching chemistry in schools, I hope that many of the ideas and issues covered will be of interest to the second-level chemistry teacher, as well as to the third-level chemistry lecturer.

Junior Cert debacle

As I write this the future of the new Junior Certificate Student Award (its new title) seems up for grabs. The main teacher unions have major objections and have refused to cooperate wih its implementation. Without the cooperation of the unions the new curriculum is dead in the water. The broad specifications for Science were sent out for consultation (and the closing date was January 14th). However, the information that was given was too broad and too general to make any real assessment. None of the detail was available on content, assessment, resources, CPD etc. and the devil is always in the detail. The detailed specification for science is due this year for implementation starting in 2015 English is the first new subject to be introduced, starting in September 2014. There is more discussion of this on p. 4.

It is interesting that England is moving away from teacher and school-based assessment, and a heavy reliance on coursework, to terminal examination as the main form of assessment. It is thought that coursework was partly responsible for grade inflation and the system was subject to abuse. The latest proposals (*The Times* 10/4/14) will see practical work removed from the assessment of science A levels, where up to 40% could be awarded for practical work assessed by teachers. However, A-level students are expected to do 1 practicals over 2 years, certified by the teachers, and exam questions would test their knowledge of experiments. Separate certification would indicate a student's practical proficiency, but would not be incorporated in the final grade. Ofqual (the UK body responsible for examinations) intends to extend the principle to science at GCSE and stop awarding marks for practical skills, currently marked by teachers. Science organisations in the UK have protested at the move because they think it is likely to downgrade the importance of practical work in schools and even lead to the dropping of science experiments, which are expensive and time-consuming. What is intended in England is essentially the current Irish system at LC level.

Two issues are being conflated here: ensuring that students do enough practical work and develop practical skills and rewarding students for doing practical work in the overall assessment. Achieving the first aim does not necessarily require formal assessment, providing it is monitored effectively; assessment does not necessarily mean that it is done by a student's own teacher. An externally marked practical exam, run in school and invigilated by the teacher, avoids the problem of teachers assessing their own students. It is interesting that this was the O-level and A-level system 50+ years ago when I did science in the UK.

There is a real danger of Ireland adopting a flawed system of teacher-marked coursework as a mainstay of the assessment process in all subjects in the junior cycle. Heavy dependence on coursework has been shown to be subject to abuse, and results in grade inflation and inconsistent standards, and these are the main objection of the teachers' unions to the new junior cycle proposals. They may well be right.

Achieving the desired aims in both junior and senior cycle of less rote learning, more creativity, critical thinking and problem-solving, could be achieved by redesigning the nature of the assessment, and linking it closely to learning outcomes and pedagogy. We will return to this in a future issue.

Peter E. Childs
Hon. Editor

Education News and Views

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

Ag Science to be revised at last!

In March (Irish Times 3/3/14) it was announced that the Agricultural Science syllabus is to be revised. The current syllabus was introduced in 1972 and the new syllabus will be available for consultation in Autumn 2015. I assume this means it will not be introduced until 2017 at the earliest, which will be 45 years since it was last changed! This has to be some sort of world record, except that the combined Physics with Chemistry course is in the same state. A major revision was produced several years ago but never implemented. The Agricultural Science course is now the 3rd most popular science and if it continues to grow at its current rate will pass Chemistry in a year or two.

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Who teaches what?

All teachers now have to registered with the Teaching Council in order to get a job or to retain their job. To satisfy the Teaching Council the second level teacher has to have had enough hours (ECTS credits) in their degree. This means that teachers are now identified by what they can teach. In the DoES 2012/13 Statistical Report there is a listing of registered teachers. However, the total number is listed only 9,785, which is far less than the 25,374 second level teachers given elsewhere in the Report. Is this because the data hasn't caught up with the registrations? If so this means we would have to scale up the figures given by 2.5 to get the correct figures. However, the subject specialism listed is still interesting in what they tell us about the subject balance within second level science teachers. There have to be more science teachers in schools since the numbers listed are less than the numbers of schools offering the LC science subjects (see article on the 2013 LC Results on p. **. However, teaching a subject does not imply a qualification in the subject and once registered and in a school, a teacher can be asked to teach any subject!

Many science teachers teach more than one subject and many also teach Mathematics. From these data science teachers make up 11.35% of all second level teachers. Given that there are 694 second level schools it seems likely that not all science and Mathematics teachers are included in these statistics. Many people teaching Mathematics do not have a primary qualification in Mathematics and there is an ongoing CPD programme to qualify out-of-field teachers in Mathematics, which is training hundreds of teachers. On a smaller scale short courses in Chemistry for Non-Specialists were started in 2012 by the Royal Society of Chemistry's Education Division Ireland Region.

The numbers of registered science teachers 2012-2013 (Source: DoES)

	Males	Females	Total
Biology	105	259	364
Chemistry	63	134	197
Physics	60	43	103
Agricultural Science	27	45	72
Total science teachers	255	481	736
Mathematics	141	249	390
Total second-level teachers	3,541	6,244	9,785

What these figures do show is that Biology teachers make up nearly 50% of science teachers and 65.3% are female. If we add in Agricultural Science to Biology, the life sciences teachers make up 59% of science teachers. Physics teachers are particularly thin on the ground and the gender balance in the teachers reflects the gender balance in the LC science student population.

If we scale up the figures above by 2.5 this would mean there are about 1,840 teachers. Given that there are 694 second level schools, all of whom teach Junior Science and some LC science subjects, we would expect all schools to have at least 3 science teachers and some have many more. If we took an average of 5 per school, this would give a total of 3,475 science teachers. This would be a substantial pool of possible members for the ISTA, which has ~ 1,000 members. It will be interesting to see if the 2013-14 Statistical Report will include all second level teachers and their specialism.

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The new Junior Cycle science specification

In Sept. 2013 a draft Background Paper was sent out for consultation on the new Junior Cycle Science specification. This was open for consultation for 6 months and a Consultation Report has now been published (Feb 2014). It is intended that the draft specification be submitted to the NCCA for approval in June 2014 and then sent out for consultation. The intention is that the new Science course would be introduced in September 2015. However, this may not be possible given the industrial action taken by the teachers' unions (ASTI and TUI) to boycott all cooperation with the new Junior Cycle proposals.
You can read the background paper at:
http://www.juniorcycle.ie/NCCA_JuniorCycle/media/NCCA/Documents/Curriculum/Subjects/JC-Science_BP.pdf

The brief for the new specification is given below.

Brief for the review of Junior Cycle Science

The review of Junior Cycle Science will lead to the production of a specification in line with the standard template for junior cycle specifications.
The principles for junior cycle education as they appear in the Framework for Junior Cycle will inform key decisions made in the development of the specification for Science. In its work, the development group will be conscious of the extent to which the specification relates to various statements of learning in the Framework and in that context, how it might assist a school in planning and evaluating their junior cycle programme.

The specification will be at a common level.

It will be designed to be taught in a minimum of 200 hours.

It will be structured or organised around strands and learning outcomes.

The key skills of junior cycle, as appropriate, will be embedded in the learning outcomes of the specification.

The skills of literacy and numeracy will be promoted through specific aspects of the specification.

It will be completed for Autumn 2014.

The development of the new specification for Junior Cycle Science will take account of current research and developments within the field of science education, particularly the emerging understanding of the *Nature of Science*.

The development of the new specification will address continuity and progression. It will consider whether first year Science should be taught as a common introductory course (CIC), with a particular focus on consolidating learning from primary school and on the development of students' understanding of the *Nature of Science*. Some consideration should be given to the development of bridging units to be commenced by students in sixth class and completed at the start of first year.

More specifically, the development of the new specification will address:

- The purposes of junior cycle science, making them transparent and evident to students, teachers and parents in the specification
- How the specification, in its presentation and language register, can be strongly student-centred, having a clear focus on what the students can do to develop and demonstrate their scientific literacy and achievements
- How inquiry-based teaching and learning should be promoted.
- How the course will be organised; whether it will continue to be structured around the three major areas of science: biology, chemistry and physics, or around thematic units of science.
- Continuity and progression: how to connect with and build on primary science as well as provide a platform for the study of science in senior cycle.
- How personal and societal interests about science can be used as a reference point from which the curriculum is specified.
- The ongoing assessment of student learning as well as the components related to assessment for certification.

 How to highlight the relationship between science and technology.

 The emphasis placed on discussion and analysis of scientific, environmental and sustainability issues that permeate contemporary life.

 How to tap into the natural curiosity of students and their desire to create and work in practical ways through practical activity.

The work of the subject Development Group will be based, in the first instance, on this brief. In the course of its work and discussions, elaborations of some of these points and additional points may be added to the brief.

From a long-term perspective all science curricula are in a constant state of change. The success of the new specification will be measured by the extent to which junior cycle students and their teachers become more excited about science and how science works.
http://www.juniorcycle.ie/NCCA_JuniorCycle/media/NCCA/Documents/Curriculum/Subjects/JC-Science_Brief.pdf

For more information contact the Education Officer: Barry Slattery at barry.slattery@ncca.ie

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The state of chemical education in Ireland

Dr Peter Childs has written an up-to-date assessment of the State of Chemical Education for *Irish Chemical News*. This is available online at: *Irish Chemical News* is the electronic journal of the Institute of Chemistry of Ireland.

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PISA Report on problem solving ability

Latest PISA results in problem solving show Irish students ranked 22nd out of 44 countries

The latest report from the OECD's Programme for International Student Assessment (PISA) shows that 15 year old students in Ireland performed at the average level of participating countries on computer based assessment of problem solving.

Ireland ranked 17th of the 28 OECD countries who took part in the study, and 22nd out of all 44 participating countries. Countries like the United States, Norway, Denmark and Sweden performed similarly to Ireland; while Canada, Australia, Finland and the UK performed significantly better than Ireland. The top six performing countries are in Asia, with Singapore ranked first.

Both the lowest and highest performing students in Ireland for problem solving score similarly to the OECD average; there is no significant difference between the performance of male and female students; while the performance of students from immigrant backgrounds is significantly higher than the corresponding average for the OECD, it is still significantly lower than those for native students.

Minister for Education and Skills, Ruairí Quinn said, "The performance of Irish students on problem solving in this PISA study is good, but there is considerable room for improvement."

"I believe we have the methods to significantly improve such skills at our disposal, we just need to embrace them wholeheartedly. Project Maths and the emphasis on skills development in the new Junior Cycle Student Awards (JCSA) offer students and teachers new ways of thinking and learning that should improve our 15 year olds' problem solving capabilities."

Compared to the PISA results for Maths, English and Science in 2012 which were released late last year, Ireland performed less well than expected in computer based problem solving. The findings also suggest a lack of familiarity with using computers, at home and school, for school-related tasks, and this may have contributed to a lower performance.

Minister Quinn said, "The short-comings identified in this and previous PISA reports have informed the changes that we are introducing through Project Maths and the JCSA."

"There is also evidence which suggests that the student centred approaches and ICT activity of Transition Year result in better problem solving skills. Such problem solving skills are promoted and embedded in the six key skills outlined in the new framework for Junior Cycle

"Improvements in ICT, such as high speed broadband being available in all second level schools from September and the new Digital Strategy for Schools which my Department is drafting, will also benefit students," concluded Minister Quinn.

Minister of State with responsibility for STEM, Sean Sherlock T.D., added, "Most of the students who participated in this study had not experienced the implementation of Project Maths. With its emphasis on skills development, problem solving in real-life contexts and use of ICT, I believe once the new methodologies for Project

Maths are fully embedded they will help to raise all students' achievements."

In 2012, problem solving was included as an optional assessment in PISA. It was a 40 minute computer-based assessment of problem solving. In Ireland, 1,303 15 year olds in 183 schools participated.

- See more at: http://www.education.ie/en/Press-Events/Press-Releases/2014-Press-Releases/PR14-04-01.html#sthash.DudWQD70.dpuf

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STEM Education Review set up

20 November, 2013 - Minister Sherlock announces launch of STEM Education Review Group

STEM Education Review Group will examine aspects of STEM Education in Ireland

The Minister for Research and Innovation, Seán Sherlock T.D., today announced the launch of the Science, Technology, Engineering and Mathematics (STEM) Education Review Group.

The STEM Education Review Group will be chaired by Professor Brian Mac Craith, President of DCU. Speaking at the launch in the Royal Irish Academy this morning, Minister Sherlock thanked Brian and the group members *"who have most generously agreed to give of their time and expertise"*.

"The STEM Education Review Group will explore the potential of Research into STEM Education, particularly at primary and post primary level," he said.

"The Literacy and Numeracy Strategy, published in 2011, has increased the amount of time devoted to literacy and numeracy in the classroom. There has also been significant investment in Continuing Professional Development (CPD) in order to fully implement the Literacy and Numeracy Strategy," he continued.

"I believe that further academic research into STEM Education along the primary/post primary continuum will help build upon these positive changes.

"I want to ensure that the Irish education system can measure up to international best practice and even challenge international leaders in this space. STEM drives learning, and learning can drive STEM," Minister Sherlock concluded.

Speaking at the launch, Professor MacCraith said *"Given the pivotal role that STEM subjects play in our society and in our globalised economy, we should ensure that STEM education in Ireland is of the highest international quality. We owe this to our children.*

With that objective in mind, I am delighted to accept the Minister's invitation to chair this important Review process."

STEM Education Review Group membership:

The Minister proposes to appoint the following members to the Review Group:

· Prof. Brian Mac Craith (Chairperson): President DCU

· Mr. Bill Kearney: Director Dublin Lab, IBM Software Group (IBEC representative)

· Dr. Pádraig O'Murchú: Education & Research Manager, Intel

· Ms. Anna Walshe: Education Officer, NCCA

· Mr. Seán MacCormaic: Chair of the Irish Maths Teachers Association

· Prof. John O'Donoghue: NCE-MSTL and Department of Mathematics & Statistics, UL

· Dr.Thérese Dooley: Lecturer in Mathematics Education, St. Patrick's College

Terms of Reference

1. The preparation of teachers (at 1st and 2nd Level) for STEM education in Ireland
2. Means of supporting/enhancing the current cohort of STEM Teachers within the system (consider innovative means of supporting targeted CPD for STEM teachers by Private Sector leveraging of current state resources)
3. The use of inquiry-based and problem-based learning approaches and the impact of different assessment modalities for STEM subjects in the context of, but not limited to, the developing Junior Cycle reforms
4. The use of technology to enhance learning (especially on-line approaches) and the way in which the private sector could provide support
5. Increasing the engagement in and understanding of STEM subjects for students

See more at: http://www.education.ie/en/Press-Events/Press-Releases/2013-Press-Releases/PR2013-11-20.html#sthash.0Qgp4fgT.dpuf

The Chair of the STEM Education Review Group, Professor MacCraith, has convened a discussion on STEM Education in Ireland, hosted by the Royal Irish Academy in Academy House, Dawson Street, Dublin 2 on **Thursday 17 April 2014, 10.30am - 4.30pm.**
The keynote address will be given by Sir John Holman, Senior Education Advisor to the Wellcome Trust and the Gatsby Foundation, and Emeritus Professor in the Chemistry Department of the University of York.

This event will bring together educators, policy makers and industry partners to share and discuss current practices and future initiatives that may advance STEM Education in Ireland. In order to stimulate an informed and broadly representative dialogue, it is explicitly intended to be a multilateral exercise in which all parties are active and equal participants in the discussion. There will be time to question and engage with participants after each segment of the forum.

(We hope to report on this meeting in the next issue of *CinA!*.)

Comment:

I was pleased to hear of the setting up of the STEM Review Group but amazed at its unrepresentative composition. In my opinion it is over-weighted in favour of mathematics (3 out of 7 people), although mathematics is only 1/3rd of STEM education (always assuming the Technology and Engineering are combined). There are 2 industrialists, who are both from the ICT sector. The only science person is Anna Walshe from the NCCA. The mathematics teachers' association is represented but not the science and technology teachers' associations. There is no-one representing primary science/teacher training and no-one representing the second level science teacher training/science education sector. I know that the ISTA made a request to be represented, but this was not acted on.
A similar thing happened when the Task Force on the Physical Sciences was set up in 2000 – it had a very broad representation but omitted the second level science teacher training/science education sector. When this was pointed out to the Task Force chairman by the Irish Association of Science Education Lecturers (IASEL), the omission was rectified.

The STEM Review Group is holding a discussion with a wider range of interested parties on April 17th, which is a welcome initiative. But you can't beat having all the relevant interests around the table, where the real work is done and decisions are made. I have to say that I think that this STEM Review Group is not well structured to represent all the relevant interests. It is due to report in June and I will await its findings with interest.
Peter E. Childs, Editor

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Report of the Royal Irish Academy and All European Academies Forum 'Academia-industry alliance- joint efforts in science education'

20 Nov. 2013

http://www.ria.ie/getmedia/105a6bdc-e911-4689-bab0-3160332a5feb/RIA-ALLEA-report--(January).pdf.aspx

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Appreciations:
Hans-Jürgen Schmidt 1913-2013

A very characteristic photo of Hans-Jürgen Schmidt, taken at his 80th birthday celebration in Sept. 2013 in Dortmund.

#1. Prof. em. Dr. HANS-JÜRGEN SCHMIDT died on 20 October 2013, at the age of 80 years. In September 2013, the TU Dortmund University celebrated his 80th birthday together with lots of friends and colleagues within a beautiful ceremony.

HANS-JÜRGEN SCHMIDT was a nationally and internationally known researcher on chemical education. During his whole career, he worked on issues of laboratory school chemistry and on student conceptions. It was always one of his greatest concerns to interpret student ideas and misconceptions in terms of stumbling blocks which have to be overcome. The advancement of methods of empiric research formed another main focus of his work.

The results of his works were published in respectable national and international journals and, moreover, have led to various textbooks.
The big international reputation of HANS-JÜRGEN SCHMIDT led to an appointment as a guest professor at the University of Karlstad/Sweden after his retirement. For about six years, he was engaged in establishing and enhancing research in chemical education at his guest university.
HANS-JÜRGEN SCHMIDT liked this new challenge very much. He learnt Swedish very well, for example.

Very often he reported and wrote about his various Swedish experiences. It was his credo that the international view is essential not only for the development of research but also for a better understanding of the diverse educational systems.
Many teachers and colleagues will cherish him as an outstanding researcher and respected speaker.
Bernd Ralle,University of Dortmund
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#2. Professor Emeritus Dr Hans-Jürgen Schmidt has been a towering figure in chemical education research (CER) in Europe for 40 years and has played a major part in establishing CER as a recognised discipline in Europe. Most of his career was spent in the University of Dortmund, Germany, where he was Professor for Education in Chemistry from 1971. After retirement from Dortmund in 1998, he then spent 7 years as a Guest Professor for Education in Chemistry at Karlstads University, Sweden. In 1981 he started the influential biennial Dortmund Symposium for Chemical Education, which still continues. He has been active in national and international organisations in chemical education, has spoken at many conferences and was on the editorial board of several science/chemical education journals. Most German universities have Departments of Chemical Didactics within the chemistry departments and the reputation of these departments and their involvement in CER is in no small part due to Hans-Jürgen Schmidt in making CER respectable and in training a generation of researchers. He has published many papers in CER in both German and English language journals and his papers on chemical misconceptions in high school students have been widely cited. One aspect of his work has been the emphasis on quantitative research. His published papers stretch back over 30 years and his most recent paper was published in 2009 at the age of 76. Although Hans-Jürgen Schmidt's work has been mostly done in Europe, his influence on CER has extended worldwide through his papers and conference presentations.
Peter E. Childs, University of Limerick

From the RSC:
It is with great sadness that we have learned of the death of Professor Hans-Jürgen Schmidt, a much respected chemical educator and long-time member of the advisory panel of this journal, aged 80. An interview with Prof. Schmidt about his work in chemistry and chemistry education was published in the journal in 2003:
Cardellini, L. (2003). An Interview with Hans-Jürgen Schmidt. [10.1039/B3RP90005C]. *Chemistry Education Research and Practice*, 4(1), 11-17. doi: 10.1039/b3rp90005c
http://pubs.rsc.org/en/content/articlelanding/2003/rp/b3rp90005c#!divAbstract

There will be a symposium in Hans-Jürgen Schmidt's memory at the ECRICE conference in Finland, 7-19 July 2014.

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Eurovariety 2013, 3-5 July, University of Limerick

Eurovariety in Chemistry Education (EViCE) was held at the University of Limerick from 3-5 July 2013. This conference was aimed at university and college chemistry lecturers and those involved in chemistry teacher training.
It was organised under the auspices of the Education Division of EuCheMS, the body representing chemists in Europe, and the participants came mainly from Europe, with others from N. America and Australia. This issue of *Chemistry in Action!* contains the four plenary lectures and is being sent to registered participants as well as our usual readers. Although the focus of the articles is teaching chemistry at third level, and chemistry teacher training, I think there is much in these articles to interest the second level chemistry teacher as well.

The message of welcome from the President of UL and from the chair of the EuCheMS Division of Chemical Education is given below.

Welcome from Professor Don Barry – President of UL

Conference Delegates:

It gives me great pleasure to welcome Eurovariety 2013 to the University of Limerick.

Eurovariety attracts chemistry lecturers and educational professionals from around the globe to improve their shared understanding of chemistry teaching and learning at the tertiary level. We are proud to support any event which brings people together, opens dialogues and promotes innovation.

We are also pleased to support and encourage the teaching of the sciences, as these subjects are so important to the expansion of Ireland's technology industries, the stimulation of jobs and the continued growth of the Irish economy.

The theme of this year's conference is 'Smarter Teaching – Better Learning'. This theme serves to remind us that the purpose of all academic activity is to generate discussion and to enhance learning. Over the coming days I encourage you to engage with your colleagues, to listen and to learn and to build your own professional practice.

It is in this spirit of open dialogue that I welcome you to UL, invite you to explore our beautiful campus and take the opportunity to tour the wider Limerick Region.

From Ilka Parchmann, the Chair, EuCheMS Division of Chemical Education

Dear participants of the 5th European Variety Conference: Eurovariety 2013!

In the name of the Division of Chemical Education of EuCheMS, the European Association for Chemical and Molecular Sciences, I would like to welcome you all to our 2013 conference in Limerick.

This conference offers a great opportunity for researchers and lecturers at university level in many different European countries to get new and interesting ideas, to discuss problems and challenges in tertiary chemistry education with each other and finally to learn from each other. It is unique in its combination of experienced practitioners and chemistry education researchers that does not exist in many other disciplines. In the name of our Division, I would like to thank all presenters and discussants for their active contribution to our common field of interest: to make the teaching and learning of chemistry even more successful and interesting than it already is in many European countries!

The Division of Chemical Education sponsors two series of conferences: Eurovariety and ECRICE, European Conference on Research in Chemical Education, which alternate. I would like to take this opportunity to invite you to come to the next ECRICE conference, which will be held in Jyväskylä, Finland, 7-10th July 2014: see https://www.jyu.fi/kemia/en/research/ecrice2014// for details.
See you there again!

Ilka Parchmann

Teaching Content, Context, Collaboration, and Communication in College Chemistry

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Introduction

The pace of the expansion of the frontiers of science is increasing and this poses an ever more pressing problem for science education. The gap between the way students are taught and how students might employ scientific knowledge has become nearly unbreachable. The overwhelming majority of students are taught chemistry concepts in isolation from the scientific process and the concepts' actual applications. In its 1996 report *Shaping the Future–New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* (STEM) [1], the National Science Foundation of the United States (NSF) recommended that faculty *"model good practices that increase learning; start with the student's experience, but have high expectations with a supportive climate; and build inquiry, a sense of wonder and the excitement of discovery, plus communication and teamwork, critical thinking, and lifelong learning skills into learning experiences."* This policy is aligned with a century of general education policy [2] and the policy addresses a fundamental pillar for a democratic society, the need for a literate citizenry [3]. Thomas Jefferson famously wrote in 1787, that *"the basis of our governments being the opinion of the people, the very first object should be to keep that right; and were it left to me to decide whether we should have a government without newspapers or newspapers without a government, I should not hesitate a moment to prefer the latter.* ***But I should mean that every man should receive those papers and be capable of reading them*** [emphasis ours]." In today's modern society, literacy increasingly means *scientific* literacy [4-6] and Jefferson's mandate requires science literacy, a basic appreciation for the science process by the general public [4], and also the public engagement by scientists [7].

Chemistry Is in The News (*CIITN*) has been developed over the past fifteen years with the aim of teaching chemistry in the context of real-world issues and exposing students to all aspects of science communication. The pedagogical framework [8-10] and technical issues [11] of implementation have been described and reviewed [12-14], and results of assessment [15,16] have been reported. The *CIITN* activities consist in the study, creation, and peer review of online projects that are based on actual news articles from the popular press and aimed at connecting real-world social, economic, and political issues to the teaching of chemistry. *CIITN* is based on constructivist learning theory [17], which holds that connecting abstract scientific concepts with real-world experience can help students learn and remember content. The *CIITN* peer review includes an evaluation framework for both individual and group evaluations, detailed and flexible rubrics to guide peer review, a requirement of written justifications of the peer review scores, and an intragroup peer review tool. *CIITN* was developed for lower-division, large lecture college courses and *CIITN* also has been implemented in high schools in the United States.

Here, we describe our more recent curriculum innovation [18], which embraces the spirit and expands on the concepts of *CIITN* to educate upper-level science majors about the science process, scientific writing, scientific peer review, and professional issues. Specifically, we describe the framework of an assignment-based curriculum of a writing-intensive, upper-level undergraduate seminar taught at the University of Missouri in Columbia (MU), which integrates content, context, collaboration, and communication in a unique fashion. The topic of the seminar is "Scientific Writing in Chemistry" and an assignment-based curriculum was developed to instruct students on best practices on all aspects of science communication and to educate students about the scientific publication process and peer review. To effectively teach students how to understand science, one must include both the content and the process and peer review is an integral and essential part of the process of science. The curriculum was developed for a semester-long, three-hour seminar course with limited enrolment (< 36 students). The curriculum was taught in the spring semesters of 2010 – 2013 and results of assessments are presented to demonstrate the success of the adaptation.

The educational goals of education in science communication are strongly connected to the general education goals of writing programs. For example, the premise of MU's Campus Writing Program [19] states that *"Writing Intensive courses help produce an educated, articulate citizenry capable of reasoning critically, solving complex problems, and communicating with clear and effective language."* It's a simple equation: *Scientific Writing & Communication = Science Content + Writing-Intensive Principles*. This natural alignment between science communication and writing programs can be an effective catalyst for the initiation of science communication programs in science departments. We have been working closely with the Campus Writing Program (CWP) on the *CIITN* curriculum, and we have been developing the "Scientific Writing in Chemistry" curriculum with continuing support from CWP and many WI-faculty from a variety of disciplines. The assignment-based curriculum meets CWP's criteria for writing-intensive courses, and the curriculum was reviewed and approved by an interdisciplinary group of faculty peers prior to each implementation.

While the curriculum has been developed for students at an American research university, the *framework* of the assignment-based approach is *entirely transferable to other sciences and other educational levels*. Most science departments do not offer formalized courses to teach science process skills at the undergraduate level and/or to beginning graduate students. Evidence suggests that the teaching of process skills at the undergraduate level can enhance the students' understanding of science content [20], and prepare them for the increasingly interdisciplinary and collaborative nature of the modern scientific enterprise [21,22]. To affect lasting and sustained growth in the understanding of the science process, however, these educational efforts should not be limited to the college and university levels. Instead, faculty at the college level ought to commit to improving the training of teachers and to working with teachers on the implementation of more scientific approaches to science instruction [23]. The curriculum for the education in science writing and science communication is very much in the spirit of the Next Generation Science Standards [24,25] and its implications for college teaching [26]. While educational standards used to be formulated by professional organizations in the various subject areas, the next generation standards call for "fewer, clearer, and higher" and more integrated standards. The goals of literacy and STEM education should enable citizens to argue from evidence. To move education in that direction will require more attention to science process (problem definition, model formulation, data analysis) and draw on elements from science, mathematics and ELA ("literacy", English Language Arts). Thus, it is hoped that this article will contribute to the wide and open dissemination of this curriculum on science writing and science communication.

Framework of the Assignment-Based Curriculum and Organization of the Course

We describe a *framework* of an assignment-based curriculum. The *types* and *sequence* of the assignments and the *modes of their assessment by peer review* constitute this framework and remain essentially the same from one implementation to the next (Table 1). Every *implementation of this framework* presents a unique curriculum because all assignments are original and connected to an overarching theme of the course.

Our original implementation in the spring semester of 2010 (SP10) was built around the theme "Aspirin and Other Painkillers." In the following years the course was built around the themes "Dyes, Indicators, and Chemical Sensors" (SP11), "Soaps, Detergents, and Other Ambiphiles" (SP12), and "Solar Energy and Other Renewables" (SP13). As this article is being written, students are taking this course with the theme "Nutraceuticals: Sources, Delivery, and Functions" (SP14). All of these assignments, associated data and sources, peer review devices, and samples of completed assignments are available online and the URLs for the course web sites are provided as footnotes to Table 1. The *framework* of the curriculum has been developed with a few elemental criteria in mind and these are: Compartmentalization of Tasks, Incremental and Iterative Progress, Clarity of Process and Requirements, and Clarity of Purpose. .

Table 1. MU Course Design: Content, Software, and Resources

Week	Task	Content	Software and Online Resources
1		Reading Chemical Literature, Publication Types	Browser, Portals: ACS, Wiley-VCH, RSC
Skill Development for Scientific Writing			
2	A01	Mindmapping & Outlining, Text	Word
3	A02	Schemes; Integration of Text & Art	ChemDraw, Word
4	A03	Tables, Statistics & Graphing	Excel
5	A04	Simulation & Graphing	Excel, Word, ChemDraw,
6	A05	Search, Citation & Bibliography	SciFinder, Word, ChemDraw
7	A06	Oral Presentation	Powerpoint
8		Oral Presentation Week	
9	A07	Structure and Modeling	Chem3D, Jmol etc.
Near-Authentic Exercise in Scientific Writing and Authoring			
10	A08	Writing I. Materials, Methods, Appendix	*J. Org. Chem.*, Guidelines for Authors
11	A09	Writing II. Intro., R & D, Concl., Abs., Cover Letter	Authentic Examples provided
12	A10	Scientific Peer Review	Ethics Guidelines: ACS and NAS
13	A11	Revising & Responding to Peers, Graph. Abstract	Authentic Peer Review Examples provided
14		Scientific Conduct and Misconduct	PR-Cases & ORI-Resources

(a) In SP10, the oral presentation was "Project #1" and it became A06 in subsequent implementation. Hence, A06 – A10 in SP10 correspond to A07 – A11 of all subsequent implementations.
(b) Spring Semester 2010: http://faculty.missouri.edu/~glaserr/RG_T_SP10.html
(c) Spring Semester 2011: http://faculty.missouri.edu/~glaserr/RG_T_SP11.html.
(d) Spring Semester 2012: http://faculty.missouri.edu/~glaserr/RG_T_SP12.html.
(e) Spring Semester 2013: http://faculty.missouri.edu/~glaserr/RG_T_SP13.html.
(f) Spring Semester 2014: http://faculty.missouri.edu/~glaserr/RG_T_SP14.html.

Writing a paper is very hard! And writing a paper requires proficiency in many skills. One needs to learn how to find, access, and read literature, one needs to learn how to collect and work with data, how to create schemes and figures, and one needs to acquire computer skills to handle all kinds of software pieces needed to perform the desired tasks, and one must learn about the publication process and peer review. Evidence suggests [27,28] that it is best to compartmentalize these various tasks as much as possible and to gradually move from relatively simple tasks to more and more complex tasks, which build on previous assignments and require the integration of several skills. Hence, we dedicate more than half of the curriculum to modules for "Skill Development for Scientific Writing" (A01 – A07) and, with this preparation, the students then engage in a "Near-Authentic Exercise in Scientific Writing and Authoring" (A08 – A11, vide infra).

The incremental increase in the complexity of the tasks is reflected in the gradual increase in the students' autonomy regarding their selections of topic and sources. In assignments A01 – A04, the students work on <u>common topics</u> and they select literature from a provided pool of sources about the theme area. In assignments A05 – A07, the students work on <u>different topics</u> and they select one topic from a provided pool of pre-selected topics within the theme area. Finally, in assignments A08 – A11, the students work on <u>different topics</u> they select freely from the primary literature covering the theme area, and a pool of journals is provided to facilitate their access to the primary literature of theme area.

All the activities in this course are performed by pairs of students. This stratagem has the immediate organizational benefit that every group can stay on schedule in spite of the occasional absence by one of the collaborating students. Moreover, this stratagem also offers peer support [29] and several pedagogical advantages [30,31]. We have found that working in pairs greatly helps the students to manage the novelty of the course and to alleviate any doubts students might have as to whether they can live up to the challenges. Working on the assignments and on the peer reviews harvests the benefits of peer-to-peer learning [32,33] and especially promotes learning through collaborative argumentation [34].

The learning goals of the theme-based, research-oriented curriculum are well aligned with modern pedagogical principles. The framework of the curriculum emphasizes crosscutting concepts (structure & function, pattern recognition, cause & effect, etc.), informs about science practices, and provides instruction about all aspects of actual research. Table 2 shows how scientific writing correlates with the practices of science and engineering for the promotion of inquiry recommended by the National Research Council [35]. We encourage the selection of themes that are timely and relevant. Science affects every aspect of modern society and students need to learn to use employ their science knowledge when they recognize options and make choices mindful of the consequences. The MU Campus Writing Program suggests that assignments should be "unique, original, or specific to a task or problem" and provides specific recommendations to guide assignment design. Assignments that match these criteria also minimize any concerns about plagiarism [36].

Table 2. NRC's Eight Practices of Inquiry in STEM Education and Scientific Writing

NRC's Operational Criteria for Inquiry	Standard Science Sequence
(i) asking questions & defining problems	Introduction
(ii) developing & using models	All Sections
(iii) planning & carrying out investigations	Materials & Methods (M&M)
(iv) analyzing & interpreting data	Results & Discussion (R&D)
(v) using mathematics & computational thinking	R&D
(vi) constructing explanations & designing solutions	R&D
(vii) engaging in argument from evidence	Conclusion, R&D
(viii) obtaining, evaluating, & communicating information	All Sections

Evaluation of Assignments by Various Forms of Peer Review

The scholarly community has long had a love-hate relationship with peer review [37]. To a significant extent, the ill feelings toward peer review are a product of *viewing peer review simply as a practical tool for quality control* [38]. However, Knoll [38] argues that one should see peer review as a social process, that is, *"as a discussion among honest and able people, working within the social system of institutionalized science, making the clearest sense they can of the information they all share."* It is this *discourse* that is the essence of science.

Most scientists have their first experience with peer review when they publish their first paper and *receive* peer review. For a working scientist, however, both *receiving* and *providing* peer reviews are regular activities, and students should develop the ability to deal with and benefit from received peer review and also the capacity to produce quality feedback on the works of others [39]. The assignment-based curriculum includes peer review activities that exercise both of these dimensions of peer review in a *gradually evolving fashion* over the *course of several months*. We hold that a thorough development of peer review skills is intrinsically connected to the development of writing skills: In the absence of well-developed writing skills and some experience in scientific writing, one cannot judge the creative works of others "as a peer." Meaningful curricula for science writing and peer review thus can be connected to laboratory courses [40] or to lecture courses with significant [16] or intensive writing components.

Several forms of peer review are employed. The peer review tasks evolve from rubric-based peer assessments [41,42] to free format peer review. At the same time, the peer review tasks evolve from assessments of the writer's technical and formal proficiencies and of the completeness of the assignment all the way to an evaluation of the writer's capacities for excellence in topic selection, for logical organization and sequencing, for the logical construction of arguments and their clear presentation, and for sound judgments in the formulation of conclusions.

Rubric scoring is employed in the peer reviews of all of the assignments in the "Skill Development for Scientific Writing" phase of the curriculum (A01 – A07). In this phase, each assignment usually is assessed by single peer review, and the peer review is managed to ensure that every group reviews another group only once. The oral presentations (A06) occur in three class meetings with 5 presentations per meeting. The presentations are assessed by rubric-based peer review by the students in the audience of a given session and excluding the students who present in the same session and the co-chairs of the session. With the rubric-based peer reviews given and received in A01 – A07, the students are well prepared for the "Near-Authentic Exercise in Scientific Writing and Authoring" and its three-fold, journal-style scientific peer review (*vide infra*).

Scientific Writing & Peer Review: Manuscript Preparation, Review and Revision

Science at its very core is "data-based, rational analysis" and the overwhelming majority of scientific papers contain original data. Aspects related to the acquisition of the original data are described in the "Materials and Methods" section and the original data are documented either in the paper or in an "Appendix" (Supporting Information). An authentic exercise in scientific writing must be concerned with the rational analysis of original data within the existing context. Yet, there are obvious limitations to original data generation in writing classes and the question is "How to write a scientific paper without original data?" To resolve this conundrum, we ask the students to identify a suitable topic in the theme area, to collect all relevant information about a recently described molecule/material (structure, preparation, chemical characterization, performance) and to "adopt these data as their own." Hence, the students browse the recent primary literature in search of a subject of their choice, and a list of professional journals in the theme area is provided for initial guidance. Obviously, the students only *pretend* that the discovery of their "new" molecule/material is theirs. Each group is required to provide all sources about their molecule/material as a bibliography on the last page of the appendix of their paper. With this premise, assignments A08 – A11 constitute a contiguous sequence that creates a near-authentic experience in scientific writing and its assessment by scientific peer review.

The manuscript preparation requires a significant effort and the task is performed in two steps in assignments A08 and A09. Assignment A08 consists in the selection of the subject, the collection of all the required information, and the documentation of experimental methods and results in the materials and methods section and in the appendix of the projected paper. Assignment A08 is evaluated by rubric-based peer review to ensure that the groups are on track before they progress to the completion of their manuscripts in assignment A09. Assignment A09 builds on A08 and requires the writing of the sections Introduction, Results and Discussion, Conclusion, and Abstract. The students are required to compare the characteristic features of their "new" material to those of two other prominent materials with the same kind of function. This sort of comparison is very much a part of authentic research planning and reporting. With A09, the focus shifts from "reporting and documenting" to "analyzing, explaining, judging and concluding." In addition, with A09 begins the instruction on the author's publication correspondence and the students need to write a cover letter to accompany the submission of the paper.

Thus, everybody will write a paper on the general theme of the course and, at the same time, the papers will vary greatly because of the students' original selections of their specific topics. It is this commonality of the general theme together with the variety of the specific topics that ensures competent peer review and, hence, assignments A10 and A11 truly provide instruction and practice in "scientific peer review." Assignment 10 consists in the scientific peer review of A09 submissions. Every paper is peer reviewed by three groups following the peer review format and criteria of the *Journal of Organic Chemistry*. In assignment A11, the students respond to the peer reviews received. The students revise their manuscripts, write a rebuttal letter (i.e., a cover letter that describes and justifies all the changes made), and submit these items for a second round of peer reviews by the previous three referees. This review of the revised papers is a rubric-based peer review and the average score of three reviews becomes the A11 score.

Grading Scheme: Encourage High Quality Original Submissions

The grading scheme has evolved over the years. Initially, student course grades were based on their completion of all assignments in an "acceptable manner." With growing confidence in the quality and fairness of the peer review process, the grading scheme increasingly considered the peer review scores, and we describe the grading scheme implemented since the Spring Semester 2013.

The peer review of an assignment results in a peer review score (PRS) up to a maximum of PRS = 20. Various modes of revision are required depending on the peer review score of an original submission (PRSO). We value and reward high quality original submissions during the "*Skill Development for Scientific Writing*" phase of the course, and various types of revision are requested depending on the peer review score. No revision is required for a submission with PRSO ≥ 19 ("accepted as is"). More usually, the score falls in the range 19 > PRSO ≥ 15 ("minor revision required") and the students are asked (a) to read the peer review comments carefully, (b) to revise their assignment considering the reviewer comments, and (c) to submit the revision in electronic form to the instructor with changes made with "tracking on." The assignment is completed once the instructor accepts a satisfactory revision. Peer review scores PRSO < 15 ("major revision required") happen rarely. In such an event, the students are asked to perform tasks (a) – (c) and the additional task (d): The submission of the revision needs to be accompanied by a description of the changes made and an explanation as to how these changes address the comments by the peer reviewers. The revision will be accepted once it scores above 15 points.

In the "*Near-Authentic Exercise in Scientific Writing and Authoring*" phase of the course, we again reward high quality original submissions of assignment A08, because all of the skills required for the execution of A08 have been acquired and practiced in A01 – A07. However, the original paper is scored only after scientific peer review and revision; i.e., A11 is scored while A09 is not scored.

Students are provided periodically with class performance measures (*i.e.*, average, standard deviation, minimum and maximum scores) to assess their relative performance, and grades are assigned at the end of the course based on the student's average of PRSO scores (<PRSO>) as follows: "A" if <PRSO> ≥ 19, "A-" if <PRSO> ≥ 18, "B+" if <PRSO> ≥ 17, "B" if <PRSO> ≥ 16, "B-" if <PRSO> ≥ 15, and so on. In addition, students can improve their grades by provision of exemplary work (which will be posted as sample, seven opportunities) and by delivery of an outstanding oral presentation (top three presentations) and/or submission of an outstanding final paper (top three papers). Every instance of a special recognition improves the grade by one notch. For example, a student with an average original peer review score of 17.5 and one submission selected for posting as a sample will receive an “A-”.

Results of Assessment

Informal Assessments. Toward the end of the course, the students were asked to list the ten most pertinent keywords they associate with the course. The frequency analysis of the collected keywords provided a “wordle” of the type shown in Figure 1, where the font size of each word reflects its frequency. “Writing,” “Research,” and “Chemistry” usually are the top three association, and their relative frequencies vary from semester to semester. The fourth most frequent word usually has to do with the theme of the course (i.e., “Detergent” in SP12).

This outcome of the free association exercise is nicely aligned with the intended learning goals. The course educates in scientific writing in chemistry and it is research intensive. The themes of the courses facilitate these educational goals, and the themes are chosen to be sufficiently interesting and appealing to a general audience so that chemistry content issues do not dominate the discourse. It also is noteworthy that some words occur only with low frequencies, and words associated with peer review fall into this category. Peer review was not a source of apprehension and, instead, the students were comfortable with the peer review process.

Figure 1. Wordle of the top-10 associations by the SP12 student at the end of the seminar course.

Formal Assessment. The students of all courses offered by MU’s Department of Chemistry are asked to rate the course and the teacher on the seven criteria listed in Table 3 using a five-level Likert scale (0 – 4, 4 is high). The “overall rating” is determined as the average of the numerical scores of the seven department questions, and this aggregate score is commonly used to measure teaching performance. The second part of the questionnaire asks the students to provide written answers to six questions and these are: 1. List the strong and weak features of the lecturer and

Table 3. Student Teaching Evaluations, Spring Semesters 2010 to 2013

#	Criteria of Evaluation	SP10[a]	SP11[b]	SP12[c]	SP13[d]
1	Organization and preparation of lectures and discussions	3.73	3.61	3.90	3.84
2	Instructor’s enthusiasm for the subject matter	3.96	3.96	4.00	3.96
3	Helpfulness in answering questions and clarifying points	3.50	3.35	3.76	3.84
4	Ability to lecture in a manner which is easily followed	3.46	3.52	3.76	3.72
5	Ability to stimulate interest in the subject	3.07	3.22	2.97	3.72
6	Overall rating of the instructor	3.69	3.57	3.66	3.88
7	Your rating of how much you have learned	3.34	3.26	3.34	3.66
8	Overall rating, Average of Questions 1 – 7	3.53	3.50	3.63	3.80

(a) Spring Semester 2010: http://faculty.missouri.edu/~glaserr/3700s10/3700s10_evals.html.

(b) Spring Semester 2011: http://faculty.missouri.edu/~glaserr/3700s11/3700s11_evals.html.

(c) Spring Semester 2012: http://faculty.missouri.edu/~glaserr/3700s12/3700s12_evals.html.

(d) Spring Semester 2013: http://faculty.missouri.edu/~glaserr/3700s13/3700s13_evals.html.

include suggestions for improvement. 2. Compare the lecturer to others you have had (especially with those in science courses at this level. 3. List the strong and weak features of the overall course (not the lecturer) and include suggestions on how its quality might be improved. 4. Compare the course with the others you have taken. 5. Your overall rating of the course (circle letter grade): A B C D E. 6. My approximate GPA prior to the current semester was ____.

The students fill out the questionnaire toward the end of the semester and in the absence of the teacher. The teacher allocates 10 – 15 minutes of class time for the students to fill out the questionnaires and asks one student to collect the questionnaires and to deliver them directly to departmental staff. The results of the teaching evaluations (average scores to Likert scale items) and transcripts of verbatim comments to the above questions become available to the teacher after all grades are filed. It has been a practice of the first author to post all of these data (average scores and complete and verbatim student comments) online and freely accessible, and the URLs are provided as footnotes to Table 3.

The results of assessment show that this assignment-based curriculum has enjoyed a high level of acceptance by the students every semester (Table 3). The curriculum is more than accepted, it is welcome & desired! In particular, the peer review systems works very well. We believe that this high level of acceptance reflects the clarity of the purpose of the new curriculum. The learning goals of this framework are compelling and self-evident, and there has never been much need to justify this curriculum to the students. In fact, my students frequently said that they would have liked to take more courses of this type and they expressed the sentiment that taking such a course earlier in their student careers would have been beneficial.

Conclusion

As this article is being written in SP14, MU students are taking Chemistry 3700 with the theme “Nutraceuticals: Sources, Delivery, and Functions.” Last week was oral presentation week with talks on a variety of dietary supplements: alpha lipoic acid, glucosamine, CoQ-10, magnesium, selenium, vitamins D and B_6, ginseng and garlic, flavones, omega 3-6-9 fatty acids, caffeine and taurine. The students needed to study the functional components of common nutraceuticals and formulate and examine plausible scientific hypotheses regarding the claimed function of the nutraceuticals. The need for scientific literacy becomes truly self-evident when it comes to food, and our themes are selected every semester mindful of Jefferson’s mandate.

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Biography

Dr. Rainer E. Glaser, studied chemistry and physics at the Universität Tübingen (Diplom 1984), at the University of California at Berkeley (Ph.D. 1987), and at Yale University (post-doctoral), and he is currently a Full Professor of Chemistry at the University of Missouri, Columbia. Glaser is a physical organic chemist with interests in optical materials, catalysis, cancer chemotherapeutics and biomimetic CO_2 sequestration. Dr. Glaser has been interested and engaged in higher education throughout his career and with focus on fostering interdisciplinary learning. In 1995, Glaser began his education research with the novel curriculum, Chemistry Is in the News (CIITN), that he designed for chemistry education of science majors with funding by the Dreyfus Foundation and by NSF. More recently, since 2009, Glaser has been serving as co-PI on the NSF-PRISM grant Mathematics and Life Sciences, and he has been developing a new curriculum to teach Scientific Writing in Chemistry both a MU and at the University of the Chinese Academy of Sciences, Beijing. Glaser has enjoyed extensive collaborations with chemists, biochemists, physicists, mathematicians, astronomers, educators and journalists in the US, Europe and Asia. Glaser was elected AAAS Fellow in 2004 and Fellow of the Royal Chemical Society in 2006.

Translating University chemistry for the classroom

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Introduction

When university studies are reflected on retrospectively by young in-service teachers, a majority of them expresses the feeling of not having been prepared adequately by university courses for the job of teaching chemistry. Many of these teachers describe having entered a state of shock when they started teaching at school, because their everyday school life experience differed to a considerable extent from what they were taught in university courses. Just 6% of the beginners felt well-prepared (Schumacher & Lind 2000, p. 25). Most, however, pointed out that they experienced unbalanced relations between aspects of chemistry science on the one hand and pedagogy and chemistry education on the other, in subject-oriented teacher training courses: *"I feel pedagogically under-qualified and subject specifically over-qualified"* (Schumacher & Lind 2000, p. 25).

The Division for Chemistry Education of the Freie Universität Berlin (FUB) works against such views and started to investigate how students experience their studies – the chemistry education courses in particular – during the five years they spend at university using a formative assessment design. In 2012 and 2013, 54 students who had just started their educational courses at the Freie Universität were surveyed on their opinions about the requirements they should have as future chemistry teachers, as well as on their expectations concerning chemistry education courses. The students were asked two questions:

1. What do you think is expected of you as a teacher?

2. What do you expect from your studies, especially from your chemistry education courses?

The goal of this survey was to get an insight into the idea students have about their future profession, and to revise this idea if necessary. In addition, information about needs and wants students have in their educational training would be gathered, to enable us to respond to those wishes in training courses.

The results show that a majority of the students who participated in this survey is of the opinion that they need to be **experts** of chemistry for being teachers: *"I need to have an answer to everything my pupils are asking me"*. The second most common answer was that they need to be able to **equip** pupils with this knowledge of chemistry in an effective, creative, and fascinating way, using various methods and teaching styles. A traditional view of learning arises out of these assumptions. This view is also expressed in the expectations students have on their training courses in chemistry education. Here, they wish to be **equipped** with a catalogue of practical examples on how to get the tools and techniques for lesson planning, which help them to facilitate knowledge transmission and instruct them on how to plan a lesson. A central aspect of chemistry education courses was totally left out by all of the participating students: the aspect of science education research (SER) and its importance for teachers was not even mentioned once.

These results introduces a task to us as science education researchers and educators. We have to introduce students to science education research and to present this discipline as a practically-based and research-intensive counterargument to the simplified traditional beliefs of students. The answers from the students show how important it is to stress the impact of SER in their courses. A second conspicuous thing we find is the imbalance of the expectations students have regarding the knowledge of the subject. At the beginning of their studies knowledge is of prior importance to them. Towards the end however, subject knowledge is assessed as too important. A big challenge for teacher education arises out of these comparisions: a balance needs to be found between the subject, education, practical training skills and methods, normative expectations and standards, pedagogy and the needs of the students. The balance and connections between these fields are important to respond to the unbalanced situation between university studies and real life at school. Teacher students often experience chemistry, science education and pedagogy as distinct areas in their studies – but the interaction of these fields is of major importance to support and enhance their professionalism as a future teachers (Shulman, 1986).

Theoretical background

German school education and teacher training is based on standards, which are also important for study regulations at university. The standards define requirements teachers have to meet. The superior standard is: teachers are experts of teaching and learning. Their core task is the specific and scientifically-reasoned design and reflection on teaching and learning processes. Teachers are expected to perform their educational role properly, undertake advisory and assessment tasks, and teachers adapt their competences continuously (Standing Conference of the Ministers of Education and Cultural Affairs, 2004, p. 6). In addition to these general tasks, the Standing Conference of the Ministers of Education of each state in Germany decided more specific requirements for each subject in teacher education. Concrete descriptions of the competences students should have at the end of their studies regarding the subject chemistry and chemistry education courses are basic knowledge in organic, inorganic, physical chemistry and biochemistry, as well as knowledge in chemistry education and practical teaching skills (Standing Conference of the Ministers of Education and Cultural Affairs, 2008, p. 12). Beside these normative requirements, it is helpful to consider research about professional development to find effective ways to reach the goals.

Focusing on effective professional development research, there are aspects like prior knowledge, beliefs and expections of learners, which have to be known as a starting point and basis for developmental processes, because these influence each learning process. This also includes learning processes from adults. *"Too often the cognitive research on learning is forgotten when it comes to designing teacher's training"* (Loucks-Horsley *et al*. 2010, p. 53).

Focusing on the term 'learning', students should not only be provided with the idea of constructivism in science education courses but also doing it in our courses. Therefore, what has to be kept in mind in university teaching is, that:

- new knowledge of students is built on their prior knowledge
- learning is an active process
- knowledge is constructed through a process of change
- new knowledge comes from experiences and interaction with ideas and phenomena
- learning needs to be situated in meaningful and relevant contexts

- learning is supported through student interaction about the ideas of science (Loucks-Horsley *et al*. 2010, p. 54; Gerstenmaier & Mandl, 1995).

In addition, Loucks-Horsley points out: *"Teachers and teacher students benefit from learning experiences that are based on the same principles that they are expected to implement with students as well as from opportunities to learn what content and instructional approaches are recommended by standards and research"* (Loucks-Horsley *et al.* 2010, p. 170). Using the same methods and principles the students should use as teachers in school facilitates university courses and also emphasizes the change of roles between being a learner and being a teacher. Taking these statements and principles into account, useful guidelines for professional development can be deduced. People involved in teacher education should:

- provide opportunities for active engagement, experiences, and discussions; students should reflect upon and challenge existing ideas as well as construct new ones
- situate the learning content familiar contexts for teachers and students
- make useful connections and resolve dissonances between teacher students existing ideas and new ones
- use formative assessment to elicit prior knowledge
- provide time and support (Loucks-Horsley *et al.* 2010, p. 57).

The usefulness of knowing more about the basic knowledge of students is shown in the results of a questionnaire on the particle model (Bendict & Bolte 2010), which was used in the chemistry education courses at the Freie Universität Berlin when talking about students' concepts on particles and how to deal with the different ideas pupils could have regarding this model. The questionnaire was actually designed for pupils of 4th to 6th grade (Bendict & Bolte 2010). We used the questionnaire to analyze the concepts of the BA-students in the beginning of the chemistry education courses, as a starting point for discussions about conceptual change. More than 15% of a group belonging to the Bachelor programme answered the question "What colour does particles of water have?" with "Blue", even though they already finished courses about general and inorganic chemistry. This result shows the importance of reflecting the students' existing ideas over and over again in the process of teaching.

Summing up, professional development experiences:

- provide opportunities to build content, pedagogical content knowledge and skills and to reflect on practice critically,
- are research based and engage teacher students as adult learners in the learning approaches they will later use with their pupils,
- provide opportunities to work cooperatively and support students to deepen their professional expertise and serve leadership roles (Loucks-Horsley *et al.* 2010, p. 71).

In the following sections we report about teacher education in Germany in general, about chemistry education at the Freie Universität in particular, and how the theoretical underpinning above fits in within this.

Professional Development in chemistry education at FUB

Teacher training is quite similar in all federal states of Germany. It is divided into three stages. The first stage is the study at university. The students complete a study program (duration: five years) before they enter the second stage, the traineeship at school, where they teach pupils at school for about two years, (6 to 12 hours a week) and attend various semininars st university. The third stage is the ongoing professional development of in-service teachers.

The Freie Universität Berlin has introduced the degrees Bachelor (6 semesters) and Master (4 semesters) in teacher education in 2004. Both contain modules of chemistry education (Figure 1).

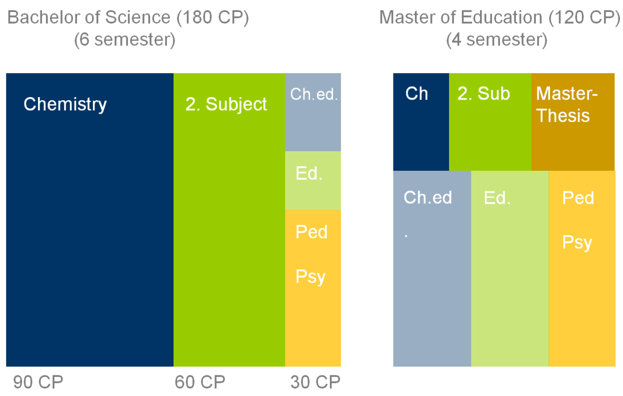

Figure 1: Overview about Bachelor and Masterprogram for chemistry teacher education at Freie Universität Berlin

In the bachelor program the chemistry education module is divided into three courses: "Introduction to Chemistry Education" (2 CP), a seminar on "How to plan a chemistry lesson" (3 CP) and a second seminar "Practical studies in chemistry teaching" (3 CP). The master program contains three chemistry education modules: "Practical Studies at School" (11 CP), "Concepts of Chemistry Teaching" (11 CP), and "Science Education Research" (6 CP). When the courses were designed, the balance between subject knowledge, chemistry education and practical teaching was taken into account.

"Practical Studies" in the bachelor program

The goal of this course is to deepen and to apply principles in chemistry education to design lessons in an early stage of the study. Usually the students attend the course in their fourth or fifth semester. For the students this course proved to be an early opportunity to try out the teacher's role. In the course students cooperate to develop and refine lessons in a cycle of prediscussion, teaching and observation, as well as postdiscussion. Literary resources offer explicit suggestions for designing practical courses. Table 1 illustrates these recommendations as well as the practical implementations conducted in this course.

Theoretical Recommendations (Loucks-Horsley *et al.* 2010, p. 206)	**Practical implementation in the course "Practical studies in chem. education"**
Defining the theme or concept to guide the lesson	Deepening basics in chemistry education
	Sitting in on class or course at school
Designing the lesson (in groups)	Planning a lesson (90 min) in pairs for the class
Teaching the lesson	Teaching the lesson
Observing the lesson	Observing lessons of other students
Reflecting and evaluating the lesson	Reflecting the lesson in the group
Revising the lesson	Revising the lesson in pairs
Teaching the revised lesson	Teaching the revised lesson
Reflecting and sharing results	Written report (incl. reflection)

Table 1. Structure of theoretical recommendations and practical implementations in BA – Practical Studies

Two different courses were offered for the practical studies. One focused on students gaining experiences by teaching a group of children aged 10 to 12; the other course focused on working together with a school class of 7th and 8th graders.

The courses for children are an out-of-school afternoon program (KieWi, 90 Minutes per week) independent from the school (Streller & Bolte, 2012). The children can participate in the science course for a maximum duration of two years. In this course, two teacher students plan a lesson together and conduct this lesson as a team, while other students watch their performance (Figure 2). Directly after the course a one hour reflection seminar takes place, where critical and successful situations are discussed. Usually, students try to choose a topic which could be exciting for the children and a topic where the children actively investigate a scientific question. This course provides the teacher students with an authentic teaching experience.

Figure 2. Teacher student teaching a KieWi-course (KieWi = children discover science)

In addition to this course, a second opportunity for the practical studies is offered. Here the students teach real classes in partner schools. Since 2008, FUB has cooperated with two schools in the university's neighbourhood – the Schadow and the Beethoven Gymnasium. Classes of 7th and 8th grade are invited to participate in a one week course at the university's laboratory (Bolte, Streller, Hofstein 2013, p.86f.). During this project-week the pupils are taught by teacher students. Before the students start to plan their lessons, they discuss their ideas with the teachers of the participating classes: what topic should be emphasized during the project week, what wishes do the teachers and the pupils have and how learning conditions in the classes usually are. This partnership is a win-to-win situation: for the teacher students the usually abstract pre-service learning situation of planning a lesson leads to an "authentic learning and teaching situation"; for the in-service teachers the project week becomes a learning situation as well. They are introduced to topics and approaches of teaching which they might not have taken into consideration before. Moreover, they finally have the opportunity to quietly observe their pupils. For one week the pupils can experience a different learning environment focusing exclusively on science. This way they have a chance to deal with a topic in a more detailed way than school teaching is usually able to do within a 90 minutes lesson (Figure 3).

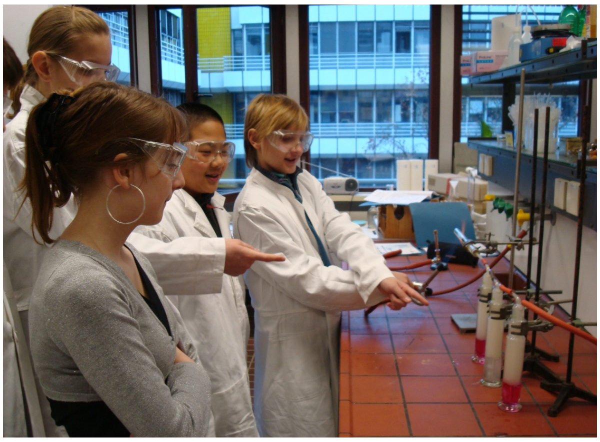

Figure 3. Pupils of grade 7 with a self-made model of a desulphurisation plant at university

During the preparation of this project week, all teacher student-groups have to try out and modify the experiments, which they plan to conduct in their lesson sequence. Moreover, materials are prediscussed with the lecturer of the seminar. The students also get time to discuss their lesson plans with their fellow students. At the end of the project week the students assess the lessons. The results are then used by them to reflect on their own lessons. Each student has the possibility to teach his or her lesson at least twice in two different classes. Students who are not teaching observe the lessons of their fellow students. At the end of each day the students discuss their lessons with their fellow pre-service teacher students, with the chemistry teacher of the class and the lecturer.

"Concepts of Chemistry Teaching" in the master program

In the master program three modules on chemistry education are offered. The goal of these modules is to bridge the gap between the subject and science education. Therefore, students get lectures and seminars on chemistry and a parallel seminar on concepts of chemistry teaching (Figure 4). In the seminar, results from science education research on how to promote effective teaching are presented and discussed. Afterwards, students are supposed to combine a chemical aspect from the lecture with a specific approach to science education from the seminar and develop their own sequence of lessons for upper high school classes, working together in groups. These planned lessons have to be based on the criteria of the selected approach and on a high level of student activity and interdisciplinary aspects. In the following part, these two basic seminars as well as the final bridge between the subject and science education will be described in more detail.

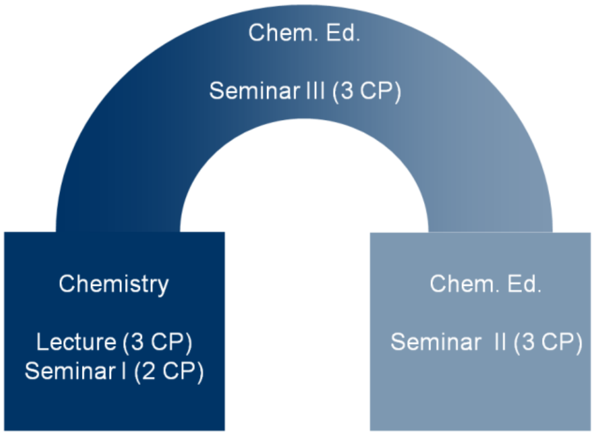

Figure 4. Structure of the module "Concepts of Chemistry Teaching"

The first basic seminar is formed by a chemistry course with two different core topics:

1. A focus on organic chemistry with biomolecules: carbohydrates, proteins, lipids, enzymes, other natural products and metabolic pathways, and
2. a focus on physical and environmental chemistry: pollution of atmosphere, water, soil; aerosols, renewable energy, clouds, photovoltaics, photo-oxidation, and analytics.

The lectures are held by a professor of the Institute of Chemistry and Biochemistry. In the chemistry seminar students have to prepare a scientific presentation based on an article from a chemistry journal. These lectures and the seminar are classical university courses, and are also in the master degree program for chemists. In a parallel seminar on chemistry education, the students learn about different approaches, including concepts, methods and procedures of how to teach and learn chemistry, e.g. context-based chemistry learning, active learning, problem-oriented approaches, socio-scientific issue based chemistry learning, meaningful learning.

The third part of the module aims at bridging between the subject and science education. Here, students choose a scientific topic from the chemistry seminar as well as an appropriate teaching approach. Then the students develop a sequence of lessons for upper secondary school in small groups. An examples for a sequences is: *The world of flavour – terpenes*. The idea to use the context flavour came from the article "Pesto – Mediterranean Chemistry" (Roth, 2006). The students present this sequence to the other students and demonstrate the lessons they have planned. The important thing about the trial is to practice demonstrating experiments in front of a group of people. Towards the end of the seminar, students are also allowed to present their ideas to the participants of an in-service teacher training course (Figure 5). This step is important because it offers students the possibility to get into contact with teachers and to receive feedback on how realistic an implementation of their developed sequences would be in the context of school chemistry classes.

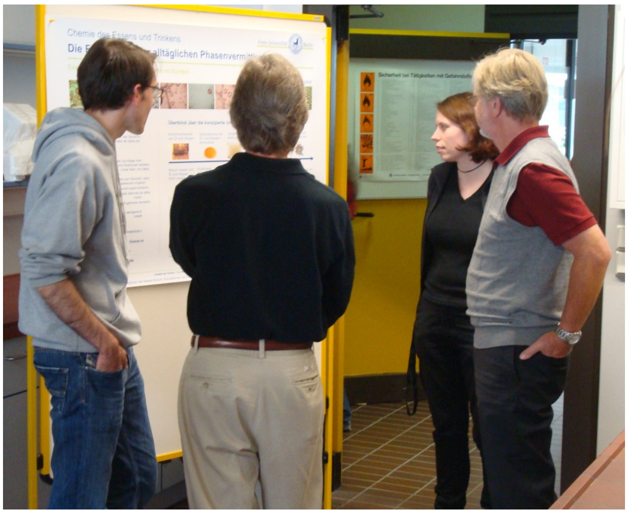

Figure 5. A Student (left) presenting his lesson sequence to teachers

Conclusion

The Division of Chemistry Education at FUB tries to find a balance between the different relevant areas of chemistry education, pedagogy and the subject chemistry. Moreover, in our seminars we try to offer these areas to students of chemistry education courses in authentic learning situations. This means, the students get exposed in an early stage of their study to the opportunity to teach pupils in a class. The courses described in this article are subject to intensive testing and evaluation. The aim of these surveys is to provide information about the impact of the courses. The feedback from the surveys will then be used to optimize contents and topics of these chemistry education courses. The results of the first survey showed that students judge an expertise in chemistry, as well as the ability to impart knowledge about chemistry to students, is of major importance for their role as future teachers. Further surveys will be conducted to reconstruct changes in these attitudes towards chemistry education and teacher roles in the process of their study. For that purpose we also use an adopted version of the stages of concern questionnaire (Schneider & Bolte, 2012). The feedback from the surveys and the questionnaire will then be used to optimize the contents and topics of chemistry education courses.

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Biography

Sabine Streller is a fully trained grammar school teacher for chemistry and biology. She did her PhD in chemistry education. She has several years' experience in pre- and in-service science teacher training, especially in running CPD courses for science teachers. Her main research interests are students' interests in science and approaches to enhance the professionalization of in-service teachers and teacher education students. She is/was a member of the FUB group in the EU projects PROFILES and SALiS. In 2011/12 she was Professor of Biology and Chemistry education at RWTH University Aachen. She is currently a research assistant at Freie Universität Berlin, Division of Chemistry Education (chemistry didactics), and is involved in the preparation of science teachers and in running CPD courses.

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Learning Chemistry through Enquiry

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Introduction

Enquiry-Based Learning (EBL) encompasses a number of learning approaches, typically student-centred, which are driven by a process of enquiry. These include Problem-Based Learning (PBL), small-scale investigations and project work or research activity (Kahn and O'Rourke, 2005).

Kahn and O'Rourke (2005) describe some of the characteristics of EBL:

- *"Engagement with a complex problem or scenario, that is sufficiently open-ended to allow a variety of responses or solutions*
- *Students direct the lines of enquiry and the methods employed*
- *The enquiry requires students to draw on existing knowledge and identify their required learning needs*
- *Tasks stimulate curiosity in the students, encouraging them to actively explore and seek out new evidence*
- *Responsibility falls to the student for analysing and presenting that evidence in appropriate ways and in support of their own response to the problem."*

EBL can not only facilitate learner independence and an enquiry-driven style of learning in students but also the acquisition of a number of key graduate employability skills such as oral and written communication skills, interpersonal skills, time management skills and problem solving skills. This approach therefore aligns well with the QAA Benchmark Statement for Chemistry (QAA, 2007) and a report on "*Skills Required by New Chemistry Graduates and Their Development in Degree Programmes*" (Hanson and Overton, 2010).

The literature contains many examples of the use of EBL and PBL in Chemistry. This article does not aim to review these but for a number of excellent resources, produced as part of the the HE STEM programme, the reader is directed to the "*Context- and Problem-Based Learning*" webpage on the Royal Society of Chemistry website. (http://www.rsc.org/Education/HESTEM/CPBL/index.asp)

Implementing EBL

After surveying the literature and careful consideration of our undergraduate curriculum, it was decided that the most appropriate place to introduce the EBL methodology in our undergraduate Chemistry degree programmes was as part of a core first year module in the area of the interpretation of spectra. There were two main factors influencing this decision: firstly the nature of the material to be learnt leant itself well to a real-life context which is an important factor in the production of engaging EBL scenarios. The second factor related to the timing of the course which was delivered in the first week of the first year of the degree programme, so this was seen to be an ideal time to foster learner independence before students became used to a lecture-based delivery style. The course on spectral interpretation had previously been taught for a number of years in a traditional manner. This comprised six 1 hour lectures (on each of the four main spectroscopic techniques: mass spectrometry, infrared spectroscopy, ^{13}C NMR spectroscopy and ^{1}H NMR spectroscopy) with six 2 hour workshops delivered in parallel.

Before implementing EBL in full, the EBL technique was trialled using a small scale pilot study with twelve first year student volunteers who had already completed the traditional delivery of the course on the interpretation of spectra. An icebreaker and an EBL scenario were piloted along with a questionnaire which was to be used for evaluative purposes in the full study. The questionnaire piloted was based on one produced by Moore (2006, 2007) and included Likert-style questions (Likert, 1932) as well as a number of open-ended questions. The findings from the pilot study were positive for the icebreaker, EBL scenario and questionnaire and so it was decided to implement the EBL delivery in full as a research study. The full study subsequently led to the successful completion of an MPhil in Chemical Education by Timothy Lucas at the University of Birmingham in 2009 (with the author as his main supervisor), the findings of which have been published in full (Lucas and Rowley, 2011).

The full scale EBL approach involved inverting the traditional teaching delivery method: students were learning how to interpret spectra through problem solving in six 2 hour workshops *before receiving any lectures on the techniques*. It must be emphasised that the students did have some prior knowledge of the spectroscopic techniques from their previous A Level studies in Chemistry. Students were grouped according to a questionnaire, given out during induction week, which asked students to self-assess their (perceived) confidence, both in understanding how each of the spectroscopic techniques worked and in their ability to interpret spectra from each of the techniques. This was carried out so that in any group at least one of the students had expressed (perceived) confidence in the interpretation of spectra from each spectroscopic technique, *i.e.* as a group the students had (perceived) confidence in interpretation of spectra from all of the spectroscopic techniques.

Over the course of the first six weeks of their first year, students spent two hours per week in face-to-face EBL workshops during which new scenarios were given out and initial support was given. The students had to complete the work required each week outside of the workshops (there was, deliberately, too much to complete within the two hours) which meant that each group needed to meet up (virtually or face-to-face) and to work together to complete the tasks in order to hand in their reports at the start of the subsequent EBL workshops. Once the work had been handed in verbal feedback was given to the students so that they could gauge how well they had performed. Their hand-written group reports were then scanned and marked electronically (using a tablet PC) and feedback was posted online to each group, in their VLE discussion area, within 24 hours. In addition, a model answer guide was posted online. This arrangement meant that students could use their group feedback, along with the model answer guide, to improve their performance for each successive scenario. The sessions were carried out in a large flat room with movable tables and chairs and were facilitated both by a "*floating*" facilitator (member of staff) and by four trained postgraduate "*fixed*" facilitators, each of whom was allocated a number of groups for the full six weeks.

The first EBL workshop placed students into their groups with each group comprising six students. The students participated in an ice breaker and received introductory information explaining to them why the EBL technique was being used, how it would help them, and what to expect. The students then had to produce a set of group rules which outlined how they would function as a group to work effectively and to complete the forthcoming tasks. They had to post their group rules online in their group discussion area of the VLE. In addition, students were given advice on how to problem solve and on action planning. The students were also encouraged to discuss their knowledge and comprehension of the techniques and their associated spectra so that they could establish their group's prior knowledge in each of the techniques. They were also given two sets of spectra to practice their spectral interpretation as a group which was handed in at the start of the following session.

Four main scenarios were used to deliver the EBL: the "*Waste Disposal*" scenario placed students in role as a team of graduate chemists in a fictional analytical department. They received a memo from their boss saying that unlabelled chemical waste had been found in some disused laboratories and that their help was needed to identify the waste to enable safe disposal. The spectra of the compounds which the students were working on were those of common laboratory solvents in order to help them with their laboratory studies at a later date. There were sixteen sets of spectra in total and each group had a different subset of eight of these. It was a deliberate decision to provide more spectra than group members to prevent a "*divide and conquer*" approach (Duch, 1996) and to encourage the students to work together and to learn from one another and not for each group member to work individually. The next scenario was "*Down the Drain*" – this was the scenario which had previously been piloted. In this scenario dead fish had been found in a nearby river due to unknown chemical waste. The students had to use the spectra provided to determine the pollutants.

Again each group of students had eight sets of spectra (each a subset of a total of sixteen sets of spectra). The compounds in this scenario were ones which students would encounter later on in their practical chemistry. In the third scenario, "*Carbonyl Conundrum*", students were given the identity of six compounds which gave rise to twenty-four spectra. Their task was to determine which spectra belonged to which compound but this was quite challenging as many of the compounds were structurally very similar. The final scenario, "*Reaction Dilemma*", was more complex and ran over two EBL sessions. Up until this point students had been working on simplified spectra to help them to practice their interpretation skills. The final scenario used authentic spectra to familiarise students with the sorts of impurities found in day-to-day spectra. They received an email from a fictional postgraduate student who had carried out a reaction. The students had to analyse the spectra of the product, and, by communicating with the fictional student through the discussion board in the VLE, determine what had gone wrong with the reaction. After completing the EBL sessions students received five 1 hour lectures to consolidate what they had learnt and also to reinforce their learning with the underlying theory behind each of the techniques.

Evaluation

As mentioned above, this work was part of an MPhil research study in Chemical Education, and so a detailed evaluation was necessary. The overarching research question of the study was *"What are the experiences of first year Chemistry students of a new EBL approach to teaching Spectroscopy?"* with two sub-questions. The first sub-question was *"How does student perceived confidence change, if at all, as a result of their experience in using EBL in the Spectroscopy course?"* This was evaluated through semantic differential questions (Osgood *et al.,* 1957) in pre- and post-EBL session questionnaires. The data gathered enabled an examination of the changes in students' perceived confidence in understanding how each of the spectroscopic techniques worked and in their ability to interpret the associated spectra. Overall the results indicated that the students were positive about the EBL learning experience. The findings suggested that the students began with quite high (perceived) confidence in all of the spectroscopic techniques, with the exception of ^{13}C NMR spectroscopy and generally they gained in confidence through the EBL process. It should be noted that, at the time of this study, many students indicated that they had little knowledge of ^{13}C NMR spectroscopy from their previous studies. It was found, in the area of interpreting spectra, that a few students indicated a decrease in confidence, perhaps as a result of over-estimating their ability initially. A statistical analysis was not possible as the sample size was too small (N = 38 to 42).

The second sub-question was *"What are the students' attitudes towards the processes of EBL, and how do these attitudes change through the course?"* This was evaluated through Likert-style (Likert, 1932) and open-ended questions in mid-EBL and post-(EBL and lectures) questionnaires (based on a questionnaire by Moore (Moore, 2006, 2007)) as well as through two focus groups. A number of the processes of EBL were explored. These included: the learning process, difficulties and demands, memorisation and application, enjoyment and roles in the learning process. Overall there were very few changes in responses between the mid-EBL and post-(EBL and lectures) questionnaires. This suggested that attitudes formed early on remained relatively stable. A statistical analysis was not possible as the sample size was too small (N = 30 to 32). The open-ended questions revealed a more detailed insight into students' attitudes towards the EBL processes and suggested that the students found it to be extremely valuable. When asked about the positive aspects of the course comments such as *"working as part of a team"*, *"developing communication skills"*, *"problem solving individually as part of a team"* appeared on numerous occasions. The negative aspects of the course indicated by students related mainly to the timing of the EBL sessions (constrained by the timetable to be 4 pm to 6 pm on Fridays) and difficulties in some groups with unequal student participation.

Two focus groups were arranged, in order to gain a deeper insight into the students' attitudes towards EBL, and were attended by six first year students who had volunteered to participate. The focus groups were carried out in a semi-structured format and provided an opportunity to pursue points of interest which had emerged from the questionnaire data. The findings relating to group work were consistent with those from the questionnaires - on the whole these were positive although a few groups did not function as well as others as a result of unequal student participation.

The focus group participants indicated that they preferred to communicate by mobile phone or to meet face-to-face in between EBL scenarios rather than use their group discussion boards in the VLE. The students commented that the EBL scenarios were starting to become repetitive towards the end of the sessions - although the settings differed and the scenarios became gradually more complex, essentially the tasks were the same. Most of the students indicated that they would rather have had the lectures before or in parallel to the EBL sessions. However, this would have detracted from the collaborative learning opportunity afforded through the group problem solving. It was of interest to note that students saw a need for both the EBL and lectures, *e.g. "with EBL, we are learning to read spectra, but with the lectures we learnt about the background knowledge and how they work"* and *"definitely more interesting than lectures – you're in a group, you're interacting, you've got the postgrads there"*. A potential area of concern for the facilitators was if the students had been frustrated by not being given direct answers to their questions, as, instead, students were guided towards the correct answer (after the facilitator had established where the student/group was in terms of understanding). Reassuringly the findings from the focus group indicated that the students had not been frustrated by this, with one of the students commenting *"I think it's better when someone gives you the answers in a way that you're actually learning from it rather than 'this is wrong, that's the answer'. I personally like to know how I got to that answer, so that's quite a good way"*. The students also commented that the postgraduate demonstrators were generally very helpful, with one student stating that *"one postgrad was giving us clues, he wouldn't just give us the answers, which I thought was quite good."* A particular finding was of interest – analysis of the questionnaire data suggested that the students saw the term *"challenging"* differently from *"difficult"*. This was probed through a second focus group through which it was evident that students perceived *"challenging"* as something which requires some thought *e.g. "how far you can stretch yourself"*. Conversely *"difficult"* was perceived in a more negative way, *e.g. "something you struggle with more"*. The focus groups gave the overall impression that the students had found the EBL to be a highly positive experience.

Conclusion

In summary, it was clear that the majority of students had a positive experience of the EBL methodology and that they had appreciated working in groups and the opportunity to interact with their peers (although some students were frustrated by unequal participation within their groups at times). Students also indicated that they felt that their transferable skills and their ability to learn independently had been enhanced. Their attitudes towards the EBL processes seemed to be formed at an early stage, and, once formed, they remained relatively stable. The majority of students were confident in the various areas of the spectroscopy course after the EBL sessions and the findings indicated that EBL has the potential to increase students' perceived confidence in spectroscopy, especially for those students who are the least confident before the EBL sessions. However, as the same study was not carried out to examine traditional teaching methods (*i.e.* with lectures and supporting workshops) it is not possible to draw any conclusions as to the effectiveness of the EBL methodology compared to a traditional approach. As a result of this study spectroscopy continues to be delivered *via* EBL to our first year chemistry undergraduate students. It is of interest to note that, although many other factors may have been contributing, *e.g.* increasing entry grades of new students, differences in actual questions set, increased feedback through the EBL technique *etc*, the end of year examination question on spectroscopic interpretation, whose format remained the same, saw a 20% increase in mark average for several years (from *ca.* 60% to *ca.* 80%) after switching to the EBL mode of delivery (and where no other change had been introduced).

Acknowledgments

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Biography

Dr Natalie Rowley is a Lecturer and Director of Innovation in Teaching in the School of Chemistry at the University of Birmingham, UK. She became a University of Birmingham Teaching Fellow in 2006, and a Fellow of the Higher Education Academy in 2007. She has been project leader on a number of University of Birmingham Learning Development projects in the areas of e-Learning and Enquiry-Based Learning, the latter of which led to her supervising the School's first MPhil student in Chemical Education research, the findings of which have recently been published. She was also joint project lead on a National HE STEM project on Science Communication. She is currently joint project lead on a University of Birmingham Centre for Learning and Academic Development funded project looking at lecture flipping.

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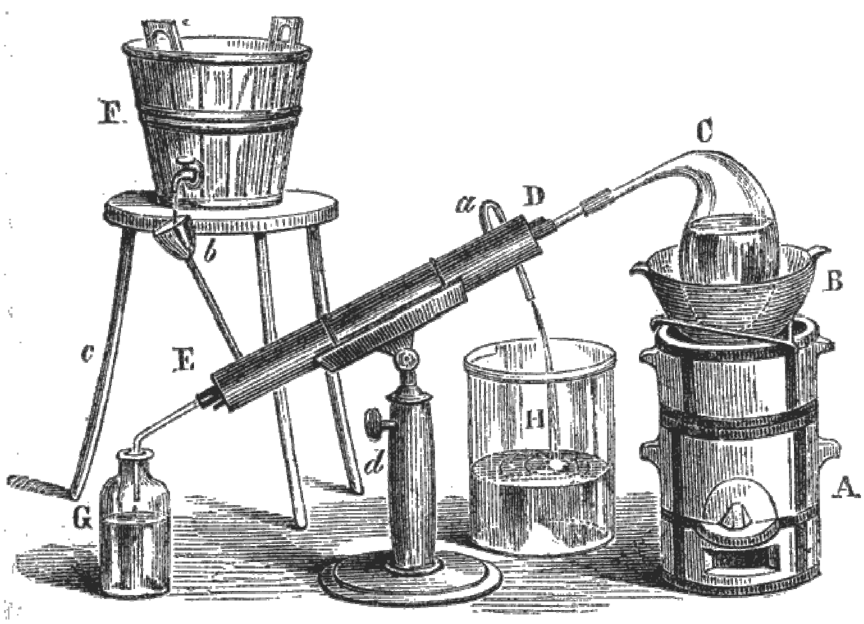
The way it was done: The distillation of ether in the 19th century

http://albumen.conservation-us.org/library/monographs/monckh/chap02.html



Technology-enhanced learning in the chemistry classroom

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Abstract

Technology has the potential to assist us in our role as teachers, but the overwhelming amount of technology can make it difficult for new practitioners to know where to begin in the process of selecting fit-for-purpose technologies.

In this article, I aim to highlight some teaching scenarios where technology can have an impact. These include the following:
(1) Pre-class activities to present some information in advance of classes, and allow learners to check their understanding of this material;
(2) Wikis for facilitating group work and providing a mechanism for tracing each group member's contribution;
(3) Worked examples to demonstrate problem solving approaches for basic problems;
(4) Podcasting and screencasting for providing supplemental revision material for all learners;
(5) Online communities to support learning.

Each example will highlight a case study from practice and further reading for those interested in more.

1. Introduction

The incorporation of technology in our teaching is now ubiquitous but such is the amount of possibilities that it can be overwhelming for those new to the field to focus on areas of use to their teaching. In considering the incorporation of technology in teaching, a potentially useful method is to consider what it is that needs to be addressed, and how technology can be used to help in that scenario – in other words the intervention is driven by pedagogy rather than technology. This is likely to lead to resources that are embedded into the curriculum and are useful to learners, meaning that the time required to create or manage a given resource is offset by their benefit to the curriculum implementation. There are several opportunities for including technology in the chemistry teaching [1-5]. In this paper, I highlight five that can be effectively addressed by incorporating technology into the curriculum delivery.

2. Addressing issues that arise in teaching chemistry

2.1 Preparing students for classroom learning

Chemistry is a complex topic involving a lot of terminology, and which can be presented in different representations [6, 7]. As such, for novice learners, it can be a difficult topic to engage with as it is easy to become overwhelmed with new information and terminology that can lead to a reduced capacity for learning. This is described well by cognitive load theory, which explains that the capacity of learners to assimilate new information is limited by the working memory space. This space is used used up by the complexity of the material (intrinsic load), the difficulty of extracting the material from the learning resources (extraneous load), and the integration of new knowledge into the long term memory (germane load).The latter load is beneficial to learning, and to maximise its scope, the level of intrinsic and extraneous loads in any learning situation needs to be considered so as not to overwhelm the learner [8].

Pre-class activities can be an effective strategy in assisting learners deal with new information that they will be exposed to during the class time. While these activities can be as simple as asking students to read a section of the textbook in advance, greater opportunities exist if a technology-based solution is used. These include tracking whether the activity has been completed, including a quiz, and providing feedback and links on areas of difficulty [9].

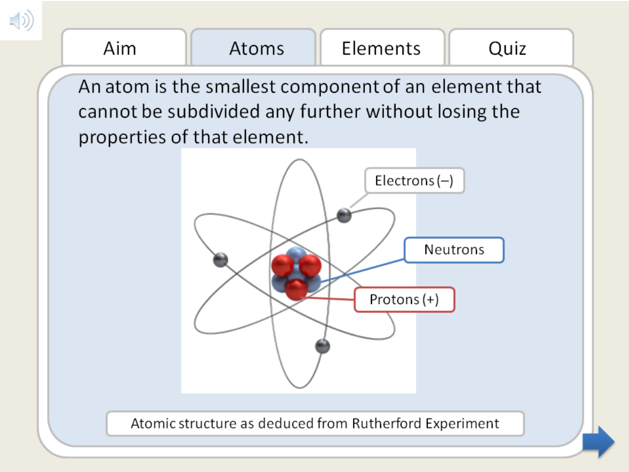

Figure 1: A pre-class activity can highlight key terminology the student will meet in the classroom

In designing the activities, emphasis should be placed on what you want students to know coming into class, not after class. Their aim is to prepare students for the class time. A useful strategy is to consider all of the new terms each class might introduce, and how these relate to the key topic in the class. Therefore a class introducing atoms might define the atom and its constituent sub-atomic particles, and explain isotopes. Therefore students who have completed the activity will have been introduced to the key terminology and been able to check their understanding of some basic principles – for example atomic number and mass number. The class can then build on this work by describing isotopes, calculating atomic mass units, etc. In addition, examining class answers to the quiz can provide valuable information on whether any particular question or topic is providing difficulty before the class begins. By incorporating a quiz at the end of the video resource, it is possible for students to obtain instant feedback on their understanding of the key terms that they need to know.

This simple strategy has been reported at school level and at college level for introductory chemistry. In the school study, two groups of students were taught about chemical equilibrium, with the experimental group scoring higher grades in the post test [10]. The implementation of these strategies at college level led to improved grades for students who had no prior knowledge of chemistry, a fact attributed to their basis in cognitive load theory [11, 12].

The technical requirements of using pre-class activities are relatively straightforward. A podcast/screencast of the material can be prepared and shared on a local virtual learning environment (VLE) or Google Sites. Similarly, the quiz can be included on the VLE or by using Google Forms or similar. It is important to structure what students will do during this time – for example by providing a gapped handout that they can complete and bring to class to build on there. This is a useful strategy for linking the pre-class work with the in-class work.

The concept has been extended further to move more and more of the content-delivery element of the class to beforehand, freeing up more time in the class to working on problems, peer instruction, laboratory work, etc. This concept of "flipping" the classroom has become a popular phenomenon after it was described by two chemistry teachers. Several resources, tips and techniques are available at the Flipped Learning Network, which also includes a chemistry sub-site [13].

2.2 Wikis for facilitating group work

One of the great difficulties in organizing group activities for students is how to ensure fair assessment. While strategies such as peer-assessment and learning logs are useful, many educators are reluctant to use group work as it is difficult to trace what went on as the group completed their project. Wikis offer a potential technological solution to facilitating group work.

Wikis are an online document editing space that can be open to everyone or just to an invited list. The wiki can be set up so that students can edit pages using a word-processing type editor as well as add pages to create a system of inter-related topics. Therefore, they offer a means to create an online site where several people can contribute. The great benefit of wikis in terms of facilitating group work is that the wiki logs all contributions to the site, when they are added, and who added them. This is visible both to the teacher and to students, and therefore they offer a high degree of transparency to group work – it is very clear who is contributing what and when. Wikis also offer a useful means to help improve student writing and argumentation.

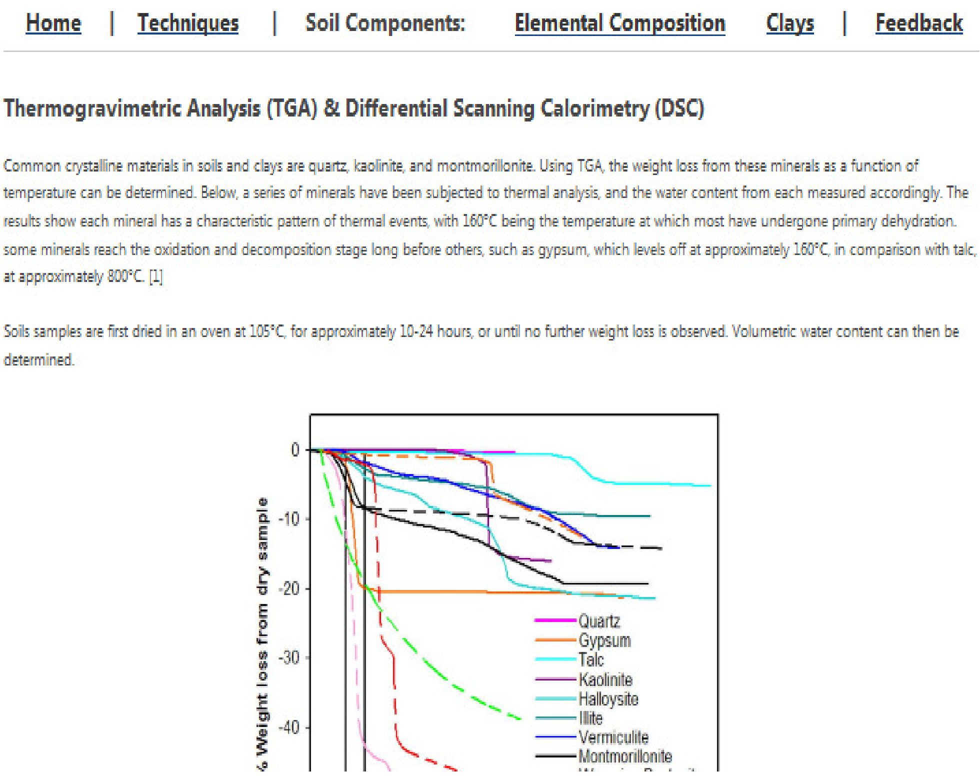

Figure 2: Wikis allow students to collaborate and complete group assignments

The technical process of wikis is very simple. Most virtual learning environments have a wiki included, and a free one for educational use is www.pbworks.com. Reports of their use in education are mostly restricted to teacher training to date [14], although there have been some pilot studies on their use with students in several UK and Irish institutions [15]. This work has found that students find wikis easy to use, although some induction is required to explain how to edit others work, and how to write in students' own words. Some initial training may be required for the teacher to become with using and managing wikis. Examples of wikis developed by school educators include a wiki where each student contributes some information about the periodic table, where students compile information on practical work, or revise particular topics for an exam.

2.3 Worked examples to show how to complete problems

A common approach in teaching chemistry, and especially any mathematical approaches in chemistry is to show a student an example and then get them to try one themselves [16]. Again, this approach can be easily automated and formalized to create a system of worked examples. Worked examples derive from cognitive load theory as they aim to show in a series of identified steps, how to approach and solve a problem. Therefore in learning how to solve the problem, the learner approaches it one step at a time. As they work through the problems, the level of assistance provided is reduced, so that in each iteration, students complete one extra step themselves until they can do the entire problem. This is called "fading" in cognitive load theory.

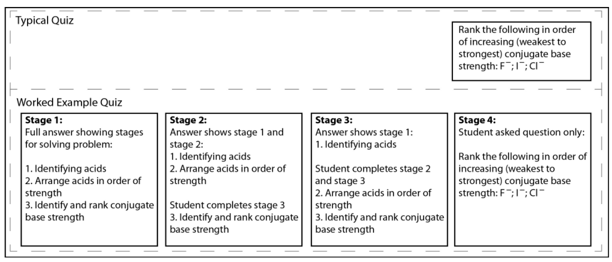

Figure 3: A typical online quiz and a quiz using a worked example (example based on Behmke [17]

The incorporation of worked examples can harness this stepwise approach very effectively. This can be easily achieved technically using a VLE quiz or Google form. For example, Behmke describes the iterative approach that was taken for a range of introductory chemistry problems such as acid and base strength, dilution calculations, etc [17]. The incorporation of the fading approach benefited learners in their ability to complete the questions. Ashworth has described a useful method to generate large amounts of calculation questions using Microsoft Excel that could be useful for teachers looking to adopt this approach [18].

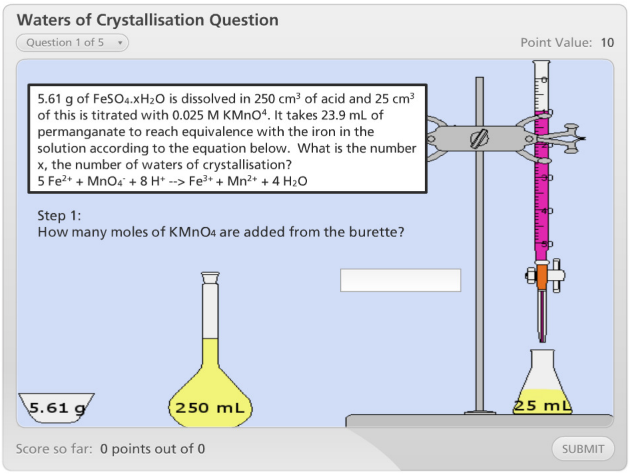

Figure 4: It is possible to incorporate graphics into the worked examples to relate it to experimental work

2.4 Podcasting and screencasting

One of the simplest and most effective ways of incorporating technology into our teaching is to create podcasts and screencasts. A podcast (audio only) and screencast (audio with video or screen capture) allows students to recover material in their own time at their own pace. There are some useful resources for how these can be created in a chemistry context [19 – 20]. These webcasts can be of two general types: either they recover what was provided in a class (substitutional) or they provide extra material or explain in further detail something that was delivered in class (supplemental) [21].

The literature appears to suggest that it is supplemental materials that have most use to students – explaining particular concepts, trying out questions, etc. Simply recovering what was done in class adds no extra benefit to students, the time is probably better spent exploring more challenging topics in more detail. Screencasting and podcasting have also proved useful in providing students with feedback [22].

Podcasts and screencasts are now easily made, and there is a variety of software to prepare them (Audacity, Jing, Camtasia). Several examples of chemistry screencasts are at the website www.chemistryvignettes.com. A website showcasing how to host podcasts on a class website is available at:
http://sites.google.com/site/becominganeteacher.

	Substitutional Podcasts	**Supplemental Podcasts**
Examples of Type	Recording of a class Class summaries Welcome Material	Worked examples on content in a class Audio feedback on report Additional material on a class topic
Advantages	Comprehensive record of what was covered, students can revisit to fill in gaps in notes	Tend to lend themselves to more active experiences for students. Allows students to structure their work with course material by providing structure to revision/feedback and/or additional information
Disadvantages	Can be a passive experience, with students duplicating their class experience rather than incorporating different supports (e.g. text book, worked examples) into their study	Students may focus on the issues highlighted rather than full course coverage. More time-consuming to create as usually bespoke.
Suggestions for Effective Use	Segment by topic and include something you want students to do with it—a question to try or link to text with suggestions on how they could annotate their notes.	Ensure they do not become over-specific and indicate at beginning where the topic covered fits in the broader curriculum. Worked examples/scaffolding should fade through the resource to allow students to test their own understanding.

Table: 1 Categorising podcasts into "substitutional" and "supplemental"

Figure 5: The "Becoming an eTeacher" website outlines how to create a class site and host, among other things, podcasts.

2.5 Online Communities

An often underused aspect of using online learning is the extension of the classroom to an online space where students and lecturers can continue interacting beyond the lecture hour. As well as lecturer-student communication, these online spaces allow for the development of an online community of peers. With increasing web technologies available, these online social interactions are becoming more commonplace, and are moving into the education domain.

One of the longest established online spaces for communities of learners is a discussion board, a space that facilitates an online conversation that can occur with different participants contributing at different times. While discussion boards are a common component of virtual learning environments, they are typically under-utilised, with their use commonly restricted to supporting fully online modules [23]. In a blended learning context, there are some reports on the use of discussion boards in chemistry education. A common first approach to the use of discussion boards is to distribute class materials, address homework queries, or sharing laboratory data [24].This offers the advantage of reducing the number of individual queries a lecturer might receive about these topics. Some suggestions for prompting student participation with discussion boards include (i) providing timely responses and feedback to questions posed; (ii) creating an environment where students feel comfortable (including allowing anonymous posting); (iii) setting an example by posting sample queries and responses; and (iv) set etiquette boundaries early on as required, including personal professionalism [25]. An important point noted by Markwell is that "lurking"—viewing a discussion board without posting—is also an effective way for students to learn. The ability of students to be able to focus on one particular task or topic at a time on the discussion board also resonates with effective application of technology in the context of cognitive load theory.

Along with tips from practice, more detailed analysis and coding of discussion board postings in discussion boards that have shown high levels of interaction has also led to some useful implications for practice. These include the lecturer being a visible presence by regularly posting messages, summarising previous posts and prompting further thought, challenging student responses in a constructive manner, requesting responses, and offering support and encouragement [26].

3. Summary

While there is a wide range of possibilities for including technology in our teaching, those that are likely to have most benefit are ones which can be integrated with curriculum delivery. The article summarises various approaches that can be taken, along with some examples from the literature and some practicalities for their implementation.

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Biography

Dr Michael Seery is a lecturer in physical chemistry at Dublin Institute of Technology and was the winner of the 2012 Royal Society of Chemistry Higher Education Teaching Award for his work in the use of e-learning in the teaching of physical chemistry. He was previously awarded the Irish Learning Technology Association Jennifer Burke Award and a National Academy for Integration of Research, Teaching, and Learning Teaching Excellence Award.

His current interests focus on prior knowledge and cognitive load in chemistry, and the reducing of this load through various teaching strategies, including e-learning. He has studied the performance of chemistry students on the basis of their prior knowledge, and introduced online pre-lecture activities aimed to reduce the cognitive load for novice learners in lectures.

He has published in Chemistry Education Research and Practice and British Journal of Educational Technology and presented at national, European, and US education conferences. He is involved in the European Chemistry Thematic Network (now EC2E2N), co-authoring two chapters in the RSC book "Innovative Methods of Teaching and Learning Chemistry in Higher Education" on laboratory education and problem- and context-based learning. He is a member of the editorial board of Education in Chemistry and writes about the use of technology in chemistry education at www.michaelseery.com.

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2013 LC Results

Peter E. Childs

We have been publishing an analysis of the LC science results and CAO points for science-related courses since 2001. Each year a 3 year overview is given. The examination statistics are available at the Department of Education and Science website at: www.examinations.ie and were published in the Irish newspapers on 14/8/13, the day the LC results were released. (See http://www.education.ie/en/Press-Events/Press-Releases/2013-Press-Releases/PR13-08-14A.html)

The overall number sitting the examinations is marginally down on last year's number by 0.4%. Of the 55,572 candidates who sat Leaving Certificate examinations this year, 37,093 (66.7%) candidates followed the Established Leaving Certificate Programme, 15,671(28.2%) the Leaving Certificate Vocational Programme while 2,805 (5.0%) candidates followed the Leaving Certificate Applied Programme. In 2013 52,767 students took the Leaving Certificate (this is the sum of LC (Established) and LCVP), slightly up on 2012 (52,499). Over 90% of JC students now stay on to do the leaving certificate course.

Table 1 Irish birth rates 2006-2013

Year	No. of births	~Date in post-primary
2006	64,237	2018
2007	71,389	2019
2008	75,173	2020
2009	75,554	2021
2010	73,724	2022
2011	74,650	2023
2012	~71,986	2024
2013	<72,000	2025

Table 1 shows the number of Irish births from 2006 to 2013 and the ~ date of entry into post-primary school. From birth it takes ~12 years to enter post-primary education and another 5/6 years to the LC exams. So the LC class of 2012 would have been born in ~ 1995 when the birth rate was 48,530. We have had a lot of immigration and more recently some emigration since then, but this figure is in line with this year's LC numbers of 55,815. The birth rate figures jump around 2001, and from 2009 they have started to decline. The figures indicate an expansion of primary numbers from ~2006 until ~2014 and in post-primary from ~2014 to 2020, which will continue to increase from year to year, before starting to decline. . These data have major implications for schools and third level institutions and more schools, more teachers and more places at third level will needed in the future. Figures from the ESRI show that Ireland still has the highest birth rate in the EU – 15.6/1000 compared to the EU average of 10.4/1000. (http://www.esri.ie/__uuid/9495a3d4-7e97-4588-a1d3-c091fa1e7838/NPRS2012.pdf)

A recent publication (July 2013) looks at 'PROJECTIONS OF FULL TIME ENROLMENT Primary and Second Level, 2013 – 2031 (available at http://www.education.ie/en/Publications/Statistics/Statistical-Reports/Projections-of-full-time-enrolment-Primary-and-Second-level-2013-2031.pdf), and is an update of one published in 2012 and the data are shown in Table 2. These projections are more than those made a year earlier and are also probably out-of-date and underestimate the growth in student numbers. This September (2013) ~71,000 students entered primary school.

These figures have massive implications for schools and for third level institutions in the future. More schools, more classrooms, more teachers will needed at primary and post-primary levels to cope with the increase in numbers. The most probably scenario for change would suggest an increase in enrolments at primary level to **596,440** by **2019**, and a continuous decline thereafter, to a level of 462,763 by 2031 and a year-on-year increase in second-level enrolments to a peak of **416,262** over the period considered (occurring in **2026**), with a decrease in enrolments occurring from that point, to a level of just under 387,400 by 2031.

Table 2 Estimated numbers at primary and post-primary levels 2012-2015

Year beginning	First Level	Second Level
2012 (provisional)	526,426	327,320
2013	539,127	335,250
2014	552,019	339,332
2015	563,744	343,208

We must take account of the changing examination cohort if we are to make sense or an increase or decrease in numbers doing a subject, as the raw numbers are related to the size of the total cohort. (See below to find out what actually happened to the popularity of science subjects in 2013 and which were the winners and losers).

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

Comments on the 2013 results

Unless specified otherwise all the statistics are from the SEC or DES websites. Table 3 shows that all the sciences, except Physics and Physics & Chemistry, gained both numbers and % share and Agricultural Science and Chemistry made the largest % gains. Over the period 2002-2013 all the sciences gained numbers except Physics and Physics & Chemistry, which have both shown a steady decline. Biology continues to be the dominant LC science subject (taken by 59.7% of the cohort) and the only science subject in the top 10 subjects (Table 9). The LC cohort decreased slightly this year by -0.4%, and Biology, Chemistry and Ag. Science all gained in market share (see Tables 3 & 11). Figure 1 shows the % taking the main science subjects since 1999 i.e. this is normalised for the change in size of the LC cohort.

Table 3: Changes in numbers doing LC Science subjects 2009-2013 (gains in bold)

Subject	**Δ2012 -2013**	**Δ% 2012-13**	**Δ2011 -2012**	**Δ% 2011-12**	**Δ2010 -2011**	**Δ% 2010-11**	**Δ2009 -2010**	**Δ% 2009-10**	**Δ2002-2012 (Δ %)**
Biology	**+959**	**+3.1**	**+214**	**+0.7**	**+1,100**	**+3.8**	**+1,089**	**+3.9**	**+9,458 (+42.8)**
Chemistry	**+69**	**+0.85**	**+409**	**+5.3%**	**+129**	**+1.7**	**+145**	**+2.0**	**+1,658 (+24.45)**
Physics	**+75**	**+1.2**	-143	-2.1	-229	-3.4	-178	-2.8	-2,203 -(25.4)
Phys+ Chem.	**+18**	**+4.4%**	-65	-13.7	**+47**	**+11.1**	-84	-16.2	-450 (-55.1)
Ag. Science	**+525**	**+7.6%**	**+416**	**+6.4**	**+686**	**+10.2**	**+515**	**+9.8**	**+4,524 (+156.6)**

Since 2002 Biology, Chemistry and Agricultural Science have all gained significantly, especially Biology and Agricultural Science (see Table 3). Physics and Physics & Chemistry have both decreased over this period. In 2013 Chemistry had the highest % doing the Higher Level course of the science subjects (82.8%), closely followed by Agricultural Science, with 80.1% (Table 4). Chemistry also shows the best gender balance (with a small excess of girls), whereas Biology has many more girls than boys doing it, and Physics many more boys than girls (Table 7). Physics is clearly in decline and this year's figures show that Agricultural Science has overtaken Physics as the third most popular science, as predicted last year. There is clearly a continuing swing towards the life sciences. Physics & Chemistry has been on its last legs for some years and continues to decline - it is definitely a ‘dead man walking’ of a syllabus, and it is a great pity that the new and innovative replacement, which was drawn up by the NCCA many years ago, has never been implemented. Sadly the new syllabus in Physics & Chemistry is still gathering dust on a shelf in the NCCA – it was a radical and innovative syllabus and it deserved an airing – it could have provided a popular alternative to the full Physics and Chemistry syllabi. If the course is not going to be revised it should be dropped as it must be one of the oldest/longest-lasting science syllabi in the world by now, along with Agricultural Science, both over 40 years old!

Biology is still far and away the most popular science subject, trailed at a distance by Chemistry and Physics: four times as many students take Biology as take Chemistry and Physics. It is clear that the Physics & Chemistry syllabus is dying on its feet, whereas Agricultural Science is growing steadily (+4,524 since 2002). All the sciences are quite elitist, with Chemistry and Agricultural Science heading the poll with 82.8% and 80.3% respectively, doing the HL course (Table 4). There is a strong case for scrapping the combined Physics and Chemistry course, or introducing a new syllabus, and for a major revision of the Agricultural Science syllabus, bringing it into line with modern agricultural practices. This marked disparity between Biology and the Physical Sciences is more marked in Ireland than it is in most other countries.

Table 4: LC Science - % doing Higher Level and Ordinary Level 2013-2010

	2013	**HL 2013 (%)**	**OL 2013 (%)**	**%LC Cohort 2013**	**%LC cohort 2012**	**%LC cohort 2011**	**%LC cohort 2010**
Biology	**31,500**	**74.4**	**25.6**	**59.7**	58.2	55.8	53.7
Chemistry	**8,155**	**82.8**	**17.2**	**15.45**	15.4	14.1	13.85
Physics	**6,448**	**74.9**	**25.1**	**12.2**	12.1	12.0	12.4
Phys.+Chem.	**423**	**78.0**	**22.0**	**0.80**	0.77	0.87	0.78
Ag. Science	**7,414**	**80.3**	**19.7**	**14.05**	13.1	11.9	10.6

Figure 1: Change in % doing Biology, Physics, Chemistry (and Ag. Science) 1999-2013

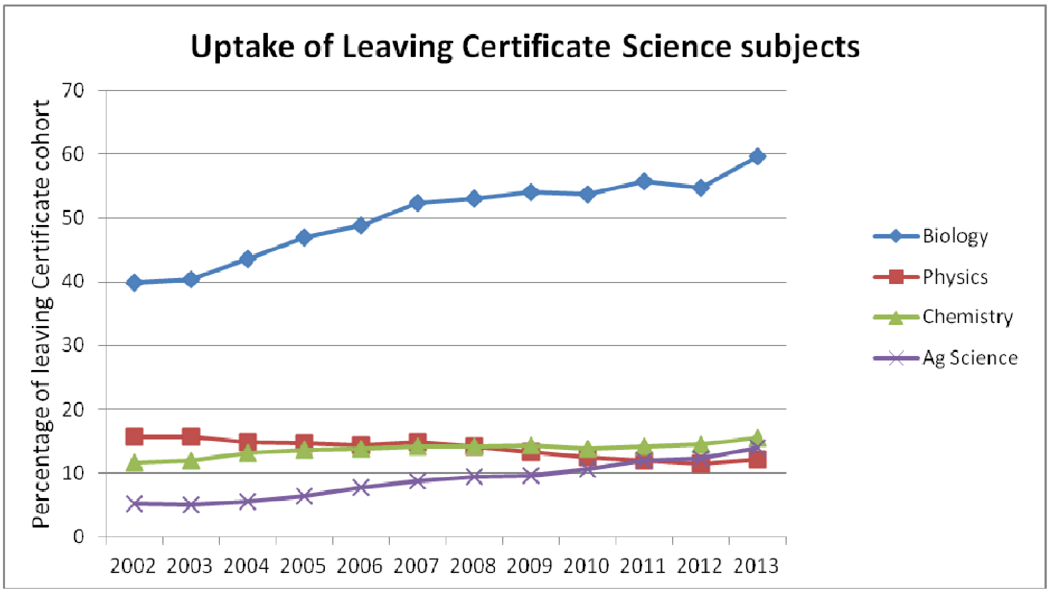

Table 5: % of different grade bands 2007-2012

a)Chemistry

	Higher level						**Ordinary level**					
Year	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**
%A	**20.4**	19.9	21.9	20.8	21.6	23.5	**7.1**	7.6	9.1	7.6	9.2	11.7
%A+B	**48.2**	48.4	52.4	50.1	52.9	54.6	**28.5**	29.7	36.4	29.8	34.6	42.2
%A+B+C	**73.4**	72.5	76.0	75.3	77.5	78.7	**58.2**	59.4	64.7	54.9	63.1	75.0
%E,F,NG	**8.1**	9.0	8.6	6.1	7.0	5.8	**8.2**	16.6	12.8	18.5	15.3	13.9

b) Biology

	Higher level						**Ordinary level**					
Year	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**
%A	**14.4**	16.7	15.6	17.4	16.0	16.6	**2.1**	1.3	2.2	3.1	3.6	4.8
%A+B	**41.7**	44.4	43.0	44.9	43.0	43.9	**23.7**	17.9	22.8	29.6	26.3	29.7
%A+B+C	**69.6**	71.1	69.9	71.6	69.9	71.5	**58.5**	39.2	59.3	62.7	59.1	63.2
%E,F,NG	**8.2**	8.4	8.3	9.2	8.8	7.9	**13.4**	13.5	13.2	14.1	15.3	11.1

c) Physics

	Higher level						**Ordinary level**					
Year	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**
%A	**20.4**	19.8	20.2	20.8	20.3	19.9	**14.5**	15.2	14.8	17.4	17.0	15.5
%A+B	**49.4**	49.6	46.0	49.6	49.6	46.4	**45.8**	46.5	44.3	49.0	49.7	47.3
%A+B+C	**73.3**	74.6	72.9	73.3	72.9	70.8	**72.7**	71.8	72.2	72.8	74.3	73.8
%E,F,NG	**7.2**	7.3	8.0	7.0	7.8	8.6	**9.3**	9.7	11.2	11.6	10.0	8.7

In Table 5 you can compare the grades obtained in each subject at Higher and Ordinary level. Four bands are shown: %As, %A+Bs, %A+B+Cs and %E+F+NG (fails). At HL Chemistry (20.4%) and Physics (20.4%) students get more As compared to for Biology (14.4%), although this represents over 3 times more students getting As in Biology. This disparity reflects the larger and academically wider intake into Biology and also probably that Chemistry and Physics attract a greater proportion of higher ability students. These results are fairly consistent over 6 years as can be seen above. At OL the differences are more marked – Physics students get 14.5% As at OL, whereas Chemistry students get 7.1% and Biology students 2.1%. The failure rates at HL for all three main sciences are very similar, as they are at OL, but remember that for Biology these represent greater numbers of students. There is no marked change in the grading over this six year period for any of the three main science subjects.

Chemistry and Physics are more selective subjects i.e. they are done by smaller numbers and a higher % take the Higher Level papers, indicating that these are taken by better students. We would thus expect a higher % of good grades and less % of fails if the student populations doing Chemistry and Physics are more selective. This is what we observe. From 2008-13 the average % getting As in HL papers in Chemistry was 21.35% and 20.2% in Physics, compared to 16.1% in Biology. This does not mean that Biology is harder than Chemistry or Physics: it means that a larger number of students take Biology and have a greater ability spread, compared to Chemistry and Physics. This is also consistent with the average % of fails in HL Chemistry of 7.4% 2008-13, compared to % in HL Physics and 7.65% in HL Biology. Again remember that the same % in Biology represents nearly 4 times as many students.

At Ordinary Level we would expect to see smaller % of good grades, as weaker students opt for the ordinary level papers - often at the last minute, and a greater % of fails. We would also expect more % fails in Biology than Physics or Chemistry, because of the greater numbers and wider ability spread of students choosing Biology.

The average % getting As in ordinary level Chemistry was 8.7% from 2008-13, with 15.7% getting As in Physics and 2.85% in Biology. The anomalies here are the high % of As in Physics and the very low % in Biology. When we look at the % fails in the ordinary level papers from 2008-13, 14.2% fail Chemistry, 13.4% fail Biology and 10.1% fail Physics, which are fairly consistent.

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

Table 6: Gender breakdown of A grades 2013

	%As overall	%As females	% As males
Chemistry	20.4 (HL) 7.1 (OL)	19.4 (HL) **9.3** (OL)	**21.6** (HL) 5.1 (OL)
Biology	14.4 (HL) 2.1 (OL)	**14.9** (HL) **2.5** (OL)	13.8 (HL) 1.6 (OL)
Physics	20.4 (HL) 14.5 (OL)	20.3 (HL) **19.8** (OL)	**20.5** (HL) 13.5 (OL)

Table 7 shows the gender breakdown of the 2013 HL and OL results for A grades. In several cases females outperform males (larger % shown in bold above), although the differences are small and boys get more As in both Chemistry and Physics, whereas girls do better at OL. The trend for females to outperform males in state examinations has become more apparent year on year. We cannot say from these data whether this difference is due to intrinsic ability or to better study methods and harder work or the effect of single-sex schools. The better LC results by females mean that the number of females entering third level exceeds that of males, and more males drop out of fulltime education at all levels.

However, the gender balance in the LC science subjects is still a matter of concern. Table 7 shows the overall gender breakdown of the five science subjects i.e. HL and OL students are combined in these figures and the F:M ratio for each subject from 2010 to 2012.

As in the past Biology is heavily dominated by females (1.45:1) and Physics is dominated by males (3:1). Chemistry shows the closest gender balance, with a small excess of females. Ag. Science has a majority of males (1.7:1), reflecting the dominance of men in farming-related careers.

In Table 8 the grades for all five science subjects are shown for 4 years from 2010 to 2013, at both Higher and Ordinary level.

Table 7: The overall gender balance in the LC Science subjects 2013 (compared to 2012- 2010)

Subject	No. females (%)	No. males (%)	Ratio F:M 2013	Ratio F:M 2012	Ratio F:M 2011	Ratio F:M 2010
Biology	18,663 (59.25)	12,837 (40.75)	**1.45:1**	1.54:1	1.60:1	1.75:1
Chemistry	4,328 (53.1)	3,827 (46.9)	**1.13:1**	1.16:1	1.23:1	1.29:1
Physics	1,521 (23.6)	4,927 (76.4)	**0.31:1**	0.33:1	0.33:1	0.33:1
Physics & Chemistry	155 (36.7)	268 (63.3)	**0.57:1**	0.62:1	0.74:1	0.61:1
Agricultural Science	2,792 (37.7)	4,622 (62.3)	**0.60:1**	0.66:1	0.59:1	0.55:1

Table 8: 2013-2010 LC Science Results at HL and OL (Current year in bold)

Chemistry	No.	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
HL 2013	6,756	9.4	11.0	8.2	9.7	9.9	8.4	7.9	8.9	6.3	5.6	6.6	5.7	1.8	0.6
HL 2012	6,705	11.5	8.4	9.9	9.5	9.1	8.2	7.3	8.7	5.3	6.1	7.1	5.9	2.5	0.6
HL 2011	6,272	11.4	10.5	10.5	10.9	9.1	7.9	8.3	7.4	4.8	4.5	6.1	5.6	2.4	0.6
HL 2010	6,298	9.7	11.1	9.7	10.2	9.4	8.5	8.6	8.1	5.4	5.0	6.3	5.3	2.2	0.6
OL 2013	1,399	2.6	4.5	4.2	7.5	9.7	9.2	10.2	10.3	7.6	6.9	9.1	10.3	6.0	1.9
OL 2012	1,381	2.0	5.6	4.9	8.2	9.0	4.0	10.0	9.3	7.9	7.4	8.7	9.9	4.8	1.9
OL 2011	1,405	3.3	5.8	7.5	8.9	10.9	9.3	8.6	10.4	7.8	7.0	7.8	6.8	4.8	1.2
OL 2010	1,250	2.2	5.4	4.9	8.6	8.7	9.1	9.1	8.1	7.9	7.7	9.8	10.1	6.8	1.6
Biology	No.	A1	A2	B1	B2	B3	C 1	C2	C3	D1	D2	D3	E	F	G
HL 2013	23,436	5.8	8.6	7.4	9.5	10.4	8.8	9.2	9.9	7.2	7.1	7.8	6.5	1.5	0.2
HL 2012	22,740	7.6	9.1	8.5	9.1	10.1	8.9	9.1	8.7	7.0	6.6	6.9	6.5	1.7	0.2
HL 2011	22,677	6.3	9.3	7.9	9.4	10.1	9.0	9.3	8.9	7.6	6.6	7.1	6.6	1.6	0.1
HL 2010	20,971	8.9	8.5	8.4	9.1	10.0	8.5	8.9	8.3	6.9	6.3	7.0	6.9	2.0	0.3
OL 2013	8,064	0.5	1.6	3.7	6.9	11.0	10.6	11.6	12.6	10.2	8.9	9.0	9.2	3.6	0.6
OL 2012	7,796	0.4	0,9	2.6	5.3	10.0	5.0	1.0	6.0	7.0	8.5	9.0	9.4	3.5	0.6
OL 2011	7,672	0.6	1.6	3.9	6.6	10.1	11.2	13.1	12.2	10.6	8.3	8.7	9.1	3.7	0.4
OL 2010	8,278	0.7	2.4	5.3	9.3	11.9	11.5	11.5	10.1	8.1	6.7	8.4	8.7	4.5	0.9
Physics	No.	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
HL 2013	4,832	10.1	10.3	9.9	9.8	9.3	8.2	8.1	7.6	7.0	5.8	6.7	5.0	1.8	0.4
HL 2012	4,753	9.7	10.1	10.3	9.7	9.8	8.8	8.4	7.8	6.7	5.4	5.9	5.6	1,3	0.4
HL 2011	4,782	8.9	11.3	7.0	9.3	9.5	9.0	8.8	9.1	7.4	5.6	5.9	5.9	1.7	0.4
HL 2010	4,877	8.8	12.0	8.4	10.8	9.6	9.2	9.4	5.1	8.8	6.0	5.0	5.2	1.4	0.4
OL 2013	1,616	6.0	8.5	7.4	11.6	12.3	8.9	8.0	10.0	4.2	5.8	8.0	5.4	2.8	1.1
OL 2012	1,620	5.3	9.9	8.3	5.0	8.0	8.1	8.6	8.6	4.5	6.4	6.4	6.4	3.2	1.0
OL 2011	1,734	6.0	8.8	6.2	10.6	12.7	6.7	10.3	10.9	4.4	6.2	5.9	7.6	3.2	0.4
OL 2010	1,868	8.0	9.4	9.0	9.8	12.8	7.5	7.2	9.1	3.9	4.4	7.3	5.8	4.2	1.6
Phys+Chem	No.	A1	A2	B1	B2	B3	C 1	C2	C3	D1	D2	D3	E	F	G
HL 2013	330	10.0	8.2	7.3	11.5	7.9	7.6	10.3	8.5	5.8	7.0	4.8	9.4	1.2	0.6
HL 2012	309	8.7	10.4	10.0	10.7	10.4	5.8	8.4	10.0	3.9	4.2	6.5	7.4	2.3	1.3
HL 2011	379	12.9	9.5	7.9	9.2	10.0	6.9	6.9	8.4	5.5	6.1	5.8	8.2	2.4	0.3
HL 2010	355	8.2	11.3	7.9	12.1	6.2	10.1	4.5	7.0	4.8	6.2	6.2	8.5	3.7	3.4
OL 2013	93	2.2	2.2	2.2	2.2	9.7	7.5	8.6	14.0	5.4	3.2	17.2	11.8	8.6	5.4
OL 2012	96	1.0	5.2	4.2	7.3	9.4	2.1	6.3	7.3	5.0	5.2	4.0	8.3	4.0	9.4
OL 2011	93	2.2	2.2	2.2	4.3	17.2	7.5	4.3	10.8	6.5	4.3	12.9	10.8	11.8	3.2
OL 2010	70	1.4	2.9	2.9	2.9	5.7	2.9	5.7	14.3	7.1	7.1	18.6	12.9	10.0	5.7
Ag. Science	No.	A1	A2	B1	B2	B3	C1	C2	C3	D1	D2	D3	E	F	NG
HL 2013	5,951	3.6	6.1	7.6	8.8	10.7	11.3	11.1	10.3	8.7	7.5	7.8	5.6	0.9	0.1
HL 2012	5,587	4.3	5.7	7.2	8.5	10.1	10.3	10.0	9.6	9.3	8.3	8.1	7.6	1.1	0.0
HL 2011	5,287	6.3	6.8	7.9	8.3	8.5	8.9	9.7	9.4	9.3	7.8	8.6	7.5	1.1	0.1
HL 2010	4,675	3.8	6.1	7.7	9.2	9.9	10.5	10,8	10.2	9.3	7.5	7.7	6.3	1.1	0.1
OL 2013	1,463	0.1	0.2	1.2	2.4	4.6	7.7	10.7	13.7	14.4	11.5	15.7	14.1	3.6	0.3
OL 2012	1,302	0.0	0.3	1.0	2.8	5.1	9.1	4.0	6.0	8.0	9.0	1.0	4.0	4.2	0.2
OL 2011	1,186	0.0	0.3	0.4	1.9	5.1	7.5	11.6	13.3	12.4	13.6	14.8	13.8	4.6	0.8
OL 2010	1,112	0.1	0.3	1.8	5.2	7.3	11.0	11.9	13.5	12.8	12.0	11.0	9.9	3.2	0.2

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

Table 9 shows the top 10 LC subjects from 2008 to 2012. Maths just slips from its first place in 2012 (despite Project Maths) being overtaken by English. Nearly everyone who stays on a school until age 17/18 does Mathematics and does an examination in it. Biology is in 4th place and the most popular Science subject. Four subjects are taken by >50% of the LC cohort. Interestingly in the UK Biology, Chemistry and Physics are all now in the top 10 A level subjects.

The papers love to see which are the top subjects for As and good grades (ABCs). However, this does not take account of the selectivity of subjects (numbers taking them and % HL students, an indication of student ability). Table 10 shows the top 5 subjects for As in 2013 and the top 5 for ABCs. Chemistry and Physics are 2= for As; Biology is 10th with 14.4%. When it comes to the %ABCs Chemistry is 19th, Physics 20th, Biology 24th and Ag.Sci. 25th.

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Table 9 Top 10 LC subjects from 2009 to 2013 (HL+OL)

Subject	**2009 Total (HL+OL)**	**2010 Total (HL+OL)**	**2011 Total (HL+OL)**	**2012 Total (HL+OL)**	**2013 Total (HL+OL)**	**% LC cohort 2013**	**Rank 2013**
Maths (+FL)	51,902	52,290	51,991	**50,442**	**50,856**	**96.4**	**1**
English	51,032	51,499	51,455	**50,517**	**50,817**	**96.3**	**2**
Irish (+FL)	45,636	41,043	44,397	**42,965**	**43,651**	**82.7**	**3**
Biology	28,160	29,249	30,349	**30,506**	**31,500**	**59.7**	**4**
French	27,675	27,574	26,766	**25,977**	**25,517**	**48.4**	**5**
Geography	25,061	26,175	27.305	**25,734**	**25,295**	**47.9**	**6**
Business	18,425	18,790	18,083	**17,248**	**16,932**	**32.1**	**7**
Home Econs.	12,936	12,535	12,400	**11,898**	**12,048**	**22.8**	**8**
History	11,990	11,910	12,106	**11,746**	**11,822**	**22.4**	**9**
Art	10,693	10,786	10,782	**10,279**	**10,295**	**19.5**	**10**

Table 10 Ranking of HL subjects for %As and %ABCs in 2013 (out of 25 subjects)

Rank	**Subject**	**%As**	**No. HL**	**Rank**	**Subject**	**%ABCs**	**No. HL**
1	App.Maths	26.5	1,470	1	Music	94.8	5,713
2=	Chemistry	20.4	6,756	2	Irish	90.4	16,669
2=	Physics	20.4	4,832	3	Design&Comm.	79.8	4,017
4	Accounting	19.8	3,933	4	Spanish	79.5	2,961
5	Spanish	16.4	2,961	5	Technology	79.2	945

Table 11 shows the change in the LC cohort (Established + LCVP) from 2002 to 2013, together with the % of the LC cohort taking Biology, Chemistry, Physics and Agricultural Science (these are shown graphically in Figure 1 above). Biology is clearly in the ascendant and numbers and its % share has climbed steadily since the new syllabus was introduced in 2002 and examined first in 2004. The new Physics and Chemistry syllabi were first examined in 2002 and since then Physics has been on a slow decline and Chemistry on a slow increase, so that Chemistry overtook Physics in 2008 and the gap continues to widen. More students are doing Chemistry now than at any time in the last 10 years. Agricultural Science numbers continue to increase and it has now well overtaken Physics, replacing Physics as the third most popular science subject. If Ag. Science continues to increase at its current rate it may well exceed Chemistry in enrolment in 2-3 years time. The continuing decline in Physics is a matter of concern, although it may have bottomed out.

Table 11 Changes in the LC cohort and science subjects (2002-2013)

	LC Cohort	Biology Total	%	Chemistry Total	%	Physics Total	%	Ag. Science Total	%
2002	58,489	22,064	37.7	6,497	11.1	8,651	14.8	2,890	4.9
2003	56,229	22,669	40.3	6,698	11.9	8,806	15.7	2,972	5.3
2004	55,183	24,027	43.5	7,229	13.1	8,152	14.8	3,237	5.9
2005	54,069	25,362	46.9	7,366	13.6	7,944	14.7	3,625	6.7
2006	50,995	24,885	48.8	7,071	13.9	7,335	14.4	3,912	7.7
2007	50,870	25,792	50.7	6,926	13.6	7,251	14.3	4,267	8.4
2008	52,144	26,607	51.0	7,114	13.6	7,112	13.6	4,738	9.1
2009	54,196	28,160	51.8	7,403	13.7	6,923	12.8	5,272	9.7
2010	54,481	29,249	53.7	7,548	13.85	6,745	12.4	5,787	10.6
2011	54,341	30,349	55.8	7,677	14.1	6,516	12.0	6,473	11.9
2012	52,499	30,563	58.2	8,086	15.4	6,373	12.1	6,889	13.1
2013	**52,767**	**31,500**	**59.7**	**8,155**	**15.45**	**6,448**	**12.2**	**7,414**	**14.05**

***New Biology syllabus examined from 2004 onwards; new Physics and Chemistry syllabi examined from 2002.**

Table 12 shows the change in size and composition of the LC cohort from 2005 to 2013. After a minimum number in 2007, the numbers doing the LC increased above 2005 levels in 2010 and then declined, however, they are due to continue increasing in the foreseeable future due to the increased birth rate working its way up through the schools system. The drop from 2010 is probably due to emigration and will be corrected in future years.

Table 12 Change in LC numbers 2005-2013

Year	LC (Est)	LCVP	Total LC (Est) + LCVP	LCAP	Total
2005	39,792	14,281	54,073	3,318	57,391
2006	36,932	14,023	50,955	3,155	54,110
2007	36,790	14,080	50,870	3,056	53,926
2008	37,639	14,505	52,144	3,445	55,589
2009	39,112	15,084	54,197	3,264	57,455
2010	38,885	15,596	54,479	3,358	57,837
2011	37,995	16,386	54,344	3,195	57,539
2012	36,762	15,827	52,588	3,228	55,816
2013	**37,093**	**15,671**	**52,767**	**2,805**	**55,572**

Provision and choice at LC level

A student cannot study Chemistry (or any other subject) in a school if the subject is not provided. There is not equal provision of science subjects in all schools as the Table 13 below shows. If a subject is not offered in a school it may be provided in a nearby school and thus becomes available. When we look at the data it is clear that Biology is offered in virtually every school but both Chemistry and Physics are only offered in some schools, and there are mixed schools where the subject is offered to males only or girls only. One of the results of the austerity measures is that schools have lost teachers and depending on which teachers have retired and not been replaced, subjects may be lost. Surveys by the ASTI of their members have shown that a significant number of schools are considering or have dropped subjects and the physical sciences, with their relatively low uptake, are in the firing line.

Table 13 Provision of science subjects in schools – number of schools (% of total) (DoES)

	Single sex schools			Mixed schools			
Totals doing LC sciences	**Total (%)**	**Male only**	**Female only**	**Total doing LC sciences**	**Male only**	**Female only**	**Male and female**
Total	***694 (100)***	***110 (100)***	***145 (100)***	***438 (100)***			
Chemistry	557 (80.3)	101 (91.8)	139 (95.9)	317 (72.4)	7	9	301
Physics	524 (75.5)	106 (96.4)	103 (71.0)	315 (71.9)	34	3	278
Biology	686 (98.8)	108 (98.2)	145 (100)	433 (98.9)	1	2	430
Physics + Chemistry	46 (6.6)	5 (4.5)	4 (2.8)	37 (8.5)	2	1	34
Ag. Science	365 (52.6)	55 (50.0)	47 (32.4)	263 (60.0)	16	6	241

There are 255 single sex schools, comprising 110 male only (15.85%) and 145 female only (20.9 %), with 438 mixed schools (63.1%). Ireland has one of the highest percentages of single sex schools in Europe. Provision of Chemistry is highest in single sex schools and lowest in mixed schools, where in a few schools it is only offered to males or females. Physics is offered least in all female schools and in 34 mixed schools is only offered to males. There is a clear gender effect in this case. Biology is almost universally available across all schools. The combined Physics with Chemistry is mainly offered in a few mixed schools. Agricultural Science, the rising star of the sciences, is offered in just over half of schools and is a little more common in mixed schools. Many more schools offer Physics than Agricultural Science (159 more) but more students are now taking Agricultural Science.

There is a long-standing argument about whether single sex schools are better for girls or mixed schools. Table 14 gives science enrolments (over the two LC years) in single sex and mixed schools. Chemistry enrolment in all female schools is greater than that in mixed schools despite there being over twice as many mixed schools. The same is true for Physics and there are three times as many mixed schools offering Physics than all female schools. The same is true to a lesser extent for all male schools – males are more likely to do Chemistry and Physics in these schools than in mixed schools. Table 13 shows how many mixed schools offer science subjects to males or females only.

Table 14 Total enrolments in science subjects in the 2012-2013 school year (DoES)

	Single sex schools (255)			**Mixed schools (438)**		
	Males only (110)	**Female only (145)**	**Total**	**Males**	**Female**	**Total**
Chemistry	3,276	4,798	8,074	4,367	4,252	8,619
Physics	4,008	1,875	5,883	6,733	1,574	8,307
Biology	10,094	17,689	27,783	16,420	20,854	37,274

Conclusions

It remains to be seen whether the cutbacks will result in the loss of some subjects, especially Chemistry and Physics, and thus to a decrease in enrolment in these subjects. Certainly the life sciences are on a roll and are likely to increase, and the decline in numbers doing Physics is worrying. The current syllabi will be with us for some time and the new LC science syllabi are not likely to be introduced until the end of the decade. This is assuming the problems with practical assessment can be solved.

□

The Instrument Makers No. 5

Daniel Gabriel Fahrenheit (24 May 1686 – 16 September 1736)

Adrian J. Ryder tutorajr@gmail.com

The Fahrenheit family was a German Hanse merchant family, originating in Hildesheim (about 30 km southeast of Hanover) but moving at various times to other Hanseatic cities. Gabriel's great grandfather had lived in Rostock, while his grandfather had moved from Kneiphof (now part of the Moskovsky District of Kaliningrad, Russia) to Danzig (Gdańsk) in Poland in 1650. Gabriel's father, Daniel, married Concordia Schumann here and Gabriel was the second child but the eldest of the five children, 2 boys and three girls, who survived childhood. His surviving siblings were named Ephraim (1688), Anna Concordia (1689), Constantin (1690) and Virginia Elisabeth (1694)

The Fahrenheit house in Danzig

Gabriel was educated by private tutors to the age of twelve when he went to a private school, the Marienschule, from where he expected to move on to the Gymnasium in 1701since his particular eagerness for learning had been noted.

His father was a successful Hanse merchant with various properties in the town and a villa in the country. As well he had a share in four sea going trading vessels.

Map showing the extent of the Hanseatic League about 1400 AD.

The Hanseatic Leaque was a confederation of merchant guilds that dominated trade across much of the northern European coast. The cities involved formed their own legal systems and furnished their own armies for mutual protection. It allowed merchants to move freely throughout the region for trade purposes. In a way it was the forerunner of the current European Union.

The death of Gabriel's parents on August 14th. 1701, as a result of eating poisonous mushrooms, had a double effect on Gabriel. First of all he was apprenticed, much against his will, to a merchant in Amsterdam. But once there he developed a keen interest in science, becoming acquainted with the small, but rapidly growing, group involved in making scientific equipment, becoming a proficient glass-blower and instrument maker.

Gabriel failed to complete his apprenticeship and a warrant was issued for his arrest for transportation to the West Indies. However, he borrowed some money and left Amsterdam to travel and improve on his scientific skills.

From 1707 to 1717 Gabriel moved through various cities, including Berlin, Leipzig, Halle, Dresden and Copenhagen, meeting the noted scientists and instrument makers of the time. He also spent some time with his brother Ephraim in Danzig. It was during this time that he began producing his own form of thermometer. The first two were alcohol-filled and he was delighted to see that they gave the same reading when placed in various warm liquids. On his return to Holland he settled in the Hague as a glassblower, where he produced barometers, altimeters and the thermometers for which he is now best known for. In the following year he began to lecture in Chemistry in Amsterdam.

By 1700 at least 35 different types of thermometer had appeared but each could only tell if one object was hotter than another, and none could give a definite degree of 'hotness'. Gabriel had produced an alcohol thermometer in 1709 and had begun using mercury in his thermometers from 1714. On his thermometers he had fixed temperature markings, the first to appear on any thermometer. He wrote, in 1724, on his decision to use mercury instead of alcohol in his thermometers as follows….

"It then came into my mind what that most careful observer of natural phenomena (Guillaume Amontons, French, 1663 - 1705) had written about the correction of the barometer; for he had observed that the height of the column of mercury in the barometer was a little (though sensibly enough) altered by the varying temperature of the mercury. From this I gathered that a thermometer might perhaps be constructed with mercury, which would not be so hard to construct."

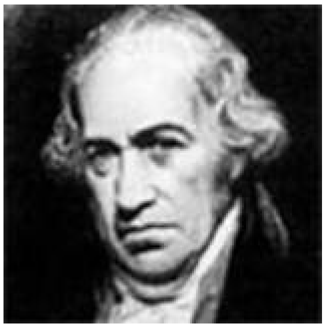
Gabriel introduced the use of cylindrical bulbs instead of spherical ones in his thermometers, as he found them easier to make and fill. This innovation quickly became the standard for all thermometers.

One of these early mercury thermometers was auctioned in October 2012 for $107,802. A good price, but only three of his thermometers are known to have survived over the years,so they are very rare.

Gabriel's genius lay in providing fixed points of 'hotness' on his thermometers. He took three 'fixed' points: the first, the temperature of the body to which he assigned a value of 96 degrees. The second, the temperature at which water begins to freeze, to which he assigned a value of 32 degrees and the third to the lowest temperature he could get using a mixture of ammonium chloride (NH_4Cl), water and ice to which he assigned the value of 0 degrees. The reasons for choosing 96 and 32 was, probably, the fact that these two numbers are easily continuously divisible by two and so permitted a scale to be provided on the thermometer easily.

Gabriel thought that, according to his scale, mercury ought to boil about 600 degrees and water somewhere over 200 degrees. Others worked out that water would boil 180 degrees above the freezing point and the scale was modified by the Royal Society in 1777 to make 212 degrees the boiling point of water. This meant that the temperature of the body came in at 98.6 instead of Gabriel's initial 96 degrees.

This scale was in common use across the world and still is that of a medicinal thermometer and in general usage in the United States and Canada. Elsewhere it is generally superseded by the Celsius scale. (Anders Celsius is the subject of the next article in this series.)



In 2012, scientists made this computer image of Gabriel's face using photos of his relatives

In 1724 Fahrenheit travelled to England where he had published in the Royal Society's *Philosophical Transactions* an account of an improved form of hygrometer, in which he used mercury instead of wine spirits, together with observations made with his instrument. For this work, and his work on thermometers, he was elected a Fellow of the Royal Society.

Just before Gabriel died, he applied for a patent on a machine that would pump water out of polders (drained land in the Netherlands that lies below sea level). Previously he had invented an improved form of hygrometer, in which he made use of mercury instead of wine spirits, and a description of this, together with observations and experiments made by him, was published in the *Phil. Trans.* for 1724.

Gabriel also devised a "thermobarometer" for estimating barometric pressure by determining the boiling point of water. However, this instrument never caught on for general usage.

Gabriel Fahrenheit never married and when he died in The Hague, aged fifty, and was buried there at the Kloosterkerk (Cloister Church), he was a poor man although very highly respected.

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Diary 2014

52nd ISTA Conference
11-13th April
NUI Galway
www.ista.ie

Irish Variety in Chemical Education
6 May
DIT, Dublin
Michael.seery@dit.ie

SMEC 2014
''Thinking Assessment in Science & Mathematics'
24-25 June
Dublin City University, Dublin
castel@dcu.ie
http://www.dcu.ie/smec/index.shtml

Chemistry for Non-specialists
17-18 June
Blackrock College, Co. Dublin
24-25 June
Ard Scoil Rís, Limerick
http://www.rsc.org/Education/Teachers/CPD/ChemNonSpec/index.asp

8th Chemistry Demonstration Workshop
23-27 June
University of Limerick
Beulah.macmanus@ul.ie

The 3rd Annual Robert Boyle Summer School
3-6 July 2014
Lismore Co Waterford
www.robertboyle.ie
calmast@wit.ie

12th ECRICE
"New Trends in Research-based Chemistry Education"
7-10 July
Jyväskylä University, Finland
www.jyu.fi/kemia/en/research/ecrice2014//

International Conference on Chemistry Education 2014
TORONTO, CANADA

23rd ICCE
13-18 July
University of Toronto, Toronto, Canada
www.icce2014.org/

2014 Biennial Conference on Chemical Education
August 3-7, 2014
Grand Valley State University, West Michigan, USA
http://www.bcce2014.org/

32nd ChemEd-Ireland
11th October
DIT, Dublin
Claire.mcdonnell@dit.ie

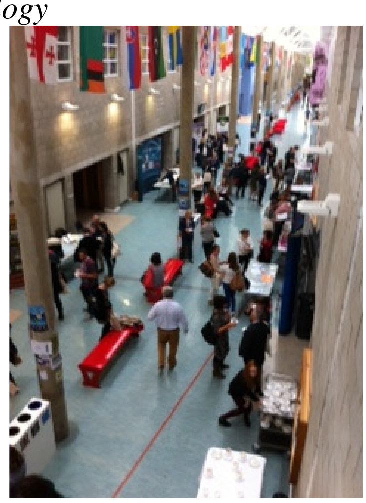
If you know of any relevant conferences or events of interest to chemistry teachers, please send in details to:peter.childs@ul.ie

Conference Reports

ChemEd-Ireland 2013

New Perspectives for Chemistry Teaching

Marie Walsh, Limerick Institute of Technology



ChemEd-Ireland returned to Limerick on October 19th 2013 at Limerick Institute of Technology Moylish Campus. The day was bright and sunny as almost 100 participants gathered for a number of talks and workshops to give new ideas for chemistry teaching.

The participants were welcomed to LIT by Paschal Meehan, Head of Faculty of Applied Science Engineering and Technology, and Michelle McKeon-Bennett, Head of Department of Applied Science, and then the busy schedule for the day began.

SESSION 1 was chaired by Anne Culhane, who introduced the first set of talks:

Fiona Desmond, State Examinations Commission, giving her first talk at ChemEd Ireland since being appointed Chief Examiner for Leaving Certificate Chemistry, spoke about the *State Examinations Commission Assessment of Leaving Certificate Chemistry.*

Maria Sheehan & Mick O'Callaghan, PDST, gave an interactive presentation on *The use of mobile phones in the Chemistry class as a tool for active learning.*

Peter Hoare, Newcastle University, introduced some *Resources for Chemistry teaching* which he went on to demonstrate at one of the workshops. His talk and accompanying workshops were sponsored by the Royal Society of Chemistry.

A break for coffee and an opportunity to browse the information stands was followed by more interactivity in the workshops. Each participant had been asked to choose two out of four workshops in SESSION 2, which were as follows:

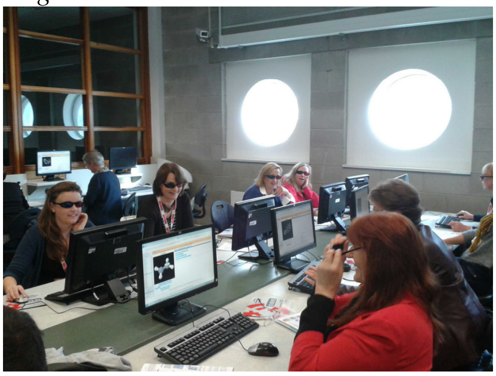
Iris Suitor - Royal Society of Chemistry - *Bonding and reactions workshop*

David Sutton Limerick Institute of Technology- *Environmental Chemistry.*

Anne O'Dwyer and **Peter Childs,** National Centre for Excellence in Maths and Science

Teaching and Learning, University of Limerick - *Molecular models in organic chemistry*:

Peter Hoare Newcastle University - *Chemistry teaching resources*:



After lunch in the LIT Scholars canteen, the conference reconvened for a keynote talk followed by a series of shorter talks.

SESSION 3 was chaired by Billy Madden. The following talks were given:

Gordon Armstrong from the University of Limerick briefly described the work of the Society of the Chemical Industry, which sponsored the talk by **Professor Mike Lyons** from Trinity College Dublin on *A new method of electrolysing water*.

Grainne Walsh, NCE-MSTL, University of Limerick demonstrated a number of ways of *Integrating Maths in the Junior Science Curriculum*.

Brendan Duane PDST: described the *New Organic Practical for Leaving Cert Chemistry – Oxidation of Phenylmethanol* (with a resource sheet developed by **Michael Seery** DIT).

Danny Walsh from Limerick Institute of Technology spoke about the BAMMBO FP7 research project *Molecules from the Sea*.

Declan Kennedy University College Cork gave the final talk of the day on *Leaving Cert Chemistry practicals - how might they be assessed.*

Throughout the day there was the opportunity to engage with a number of Information Stands on a variety of topics and projects:

- Limerick Institute of Technology Department of Applied Science
- Chemistry in Action! and TY Science resources
- SciFest

- From LIT to ISS – an experiment for space
- Royal Society of Chemistry Learning and Teaching

- Education in Chemistry and The Mole
- ISTA
- ScienceQuiz e-books Michael O'Leary

Solid State Pharmaceutical Centre, Sarah Hayes

Muireann Sheehan – SubAtomic an intervention project for chemistry teaching

- National Centre for Excellence in Maths and Science Teaching and Learning – Research and Resource Guides
- Chemistry is all around us network project

It was a packed day with lots of new perspectives (and free resources) to bring back to the chemistry classroom. At the close of the conference Marie Walsh acknowledged the work done by Peter Childs throughout the years in instigating and running the ChemEd conferences (which started in 1982). She then handed the baton over to Dublin Institute of Technology and Michael Seery who will host the 2014 ChemEd Ireland conference on October 18th 2014.

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The next issue of *Chemistry in Action!* (#102, Spring 2014) will contain written versions of the lectures and outlines of the workshops, to provide a permanent record of the event.

"Initiatives in Chemistry Teacher Training" 29/11/13

The international conference "Initiatives in Chemistry Teacher Training" took place in Limerick on 29th November 2013 in Limerick Institute of Technology City Campus at George's Quay. The aim of the conference was to share European experiences and initiatives for pre-service and in-service training of chemistry teachers and then to focus on initiatives to enhance chemistry teacher training from an Irish perspective. The Conference was funded by the 518300-LLP-2011-IT-COMENIUS-CNW Chemistry is All Around Network project resources. It was part of the prescribed activities of the Chemistry is All Around Us Network and follows on from the initial conference on Training Issues of Chemistry Teachers in Gabrovo, Bulgaria in June 2013.

The morning session centred around the European experiences collated through the Chemistry is All Around us Network Project, and the afternoon devoted to various aspects of chemistry teacher training in Ireland, and beyond, since some of the initiatives were instigated as part of European collaborations.

In addition to the conference talks, poster presentations were displayed, giving the participants had the opportunity to examine the posters presented and to discuss their contents with authors during the breaks midway through the morning and afternoon sessions. The full conference programme is available on the conference web site:
(http://www.lit.ie/ICTT/default.aspx).

Some forty participants registered from a number of European countries, with the largest representation from Ireland. These included representatives from universities, schools, educational companies and public authorities. They were welcomed to the George's Quay campus by Michael O'Connell, Limerick Institute of Technology's Vice-President for Strategy, Internationalisation and Marketing. His welcome was echoed by Michelle McKeon-Bennett, Head of Department of Applied Science in Limerick Institute of Technology. The Chairperson for the day was David Sutton, a lecturer in the Department of Applied Science in Limerick

Institute of Technology who is also a member of the Irish team of experts for the Chemistry is all Around Us Network Project.

The papers presented addressed Initial Teacher Education and In-service Education, with some of them focussing on the use of information communications technologies to enhance the teaching experience, as well as continuous professional development in the use of inquiry-based strategies. All of the European project partners spoke about issues and initiatives in their own countries, and the morning session concluded with a review of *Initiatives in Chemistry Teacher Training in Ireland* by **Marie Walsh**. This outlined the current status of reform in all education components in Ireland, which, in the case of teacher training, have been informed by the Sahlberg Report (July 2012). This concluded 'in order to advance further in its national teacher education system, Ireland needs to invest more in the continuous improvement of the quality of teaching, the role of research in teacher education, and international cooperation in all of its teacher education institutions'. The current system of pre-service training was described, with some comparison of concurrent versus consecutive training and the implications of each for subject content knowledge and pedagogical skills training. Continuous professional development to maintain the state of the art in a scientific discipline like Chemistry was recognised as being vital. To this end the talk merged with one by **Peter Jackson**, who described the role of the *Professional Development Service for Teachers* (PDST). He is a practising Chemistry teacher who is also a member of the PDST team for Chemistry. He explained the work of the team and their countrywide interaction at Teachers Centres. They ensure material presented at training sessions is useful, are forward-looking, cross curricular links are stressed, making resources available to all teachers and they address literacy and numeracy issues.

The conference lunch was held in the Hunt Museum, which was a short walk away from the venue for the talks. This gave participants a chance to meet partners from other countries and to discuss the issues in a less formal setting.

When the participants reconvened at George's Quay they heard an overview of the *Chemistry Is All Around Network Project: The Transnational Report* by M.M.Carnasciali and L.Ricco and presented by **Marilena Carnasciali**, the project leader from University of Genoa. Her report showed how the project network is expanding internationally. She has concluded that the project is making a valuable contribution to the training of teachers because it allows the experts to deal with the international reality and increase their knowledge in the field of training and to discuss with teachers of all levels, establishing a solid contact with schools, their problems and needs. It also has allowed the teachers involved to have people to contact for improving their teaching methodology and for all users of the portal to update on teaching chemistry in Europe and find ideas for new teaching methodologies.

The afternoon sessions then shifted focus to Irish initiatives. Talks were given by representatives of Chemistry and Science Education Research Groups in a number of Irish third level institutions with involvement in either or both pre-service and in-service training of teachers. Many of the presenters are members or associates of the Chemistry is All Around Us Network in Ireland. The first of these talks was from **Peter Childs**, one of the pre-eminent chemistry education researchers in Ireland. His talk *From SER to STL: translating science education research into science teaching and learning*, encouraged the implementation of research findings into teaching and learning.

The theme of 'Misconceptions' was a major component of *Pre-service Primary Teachers Ideas in Chemistry* by **Maeve Liston**. She shared her on-going research findings regarding the scientific knowledge of pre-service primary school teachers and also described proposed future work to redress the misconceptions issue: to design and implement the Conceptual Understanding Chemistry Course where the pre-service teachers will be confronted with 'chemical events' that evoke conflicts between everyday conceptions and chemical theory.

The theme continued with a description of on-going research with pre-service secondary school teachers at the University of Limerick in *Investigating and Addressing Chemistry Misconceptions in the Subject Matter Knowledge and Pedagogical Content Knowledge of Pre-service Science Teachers* which was outlined by

Muireann Sheehan and co-authored by Peter Childs. Their research has shown that the level of misconceptions is high, and worryingly, that it does not decrease over the lifetime of the undergraduate training programme. Phase 2 of the research includes design of a blended-learning intervention, including a website subatomic. The intention is that this website is a place where the Pre-service science teachers can: revise their own understanding of lower second-level (Junior Certificate) chemistry topics, learn about common pupil misconceptions which they may come across in the classroom, get diagnostic questions, resources, ideas for teaching activities and information about the Junior Certificate science syllabus, learn about research ideas and strategies relevant to developing conceptual understanding and targeting misconceptions among their pupils, and, get advice from experienced teachers/researchers about teaching chemistry (in the form of short articles).

The next two talks shifted emphasis to the use of ICT in chemistry teaching. **Claire McDonnell** from Dublin Institute of Technology addressed the topic *Applying Technology to Enhance Chemistry Education.* Claire described her experience as a guest editor for the Royal Society of Chemistry special themed issue of the journal *Chemistry Education Research and Practice*, before going on to talk about her own experiences of using Wikis and Peerwise. One telling quote has resonance for all: *"Technology will not replace teachers, but teachers who use technology will replace the teachers who do not,"* Clifford, R. (Defense Language Institute) quoted in Moeller, A. J. CALICO Journal, 1997, 14 (2-4), 5-13.

Mark Glynn from Dublin City University spoke on *Using Moodle for sustainable professional development for teachers.* This talk gave an overview of the potential for Moodle, both for in-house back-up for lessons and also for distance training initiatives.

After a short break to allow discussion and viewing of posters, the final talks of the day commenced. The first of these *The use of Visual Aids for concrete learners: Facilitating understanding in Organic Chemistry* was presented by **Anne O'Dwyer** (in conjunction with her supervisor Peter Childs), who demonstrated her research findings supporting the use of models to facilitate understanding of structures and reactions of organic molecules. She spoke about the multi-dimensional nature of Chemistry, cognitive development and its impact on the learning and understanding of abstract ideas – and particularly the cognitive demand of Organic Chemistry. The talk concluded with illustrations of the potential for using concrete models to teach abstract concepts.

Sarah Brady, from the CASTEL Centre for Advancement of Science Teaching and Learning in Dublin spoke about *Developing and Implementing Teacher Education Programmes & Resources for teaching Chemistry*. She shared experiences of developing and implementing teacher education programmes and resources for teaching chemistry. This work has been made possible through CASTEL's involvement in two particular projects. The first is the ESTABLISH project, which is an FP7 Science in Society coordination and support project which they coordinate and the second is the Amgen Science Teacher Training Initiative, which has been run as a pilot project for the last two years. Two positive results from these initiatives have been: observed changes in the profile of teachers' understanding of Inquiry based science education and very significantly buy-in from Ministries of Education to roll out national programmes of continued teacher professional development.

The final talk of the afternoon was on *Technology Enhanced Learning in the Chemistry Classroom* by **Michael Seery** who was guest co-editor of the special themed issue of Chemistry Education Research and Practice alluded to earlier. He described on-going research and practice in the implementation of ideas to reduce cognitive overload for students, ideas like the use of worked examples, wikis, jump-starting lectures, podcasting and screen-casting. This gave a myriad of ideas for in-service actions that might motivate students in their studies of chemistry, and also ensure that teachers are responding to the appropriate use of technologies.

□

A Periodic Table of Limericks

Created by Peter Davern
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Helium, He

This super-cool element's a true Big Bang article,
The gas, high-pitch'd, noble…so inertly hierarchical;
Is becoming more rare,
Still balloons fill the air,
Just avoid its light nucleus…alpha particle!

Notes:

This super-cool element's a true Big Bang article,

Helium is one of the three fundamental elements formed during the Big Bang ... the others being hydrogen and lithium. In liquid form, helium is used as an effective coolant for equipment such as MRI scanners, etc.

The gas, high-pitch'd, noble…so inertly hierarchical;

Helium sits at the top of the Noble Gas group. It is a chemically inert, lighter-than-air gas, making it an ideal replacement for flammable hydrogen in airships. Inhaled, it causes your voice to go all high-pitched and squeaky.

Is becoming more rare,
Still balloons fill the air,

Formed via the radioactive decay of uranium (U) in the earth's crust, helium is extracted from the earth along with natural gas. But worldwide stocks of helium are diminishing ... hence making it more expensive.

Just avoid its light nucleus…alpha particle!

When helium loses its two electrons, all that is left is its nucleus of two protons and two neutrons, a.k.a. an "alpha particle". These particles are formed during the radioactive decay of much larger elements such as radon (Rn) – a gas found in granite outcrops in the earth. If inhaled, radon decays radioactively within the lungs producing alpha particles which may react with the DNA in lung cells, ultimately causing life-threatening lung cancer.

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Send one hardcopy + diagrams and a copy on disc (or by email as a Word document) when submitting material.

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It is hoped to put back issues will be put on the Internet one year after publication. This is not yet fully operational and only issues 38 - 68 are now available. In time I hope that most back issues will eventually be available, 3 issues after publication.

At the same site you will also find the University of Limerick's science and technology magazine for schools, *ELEMENTS* and also information on SICICI, ChemEd-Ireland and other chemical education activities.

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Assessment