Chemistry In Action!

Issue No. 116
Autumn 2020

ISSN 0332-2637

Contents

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

For subscription details etc. see inside back cover.

Cover design: George Fitzgerald, Möbius Design

Cover photo: Lighting a fire: Sarah Hayes and sScience outreach at UL (p. 39) (Photo: University of Limerick)

Editor: Peter E. Childs peter.childs@ul.ie

Assistant editors: Marie Walsh, Maria Sheehan, Sarah Hayes, Anne O'Dwyer

Editorial #116

A birthday year

This year marks the 40th birthday of Chemistry in Action! and in the last issue (#115) we featured several retrospective articles. In fact, we had too many for this issue and so we have several articles in this issue, continuing this retrospective look at chemistry and chemical education, 1980-2020. You can find the previous issue at www.cheminaction.com

That was the year that wasn't

What a year this has been! Who thought in February at the ISTA conference, that the rest of the year would be effectively cancelled: months of lockdown, teaching online until September, conferences cancelled or postponed, and school exams cancelled. At the moment (November 2020), there seems to be no end in sight to the pandemic, although vaccines are promised by the end of the year. There was controversy over teacher-assessed LC grades, especially when some students were misgraded, leading to delayed third-level entry, and a large increase in the number of places on offer. Students carrying grades over from previous years were disadvantaged as the awarded grades were higher. JC students didn't even get grades as all were deemed to have passed. This year's 6th years are back in school but will have missed varying amounts of their 5th year work (depending on the school and their personal circumstances). The 2021 exams are planned for June but will have to be modified to allow for reduce teaching time, and nobody knows whether the pandemic will be over by then.

Many science/chemical education conferences were either cancelled, postponed to 2021 or later, or run in a modified online format. You can read details of these altered conferences on p. 4-5.

Thanks to Declan Kennedy and John O'Donoghue, ChemEd-Ireland ran on the advertised date, October 17th, but in an online Zoom format, and it was free. It was a great success with a bumper attendance (maximum of 227) and it shows that we don't have to give up conferences because of the pandemic. I wonder whether in future more conferences will either be totally online or done in a blended format: face to face but with an option to link in by Zoom. This might actually increase participation.

Uncertain outcomes

Who decided that a science curriculum specification consisting solely of learning outcomes was sufficient? The new junior science specification (now entering its 3rd cycle) is based only on learning outcomes as the only guidance for teachers. The new LC Agricultural Science course, which started in 2019, is the first of the new LC science courses and is likewise, only specified by learning outcomes. Teachers of junior science and Ag. Science are almost unanimously agreed that learning outcomes do not make an adequate curriculum, or provide enough guidance to teachers as to what to teach and to what depth. The result is that individual teachers and textbook writers then become the interpreters of the curriculum, a poor preparation for an external examination. Everyone does what is right in their own eyes, so that potentially a different curriculum is taught in every school! **This is madness.**

Despite the clear analysis by Ainé Hyland in 2014 in her report for the ISTA, showing that this is NOT best international practice, the NCCA has gone ahead and launched the new Ag. Science course based solely on learning outcomes. There was no guidance for teachers (although this was promised in 2016) and no sample papers (until the November of 6th year, 2020). **This is not good enough.** The NCCA seems to be impervious to external advice and the views of teachers, and is persisting with a seriously flawed model of curriculum development. If we're not careful, the new LC biology, chemistry and physics courses will be rushed out in the same inadequate, half-baked format. It would be far better to stick with the existing courses rather than foisting unsatisfactory courses on teachers, without there being any alternative. If we were in the UK at least teachers would have a choice of syllabuses – in Ireland it's case of 'one size fits all.' If the NCCA gets it wrong, then we are stuck with it for years. (For more discussion on this topic see p. 5.)

Peter E. Childs
Hon. Editor

In this issue #116

40th birthday features

We didn't have room in issue #115 for all the special 40th birthday articles, so several are included here. In the last issue Dr Peter Childs looked at the progress of science education research and in this issue (p. 24), he looks at chemical education at third-level (levels 8,9 and 10). Dr Martin McHugh and Dr Sarah Hayes (SSPC, UL) review the history of science outreach in Ireland (p. 39.) Dr Odilla Finlayson (DCU) describes the history of Ireland's involvement in the International Chemistry Olympiads (p. 43.)

ChemEd-Ireland 2019

Last year's ChemEd-Ireland was held in TU Dublin, Kevin Street, and celebrated the end of IYPT. We didn't manage to publish the Proceedings in the Spring issue, as is usual, as we didn't get the articles based on the talks. In this issue we have a report on the conference by the organiser Claire McDonnell (p. 14) and a short history of chemistry at DIT (now TUDublin), Kevin Street (p. 8.) We hope to publish one or more of the talks in the next issue.

Science education research

We have two articles relating to science education research in this issue. In November 2019 the second MORSE (Methods of Research in Science Education) conference was held in TU Dublin, and we have an account of the conference from an overseas visitor, Ellen Kampinga (p. 15.) Dr Aishling Flaherty (UL) describes her experience as a postdoc in the USA and compares science curriculum development in the USA (p. 18) and Ireland.

Other articles

Three colleagues from Serbia describe their work on Escape Rooms as a teaching method on p. 49.

Adrian Ryder continues his series on famous scientists on Jacques Charles (well-known for Charles' Law) on p. 54.

What is green hydrogen? The hydrogen economy is always just around the corner, but it now seems that it is more likely to become part of the renewable energy mix in the future. Find out on p. 59.

Reminder:

The current issue of *Chemistry in Action!* and a number of back issues are available at www.cheminaction.com, together with 6 TY Science modules and other articles on teaching chemistry. Thanks to Maria Sheehan who is the web editor.

In memoriam

Paraic James
1959-2015

Dr Paraic James (DCU) was one of the leading lights behind Ireland's participation in the Chemical Olympiads (see the article on p. 43 in his memory.)

Additional Olympiads

Ireland have also participated in other Senior Science Olympiad competitions, co-ordinated by staff in DCU, namely Physics (IPhO) from 1998 until 2012, and Biology (IBO from 1998 until 2010).

Additionally, there are two international science olympiad competitions for younger students that DCU have co-ordinated Ireland's participation in, (see http://castel.ie/olympiads/) namely International Junior Science Olympiad (IJSO) – a world-wide individual competition for 15 year old students in science, which started in 2004, and European Union Science Olympiad (EUSO) – a European team competition for 16 year old students, which started in 2003.

There are also other Olympiads for second level students, such as

Programming – see All Ireland Programming Competition, leading to selection for International Olympiad in Informatics http://multimedia.ucc.ie/Public/training/aipo/

Mathematics – see The Irish Mathematical Olympiad (IrMO) http://www.irmo.ie/ and the selection for the International Mathematics Olympiad http://www.imo-official.org/ and European Girls Mathematical Olympiad https://www.egmo.org/egmos/egmo9/

Linguistics – see All Ireland Linguistics Olympiad https://ailo.adaptcentre.ie/ which leads to selection for International Linguistics Olympiad https://ioling.org/

*****

Education News and Views

The Editor welcomes contributions and news of interest to chemistry teachers in this section. Please send in news items for this feature. Views and opinions from teachers on educational matters relating to the teaching of chemistry are welcome.

Questions for chemistry teachers

(reply to peter.childs@ul.ie):

1. **How are you dealing with the reduced hours and missing chemistry topics in junior science? In particular, the lack of a formal specification for chemical bonding. Are you teaching it anyway and if so, how much?**

2. **Having started teaching 5th year LC Chemistry with the first full intake who've done the new junior science course, what effect has this had on their preparation for the course and how have you altered what and how you teach to allow for a different intake?**

New upskilling course in Physics

New courses to upskill second level teachers have been announced in Physics, Spanish and Maths. The Diploma in Physics Teaching will have 60 ECTS of physics plus 15 ECTS of pedagogy over two years, starting in January 2021. DCU and Dr Eilish McLoughlin is the lead on this, with UL and NUIG also involved. The Diploma in Maths Teaching is a two-year continuation of the successful programme led by UL, which has been running for several years.

*****

ChemEd-Ireland breaks all records

This year's 39th ChemEd-Ireland conference was held online on Saturday 17th October for the first time, organised by Dr Declan Kennedy and his team at UCC. The attendance was the largest ever – over 227 at a maximum and even after 6 hours had only just dropped below 200. The online format by Zoom meant no travel and the conference was free: it was thus easier and cheaper to attend. It is hoped to put the talks in a Proceedings in the Spring 2021 issue of *Chemistry in Action!* It was a good decision by Declan to run the conference online rather than cancelling it. The BASF Summer School in UCC was cancelled in the summer but BASF kindly sponsored ChemEd-Ireland instead. The speakers' Powerpoint presentations are available on the ISTA website, with free access.

The 40th ChemEd-Ireland is scheduled for Dublin City University, probably on 16th or 23rd October (tbc), organised by Dr Odilla Finlayson. The annual conferences started in 1982 in Thomond College, Limerick (now part of the University of Limerick.)
The 2022 is due back in Limerick at LIT, 2023 in Dublin at TCD, in 2024 back to UCC, and in 2025 at TU Dublin in Grangegorman. The conferences alternate between the east and west of the country, hosted by third level institutions with an interest in chemical education.

*****

ESERA turns 25

The European Science Education Research Association turns 25 this year. It hosts as biannual conference and summer workshops for PhD students. The 2017 conference was held in DCU. The 2021 conference will be online.

*****

Conferences postponed and cancelled

Many conferences in science/chemical education were cancelled this year, postponed or held online. Some details are given below. Even ones rescheduled for 2021 are subject to the situation with the pandemic.

ASE Annual Conference 2021 online in 2021
06 January 2021 - 09 January 2021
https://www.ase.org.uk/events/ase-annual-conference-2021-online-in-january

ICCE 2022 Cape Town, South Africa 18-22 July 2022
www.ICCE2022.org.za

The **2020 ICCE** was first postponed from July 2020 to January 2021, then cancelled and now is scheduled for 18-22 July 2022 in Cape Town, South Africa. The call for abstracts will be re-opened on 4 October 2021.
https://www.icce2022.org.za/

BCCE 2020 has been cancelled. The next conference BCCE 2022 will be held in Purdue University.

2021 ChemEd conference will be in the University of Guelph, Canada in 2021 (https://chemed2021.uoguelph.ca/) This conference alternates with BCCE above.

The 11th International Symposium on Microscale Chemistry

12 - 15 July 2021, Oundle, Peterborough , United Kingdom

ECRICE 2020 was due to be held in Israel in July 2020 but has now been postponed to 11-13 July 2022.
The theme of the conference is Excellence and Innovation in Chemistry Teaching and Learning. Research in Chemistry education advances our understanding of how students learn chemistry and what can enhance chemistry learning and teaching. We, the community of chemistry education researchers, study factors that support or inhibit chemistry learning. We examine different learning environments and new ways in which technology can be integrated in chemistry teaching, and the relationship between chemistry, society and other scientific disciplines.
http://www.weizmann.ac.il/conferences/ECRICE2020/excellence-and-innovation-chemistry-teaching-and-learning

Eurovariety 2021 will be held in Ljubljana - Slovenia, 7 - 9 July 2021.
The conference, run under the auspices of the EuCheMS Division of Chemical Education, is a European counterpart of the UK conference "Variety in Chemistry Education" and is devoted to practical aspects of chemical education at tertiary level (general and vocational higher education institutions, HEIs), at both undergraduate and postgraduate levels.
http://www.eurovariety2021.si/

10th New Perspectives in Science Education
18-19 March 2021, Florence, Italy
https://conference.pixel-online.net/NPSE/

14th ESERA online conference, University of Minho (Braga, Portugal) from 30 August to 3 September 2021.
https://www.esera.org/news/esera-announcements/854-esera-conference-2021-call-for-proposals

Chemistry Education Research and Practice, *Gordon Research Conference*
Coordinating the Production and Consumption of Knowledge on Chemistry Teaching and Learning, July 11 - 16, 2021, Bates College,, Lewiston, ME, USA
https://www.grc.org/chemistry-education-research-and-practice-conference/2021/

ISTA Conference 2021
The dates and venue for the 2021 ISTA Conference are still to be decided but it is likely at this stage that it will be online.

*****

No good outcome on learning outcomes

This school year (2019/20) saw the first full output from the new Junior Science course taking either TYO (~75%) or going straight into 5th year. The school year 20/21 will se all incoming 5th year students having gone through the new Science course, although it wasn't examined this year. Many concerns have been expressed about the new course, especially by teachers: the vagueness of learning outcomes, the lack of background material for teachers, a reduction in hours for science (to 200 from 240 hors), the loss of core topics (like bonding in the chemistry section), late sample papers and a dumbed-down, common level paper. A particular concern, highlighted in the ISTA survey (2019), was that teachers didn't know how much or in what depth to teach topics, given only a learning outcome to work from. This means that every teacher becomes the interpreter of the syllabus, often dictated by the textbook they use, so there is no common content that can be examined. The common level science paper was criticised for being too easy, especially for higher ability students.

A major question this year is how the new junior science course will affect the uptake of LC Chemistry and other LC sciences. The gap between junior and senior cycles is larger than ever; most students will not have covered core topics like bonding, and this will mean that LC teachers have to start further back. It seems likely that students going into 5th year will be more poorly prepared in all the sciences, if only from reduced teaching time, and may find 5th year more difficult as a result.

The other question is whether their exposure to science in the junior science course has given them a desire to continue with one or more of the main LC sciences. Time will tell and I would like to hear from LC Chemistry teachers and their experiences.

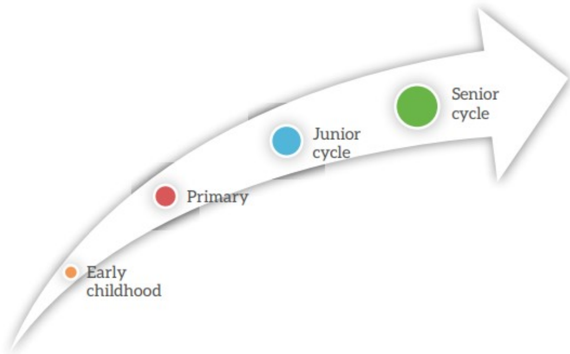


Figure 1: The Irish educational progression

Ideally curriculum reform in any subject should be seen as a continuum from 1st class in primary school to 6th year LC (as shown in the Figure above from the NCCA Agricultural Science specification.) There should be a consistent and coherent development of what students experience in science, with smooth and structured transitions from one level to another, e.g. primary science → junior science → LC Chemistry. If you make a change in the science at one level, then the next level up must be revised to ensure a smooth transition, rather than a sudden jump in level, content and pedagogy. Thus junior science should be revised to match with primary science, LC sciences should be revised to match with junior science. This means that the new LC science subjects **should have been ready** at the latest this year (better in 2019), to match the first full intake from the new junior science course, and should take account of any changes in content, level, pedagogy and duration of the lower course.

A LC Chemistry Development Group was set up, replacing the syllabus committee, and started meeting in 2019. It was due to have a completed specification in October 2020, for introduction in September 2021. The summary of the group's meetings (5 in total) are on the education.ie website; only 5 meetings were held and the last one was in February. It seems unlikely that the new courses will be ready to implement before 2022, assuming that what results is fit for purpose and acceptable to teachers. The process of producing new LC science specifications started in 2006; the first drafts were issued for consultation in 2012 leading to 'final' documents in 2014. This is when teachers found that all they were offered was a list of learning outcomes to interpret the list of topics. This led to the critical report on the proposals, based on a survey of best international practice, by Ainé Hyland (Hyland, 2014).

Ag Science: a case in point

The new Agricultural Science specification was introduced in September 2019, so it is due to be examined for the first time in 2021. All teachers had to base their teaching on were a set of learning outcomes.

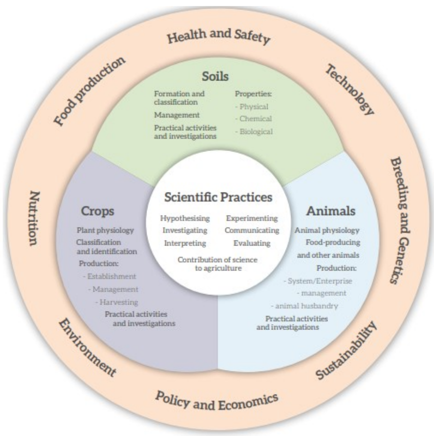


Figure 2: Structure of the new Agricultural Science course (NCCA)

Figure 2 above shows the overview and structure of the new course, which is excellent. However, teachers were promised Teacher's Guidelines from 2016 onward and as of November 2020, these have still not been received. The first examination is due in June 2021 and again no sample papers have been received by early November 2020, although they have now been received and are on the IASTA website. The Irish Agricultural Science Teachers' Association (IASTA) has sent a submission to the Minister of Education and the NCCA outlining their concerns (see extract below, https://www.iasta.ie/2020/10/31/open-letter-of-minister-norma-foley-agricultural-science-teacher-guidelines-sample-papers/).

"From the outset, it was clear to the I.A.S.T.A. that the draft specification was a vague document.

It is written using the same template as was used in writing the Junior Cycle Science specification, i.e. simply a list of Learning Outcomes with no depth of treatment provided or information about assessment which would enable teachers to interpret and implement these learning outcomes in a consistent way in the classroom."

The frustrations of teachers were also described vividly by Humphry Jones at the ISTA conference in February 2020. Teachers have been left trying to interpret and teach the outcomes without knowing what depth to cover or how long to take on each topic. Lack of a sample paper also means that they did't know what to expect in the examination and how various topics would be examined. Their experience has reinforced the experience of junior science teachers and the predictions in the Hyland Report. **Attempting to deliver a new course based solely on learning outcomes is a recipe for educational disaster.** The fact that this has been done for Agricultural Science, a course long overdue for revision, is a worrying precedent for the other LC science courses. It cannot all be blamed on Covid-19, as these specifications have been gestating for over a decade.

*****

Science week 2020

Science Week ran from 8-15th November in 2020 and this year it was a virtual week, with most events online. This might result in more children being reached as it is easier and cheaper to connect online rather than travel for a show. Although it is not the same, of course. A vidioor online presentation is not the same as a face-to-face show, where the presenter and audience can interact and feed off one another.

Young Scientist and Technologist Exhibition 2021

For the first time in its long history the BTYSTE will be virtual and online.
https://btyoungscientist.com/
The closing date was 20th November 2020.

*****

All things change and all things stay the same

I came across this quotation from an article by Professor Thomas Dillon in *Studies*, vol. XXXII #125, 1943, pp45-47, 'The relation of chemical research to our industries'. He writes (pp 55-56) in the middle of WW2:

"The first question then to ask is whether our system of education is of such a character as to foster the habits of independent thought which are necessary for the good research workere? I am afraid that the answer to that question is 'no.' Our system of secondary education, or rather our system of financing our secondary schools, is decidedly against the encouragement of independent thought. The system was not, as so many people appear to think, given to us by St. Patrick.….

Through this system of big public examinations all our secondary teachers are prevented from inculcating habits or inquiry and original thought and all out (sic) schoolboys are taught that such habits do not pay. At the risk of being thought a crank I have introduced this question here, because I am convinced it is one of the most serious obstacles to our scientific development. My own experience as a university teacher is that, unless a [sic] boy has some counteracting influence at home, it takes years to convince him that he did not come into the world solely for the purpose of learning other people's ideas and putting them down on an examination paper. An alteration of the system whereby a secondary teacher would be given some independence in his own classes would, in my opinion, remove a great obstacle to the growth of scientific inquiry in this country."

Secondary science teaching then seems to have been mainly for boys and was exam-focused and based on rote learning, with I think, payment by exam results. In many ways, not a lot seems to have changed.

*****

Evaluation of the new Junior Cycle programme

The NCCA has signed a contract with the School of Education at the University of Limerick to evaluate the introduction of the new Junior Cycle programme. It is to eb hoped that the voices of teachers will be clearly heard.

*****

The History of Chemistry Education at the Kevin Street Site in Dublin 8

Declan McCormack & Claire McDonnell,
School of Chemical & Pharmaceutical Sciences, Technological University Dublin
Declan.mccormack@TUDublin.ie and Claire.mcdonnell@TUDublin.ie

There is a strong tradition of excellence in chemistry education at our Kevin Street site, just 5-minutes walk from St Stephen's Green, that dates back to the establishment of a technical school in 1887. We are very proud of this heritage and are committed to maintaining and enhancing it as we look forward to moving to our new location and facilities in Grangegorman, in the north west of inner-city Dublin.

Early Years

The mission of the original technical school at Kevin Street was to provide the educational services needed by students, industry, business and the community with a focus on the requirements of disadvantaged sections of the local population. It was founded as a result of the Samuelson Commission on Technical Education (1881-84) which advocated the establishment and maintenance of secondary and technical schools by local authorities. The committee that established Kevin Street Technical School in October 1887 included Michael Davitt as one of the Dublin Corporation representatives and Arnold Graves who was one of the main proponents of the project. The site selected was at 18 Lower Kevin St and funding came from a Dublin Corporation grant as well as private subscriptions. Among the 19 subjects initially offered was 'theoretical and practical chemistry'. Technical classes were designed to allow students to go on to take City and Guilds of London Institute examinations.

By the academic year 1896-97, there were 925 students enrolled in the Technical School and the range of subjects had extended and included both organic chemistry and inorganic chemistry. Although the majority of courses offered were at secondary school level, from the first decade of the 1900s, some higher level qualifications were provided. As early as 1908, students were excelling nationally in chemistry; seven were successful that year in examinations for the Licentiateship of the Pharmaceutical Society of Ireland (one of them in first place), four qualified as teachers in Chemistry and several were successful in the Royal University of Ireland degree exams, with two obtaining honours in chemistry. In addition, the Royal College of Surgeons in Ireland recognised the courses in chemistry and physics as satisfying the requirements for their first professional examinations. Courses leading to the external BSc examinations of London University in physics and chemistry continued to be popular.

As time went on, the technical school was renamed to the Institute of Science and Technology and industrial chemistry subjects (gas manufacture, oils and fats, fuel technology) were introduced. In the 1950s, a science laboratory technician's course was started and the college was redesignated as a College of Technology. Due to overcrowding, neighbouring sites were purchased and a new college building was completed in 1968, which was later extended in 1987.

Establishment of Dublin Institute of Technology

In 1978, the Dublin Institute of Technology (DIT) was established and Kevin St was one of 6 City of Dublin Vocational Educational Committee (CDVEC) third level colleges that made up this new entity. This led to the Dublin Institute of Technology Act of 1992 which made the Institute substantially independent from its former parent body, the CDVEC. In September 1998, DIT was granted the power to award its own degrees, at both undergraduate and postgraduate level. Prior to this, a partnership agreement had been in place from 1976 with Trinity College and this had allowed for designated 4-year courses in DIT colleges to result in the awarding of a university degree from Trinity.

Figure 1: Teaching laboratory in Kevin St in the early 1990s

Evolution of Our Chemistry Degrees

A technician diploma course in applied science was begun in 1969. This evolved to have options in biology, chemistry and physics incorporated and these have evolved to be part of our current suite of ordinary degrees; **Science General entry (TU755)** and **Medicinal Chemistry & Pharmaceutical Sciences (TU762)**.

In 1971, the College of Technology, Kevin Street, joined the 'Group Scheme' of the Royal Society of Chemistry (RSC) and offered a programme open to chemistry diploma graduates that led to the award of Graduate of the RSC (GRSC (Part II)) on a two year part-time basis, which fulfilled the academic requirements for Chartered Chemist and Membership of the RSC (CChem, MRSC) professional status. It ran successfully for more than 20 years on a part-time basis, with the introduction of a one year full-time structure in 1989. In 1994, the School of Chemistry at DIT completed a joint validation process with the Royal Society of Chemistry and Dublin City University (DCU) and a partnership resulted whereby students qualifying with a Diploma in Chemical Sciences from DIT automatically qualified for a BSc in Chemical Sciences (honours) from DCU. Students obtaining a lower second class honours or better were eligible for the award of GRSC from the RSC. In 1999, the programme was validated for a DIT honours degree award. In 2009, it was modified from an 'add-on' offering to a stand alone 4 year honours degree open to CAO applicants. The name was changed to **BSc Chemical Sciences with Medicinal Chemistry (TU852)**. In 2015, RSC accreditation was obtained for this programme. The Institute of Chemistry of Ireland also recognises our degrees for entry to membership. Kevin St has produced two presidents of the Institute of Chemistry of Ireland, Martin Cranley, who was Principal of the College of Technology from 1952-1962 and John Cassidy, a current Assistant Head of School.

The Diploma in Applied Science was launched in 1976. Students undertook 4 years of study and could select 2 science subjects on a joint basis. The combinations involving chemistry that could be selected were chemistry and physics, chemistry and food science or chemistry and maths. Under the partnership agreement with Trinity College, graduates who successfully completed this course from 1976 to 1998 were awarded an honours degree in Applied Science. In 2003, the decision was made to develop some degree programmes that focussed on one subject only. The BSc in Forensic and Environmental Analysis was launched in 2003 and it was subsequently renamed to BSc in Forensic and Environmental Chemistry. This course reflected an area of staff expertise, analytical chemistry. In 2018, it was renamed to **BSc in Analytical Chemistry (Environmental, Forensic & Pharmaceutical) (TU851)** to emphasise this core focus and to indicate the main areas of employment our graduates were being recruited to. The joint chemistry and physics degree option evolved to become the **BSc in Science with Nanotechnology (TU855)**. Students study Chemistry and Physics for 2 years and then select one as a major subject for 3rd and 4th year.

We also offer a part time ordinary degree in the Manufacture of Medicinal Products in collaboration with
our partner, Get Reskilled, that prepares participants for careers in Ireland's vibrant pharmaceutical and medical technology sectors.

The Roadmap of Chemistry Courses diagram (Figure 2) shows the evolution of our current full-time chemistry degrees over the past 50 years.

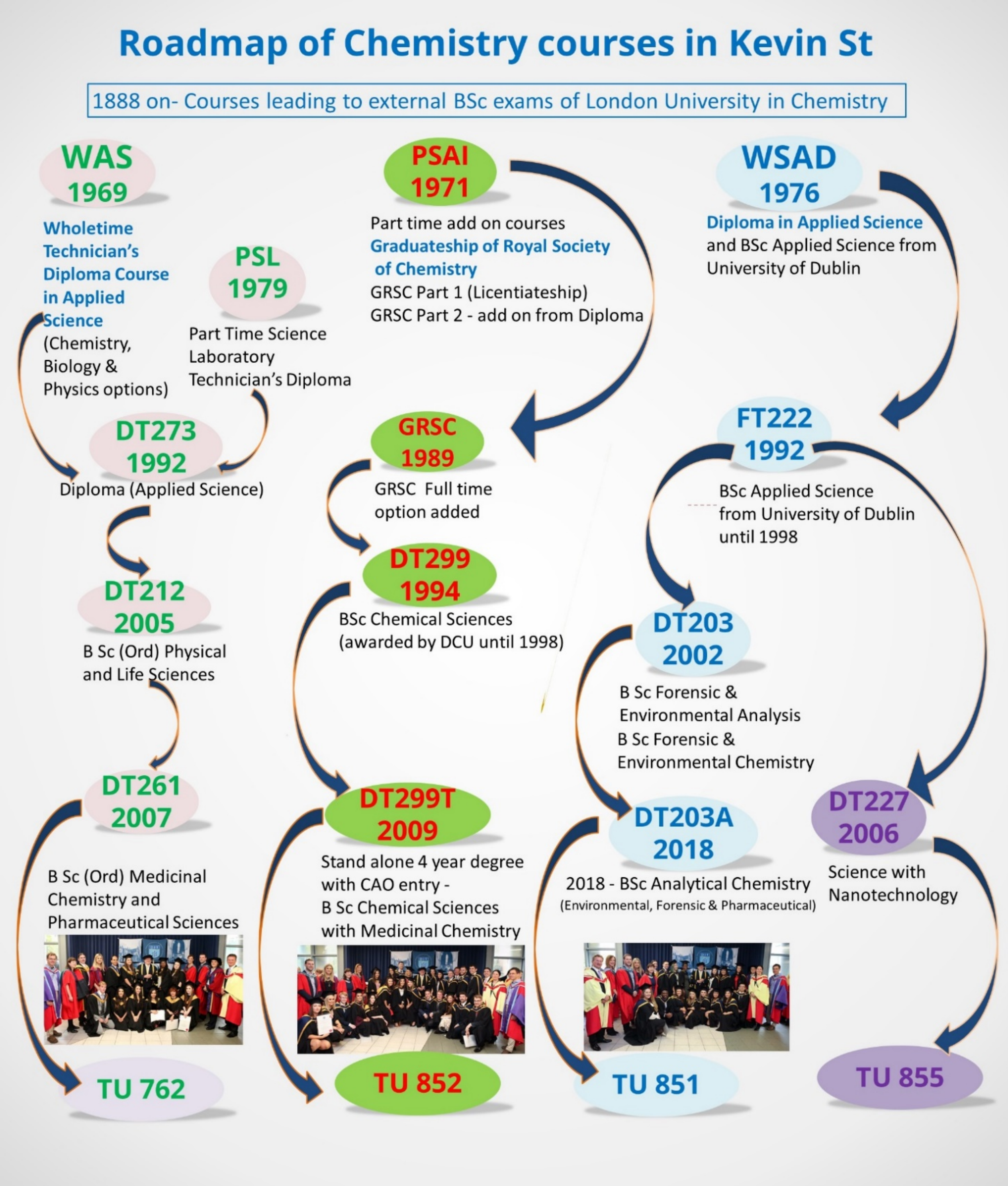


Figure 2: Roadmap of chemistry courses in Kevin St (Prepared by Dr Ann Hopper)

School of Chemical and Pharmaceutical Sciences, Technological University Dublin

A School of Chemistry developed at Kevin St in 1988 from what had been a joint School of Biology and Chemistry. During that time, there have been three Heads of School; Mr Eamon Rothery, followed by Dr Noel Russell and, currently, Prof Declan McCormack. An internal strategic review in 2005 led to a rebranding to the School of Chemical and Pharmaceutical Sciences to reflect our evolution and our course provision to both undergraduates and taught postgraduates. Throughout, our School has continued to respond creatively to the changing needs of our stakeholders. This has included embracing the benefits that advances in technology and communications can offer – for example the very first Massive Open Online Course (MOOC) offered by an Irish higher education institution was **PharmaMooc** “So you want to work in the Pharma Industry…” offered by the School in May 2013. We have also developed an online part time MSc in Pharmaceutical Validation Technology. These remote learning opportunities have become even more important during the Covid19 pandemic as have the online teaching skills that had been developed among staff. We have also maintained our commitment to providing flexible pathways into higher education for non-traditional learners, many of whom do not have the benefit of experience of higher education to draw from among their family or peers. Our aim is to enable learners in a complex technical discipline such as Chemistry to develop the skills, knowledge and attributes to contribute meaningfully and flourish in the workplace and in their community.

Figure 3: First Year teaching laboratory in Kevin St currently

The establishment, on 1st January 2019, of Ireland’s newest university, Technological University Dublin, is an endorsement of teaching and research standards across our institution. We were delighted that this was reinforced when our School was awarded the Best College of Science and Engineering at the 2020 Irish Education Awards.

A key milestone in early 2021 for us will be completion of construction of the Central Quad building on the new Grangegorman campus in Dublin’s north inner city to which all Schools in Kevin St will relocate in time for the 2021-22 academic year. Figure 2 shows the original building at 18 Lower Kevin St as well as the current building which replaced it in 1968 and the almost completed Central Quad in Grangegorman.

Taught Masters Programmes and Research

Taught masters programmes have been offered by the School since 1999. The part time MSc in Pharmaceutical Quality Assurance was designed then to up-skill graduates working in the pharmaceutical industry and, in 2000, a full-time option was developed for recent graduates. In 2006, the full-time offering was renamed the MSc in Pharmaceutical Quality Assurance and Biotechnology and the part-time programme became the MSc in Pharmaceutical Quality Assurance and Regulation. Our part time MSc in Pharmaceutical Validation Technology was launched in 2004. In 2015, the programme transitioned to fully online delivery and it now attracts part time students from across the world. The importance of providing highly educated and skilled graduates to the Pharma sector has been recognised by the Higher Education Authority who continue to fund programmes such as our innovative postgraduate diploma in Pharmaceutical Validation Technology in collaboration with the National Institute for Bioprocessing Research and Training (NIBRT). This programme offers upskilling opportunities for graduates through an internship in conjunction with leading Pharmaceutical companies including Amgen, Pfizer, Alexion and BMS.

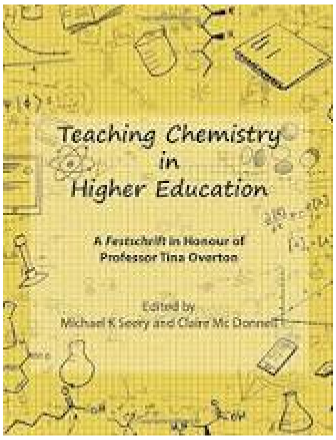
Figure 4: Some of the analytical chemistry teaching facilities in Kevin St currently

The School of Chemical and Pharmaceutical Sciences has been engaged in research for the past 35 years and maintains an active research profile in a variety of areas such as environmental chemistry, medicinal chemistry, surface/materials chemistry, nanoscience, pharmaceutical regulation and chemical education. We implemented a new research action plan in 2017-2018 as we recognised the need for a cultural shift in how we carry out research. Our new research framework consists of three research teams aligned to areas of strength in our School; Health, Environment, and Industry & Innovation. These link to Irish societal and economic needs, and are recognised as vital to a sustainable national research agenda. Underpinning this is a commitment to integration with teaching, by development of student research and enquiry skills early on through context-based learning and summer undergraduate research opportunities. Environmental chemistry in TU Dublin has been highlighted nationally as an area of excellence based on citation impact (Source: HEA Compact 2014-2016). We have successfully secured funding from the Environmental Protection Agency, Enterprise Ireland, Science Foundation Ireland, Dept of Business, Enterprise & Innovation (Disruptive Technologies Fund), EU (COST Action), RSC and industry (Henkel, Stryker, Medtronic, ESB, Powerbar, Smarter Surfaces, TEG etc.) We also draw upon the expertise of the two research centres affiliated to the School, the Centre for Research in Engineering Surface Technology (CREST) and the Pharmaceutical Regulatory Science Team (PRST).

Chemistry Education Practice and Research

Our Chemical Education Research Team (CERT) aims to incorporate best practices in emerging education research into day-to-day teaching of chemistry and to evaluate their impact. The driving motivation is to engage and support our chemistry learners. Research interests have developed in a variety of areas and we publish in journals and present at conferences regularly. CERT was recognised with one of the inaugural Disciplinary Excellence in Learning and Teaching Awards in 2018 from the National Forum for Enhancement of Teaching and Learning in Higher Education.

Lecturers in TU Dublin have won the Royal Society of Chemistry Higher Education Teaching award on three occasions; Claire McDonnell in 2009, Michael Seery in 2012 and Barry Ryan (based in our Cathal Brugha St site) in 2019. Michael Seery relocated to the University of Edinburgh in 2015, where he has become a Professor of Chemistry Education. He is also the editor of the RSC journal, *Chemistry Education Research and Practice.* He continues to actively collaborate with CERT members. TU Dublin has hosted the Irish Variety in Chemistry Education conference since 2005. Its aim is to allow people teaching chemistry at third level to share 'what works' - useful ideas and effective practice. In addition, the Methods of Research in Science Education (MORSE) conference was established in TU Dublin in 2018 and 2019 and is co-organised by Barry Ryan and Michael Seery. (See article on p. **.) CERT members have published widely and are involved in a range of national and international education activities including a recent EU project which resulted in an open online course on best practice in teaching in university chemistry laboratories. Claire McDonnell and Michael Seery co-edited a book on *Teaching Chemistry in Higher Education* with Michael Seery in 2019 and two other CERT members contributed chapters.



Engagement with Secondary Schools and the Community

The School has long supported effective engagement with second level students and their teachers. The Chem-Ed Ireland conference for chemistry teachers was hosted in Kevin St in 2010, 2014 and 2019. We also host the a SciFest science fair each year. Our community-based learning activities involve our students working with schools and youth organisations to develop meaningful hands-on science activities for young people. Other activities include School visits and open days, Science week and Transition year placement programmes. In addition to this, we have worked closely with our former graduates who have subsequently qualified as teachers to identify where we might be able to support their students. This has taken the format of site visits to their Schools as well as hosting their class groups in Kevin Street to give them exposure to our laboratory instrumentation.

The Future

We are proud that our School has a unique profile as an outward-looking provider of high quality undergraduate and postgraduate education in the Chemical and Pharmaceutical sciences that responds to sectoral and national needs through provision of taught courses with a focus on the learner experience and employer relevance, traditional and industrial PhDs, innovation and commercialisation activities and partnerships with industry and communities.

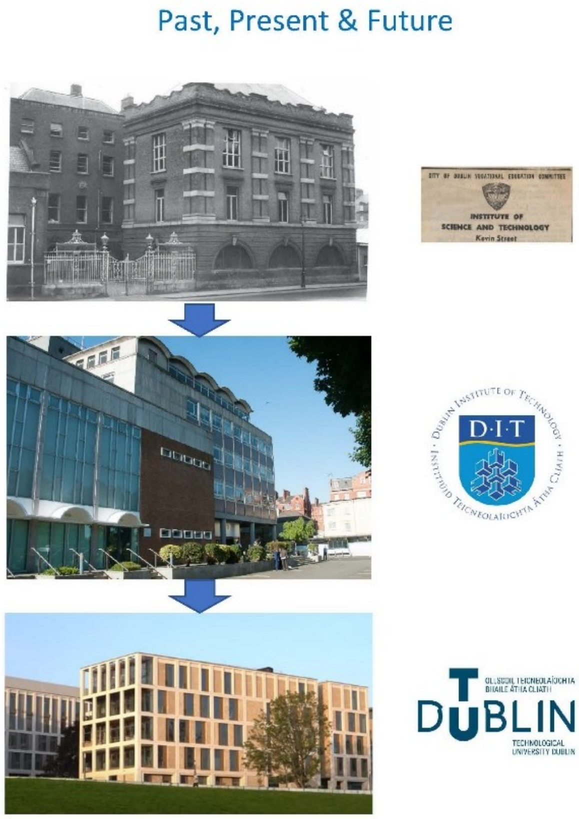


Figure 6: The original building at 18 Lower Kevin St, the current building which replaced it in 1968 and the almost completed Central Quad in Grangegorman

Figure 5: Past graduates visiting Kevin St in February 2020 for our farewell celebration

We're looking forward to the next phase of our evolution when we relocate to our new purpose-built laboratory and teaching spaces in Grangegorman and are eager to welcome industry, employers, chemistry teachers and students to visit these new facilities.

□

Biographies

Prof Declan McCormack is Head of the School of Chemical & Pharmaceutical Sciences at Technological University Dublin. He has been the Scientific Director of the Centre for Research in Engineering Surface Technology (CREST) since its establishment in 2004. He is one of the leads for the "Convene" programme involving TU Dublin and the UCD Innovation Academy which was awarded €17.5m under the HEA funded Human Capital Initiative Pillar 3 in October 2020.

Dr Claire McDonnell has taught organic and medicinal chemistry at Technological University Dublin since 2000. She became an Assistant Head in the School of Chemical & Pharmaceutical Sciences in 2016. She co-edited the book 'Teaching Chemistry in Higher Education' with Prof Michael Seery in 2019.

Conference Reports

Chem-Ed Ireland 2019 at TU Dublin, Kevin St

Claire McDonnell
claire.mcdonnell@TUDublin.ie

The School of Chemical and Pharmaceutical Sciences in Technological University Dublin welcomed 70 participants to the Chem-Ed Ireland 2019 conference on Saturday October 19th in Kevin St. This annual event provides an opportunity to network and to share resources and ideas relevant to teaching chemistry and science in Ireland and featured presentations and workshops. Teachers travelled from across the country to participate and the theme for the day was the International Year of the Periodic Table.

The programme included a series of workshops on:

- Microscale chemistry (recognised as a green and sustainable approach).
- Making a colorimeter and using it to analyse facewash.
- Safety guidance for practical chemistry school laboratories.
- Editing and writing Wikipedia pages about scientists from diverse backgrounds.

Claire Murray with a call to action for the Breaking Chemical Bias project

Presentations dealt with a wide range of topics including the 'Breaking Chemical Bias' project (Claire Murray), 'A day in the life of a chemist working in the biopharmaceutical sector' (Felicia Mutuma), 'SciFest science fairs' (Lisa Darley), 'PDST supports for senior cycle' (Enda Carr), 'Development of new Leaving Cert chemistry specifications' (Paul Behan) and 'TU Dublin chemistry research in response to global challenges'. The 'Irish Women in STEM' posters in Irish and English that were distributed at the conference can be accessed in pdf form from the links in this online article; https://www.siliconrepublic.com/innovation/claire-murray-diamond-project-m

Stefanie Herzog opening her keynote lecture

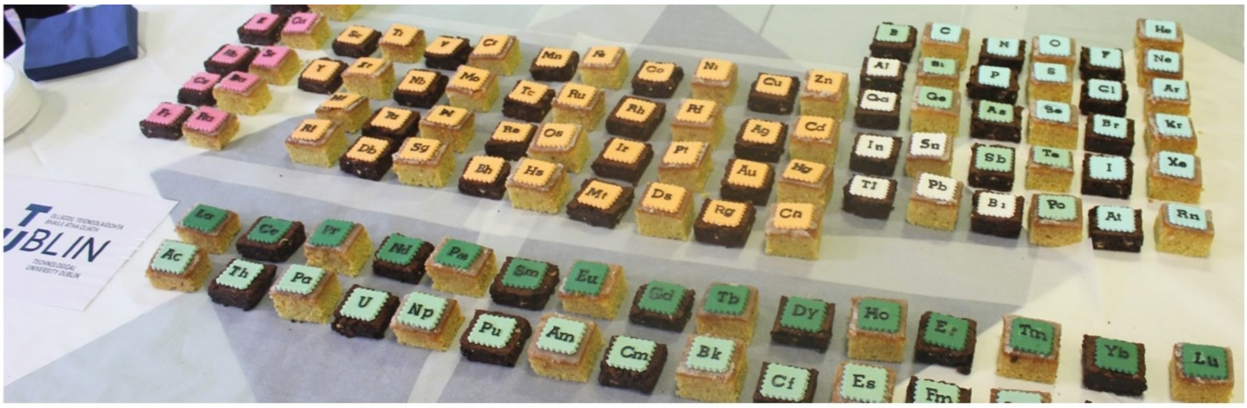
There were two guest speakers. Stefanie Herzog, Leibniz Institute for Science & Maths Education, was sponsored by *Chemistry in Action!* and presented possible teaching approaches that could be used to highlight the International Year of the Periodic Table. Bob Worley was the RSC Edcuation Division invited speaker and he gave a very engaging demonstration lecture on 'Elements to compounds & compounds to elements; the microscale approach.'

Bob Worley giving his demonstration lecture on Microscale Chemistry activities

The Irish launch of the Teach Chemistry resources website for teachers from the Royal Society of Chemistry (see https://edu.rsc.org/teach-chemistry) also took place. To celebrate IYPT, there was an edible periodic table at the coffee break that followed. We're very grateful to James Fox and Shannon Dickson in the TU Dublin School of Culinary Arts & Food Technology and their year 1 Bar & Restaurant Management students prepared this.

Further information on the event is available at the conference website: https://www.dit.ie/chemistry/newsevents/newsitems/headline176516en.html and tweets can be viewed using the hashtags #irishchemed19 and #ChemEdIreland

TU Dublin are looking forward to hosting a future Chem-Ed Ireland at our new Grangegorman campus (due in 2025.)



The edible periodic table at the Chem-Ed coffee break – thanks to the Royal Society of Chemistry for sponsorship and to James Fox and Shannon Dickson in the TU Dublin School of Culinary Arts & Food Technology for preparing it.

□

Reflective: MORSE 2019

Ellen Kampinga

Visiting researcher, Technological University Dublin, originally Chemistry Masters student from University of Groningen, NL

ellen.kampinga@student.rug.nl

Methods of Research for Science Education (MORSE) is an annual one-day conference that provides information to those working in education about the processes of 'doing' educational research. MORSE19 was the second one and the first MORSE was held in 2018.

As an aspiring science education researcher, I attended the MORSE 2019 conference (https://morseportal.wordpress.com/morse19-2/). Since starting my first project in science education this September, I immersed myself in the field not knowing what was out there and what good practice was. This conference came at the right time to give me a feeling of what the science education community looked like in person and it also provided a great chance to understand good practice in educational research methods.

I sat down at a table in the back of the St. Lawrence's Church located on the new Grangegorman campus of TU Dublin. A short chat with the person next to me, Dr. Paul van Kampen, an established researcher in science education at DCU, calmed my nerves down and gave rise to more excitement in meeting new people during the day. A welcome was given by the organizer of the day, Dr. Barry Ryan (TU Dublin). He set the tone for the day, urging us to make sure to meet new people and make connections, while we were also sharing our own experiences.

A view of the interactive sessions at MORSE19

Dr. Paul Grimes (DCU) gave the first talk of the day on discourse analysis. I was already interested in this talk due to his article on discourse analysis. Paul described how lecturers can focus on student interaction and make links to how argumentation and sense-making works; this sounded like the opposite of my university experience. The session involved a short workshop analyzing a typical conversation between students dissecting a problem. Applying discourse analysis gives great insight in how knowledge and understanding of concepts are built. The number of meanings you can assign to 'yeah', only proves that discourse analysis is an art form.

Next up was Dr. Sinead Loughran (DkIT). Her talk about content analysis involved a personal insight for me. Her motivation to move into content analysis was based on her personal traits. Relating her slightly introvert nature, her love of bar charts and her background in virology, led to her being the perfect person to work on content analysis. Since data analysis can be a long and lonely process and yet you get to make beautiful bar charts at the end, made her uniquely qualified. I thanked her in the break for showing me that my unique personality can be my strength and a powerful motivation for performing research.

After the break we continued with Dr. Jason Comerford (Ennis Community School), a secondary school teacher, outlined his use of thematic networks. We received samples of negative teacher-experiences to analyze, from which it was clear to see that giving blame to the negative nature differs strongly. As Paul named it, the reasons vary from blaming 'me, them or the universe', and this inspired me to never blame the universe again! At our table we all noticed that the experiences were so emotional, with some of the teachers blaming themselves quite harshly. It does put a great perspective by comparing third-level and second-level teaching.

The day continued with a speaker with a business background, Dr. Fionnuala Darby (TU Dublin). She presented work from a current publication, (http://ebooks.iospress.nl/volumearticle/50613), part of her doctorate work, which focused on a powerful visualization method she uses in her teaching. *Photovoice* is a way to convey a message using a photo accompanied by a caption or a description. By using this as an assignment for students, she proved the power of this method as a photo tells a thousand words. I was moved by the example of letting students photograph a place on campus where they felt the least included. Captions like: 'I stepped into this room for the first time to take this picture, I don't feel included here', hurt your heart a bit. This method can be used in a wide range of assignments, for example in labs to photograph methods that students find easy to use, or still need to master. As a starting researcher this talk really showed the width of opportunities, even in other disciplines, and how research can be multimedia in nature too. I will try and keep an open and creative mind like Fionnuala showed us.

After a lunch break, we continued to the conference with the keynote speaker: Prof. Michael Seery (University of Edinburgh). Working from his experience as the editor of *CERP*, he led a workshop on what constitutes a good article for *CERP*, emphasizing that we must start thinking about publishing immediately. We did a reverse experiment in constructing a research question after an experimental and theoretical framework are given. Comparing the different questions showed us how every theoretical framework needs a different research question. Showing a common pitfall in constructing research in reverse, I had a very interesting process of achieving a research question with my workshop partner Dr. Ronan Bree. We worked on self-determination theory which focuses on people's motivation for high-quality learning. Wording of a question is key, as it usually describes a feeling for the topic. I encountered this myself in my project and was surprised to find how natural synonyms and possibilities came to mind now, a great affirmation of a skill learned.

A talk by Dr. Jennifer MacMahon (UL) followed after a short coffee break, discussing the essence of statistics and dependence of variables. She used the digital quiz tool *Mentimeter* for several questions about variables. What struck me most was that she highlighted the importance of the sample of population used in research. A common pitfall is choosing a convenient sample, yet this is great advice for a starting researcher.

Last but not least, Adriana Cardinot, a PhD student from the NUIG talked about her work with a fundamental research method: observation. She quickly explained all relevant influences and how it takes determinism and skill to make correct observations. The room was then tasked with observing a picture of a classroom setting for one minute, after which we had to write down as many observations as possible. A discussion concluded that we saw the same things in general, but very different in detail, proving that observation is highly personal unless well structured. I found this talk very striking, since I am going to use observation in my research. Adriana definitely introduced the simplicity and the beauty of this method for new researchers like myself and armed us with useful resources. (https://www.wiley.com/en-ie/Research+in+Psychology:+A+Practical+Guide+to+Methods+and+Statistics,+2nd+Edition-p-9781405125260)
A good tip was to keep repeating important features noticed during observation in order to catch recurring trends.

The day was concluded by the organizer, Dr. Barry Ryan, and we were all invited for informal refreshments, where I joined some of the speakers and a number of attendees for informal conversation. We discussed the Irish educational system in great detail and I got to share my own experiences in response.

Reflecting on my first MORSE, and speaking with many returning *MORSErs* (first was in 2018), a recommendation for the future MORSE sessions would be to keep it biannual, as attendance had dropped since MORSE18. A smaller number gives great intimacy among the community but it limits the reach of contributions.

In conclusion, the information gained at MORSE 2019 will help me shape my view of the science education community and the work that is currently being done. I certainly have enjoyed feeling like part of this community, which can be a daunting feeling as a new researcher. The conference also informed me about the bar to reach within the field, which is not as unreachable as I perceived it to be. Perhaps in the future I will present my work at MORSE and I will be assured to know that the audience will be supportive and curious. Based on my own experience as a beginning researcher, I can recommend attending no matter if you are only getting to know the field or if you are already an expert. The conference proved to be more than just sharing work, rather it was about creating future work through collaborations or inspirations.

□

Biography

Ellen Kampinga is a Chemistry master student at the University of Groningen, NL. As an aspiring science education researcher, she was on ERASMUS-exchange at the Technological University of Dublin for a project on Digital Learning Tools and VLE use among lecturers.

Science curriculum development in the USA and Ireland:

Lessons Learned as a Chemistry Education Post-Doctoral Research Associate at Michigan State University

Aishling Flaherty
Lecturer in Science Education, University of Limerick, Limerick
Aishling.flaherty@ul.ie

Introduction

I am a Lecturer in Science Education at the University of Limerick. In this role, I direct the Professional Master of Education with Science Programme, lead science pedagogy modules to pre-service science teachers and carry out science education research. I took up this role in July 2019 following my time as a Post-Doctoral Research Associate in Professor Melanie Cooper's lab at Michigan State University (2018-19). For the purpose of *this CinA!* article, I will reflect on my experiences of chemistry education research in the US and Ireland.

The Chemistry Education Research Landscapes in the US and Ireland

The Research Groups

Chemistry education research in the US and Ireland are in some ways, two very different worlds. When I was completing my PhD, I was just one of a small number of individuals in Ireland pursuing a PhD in chemistry education. There were not many more doing what I was doing in the United Kingdom either. Given that there was only a small number of us, our identities in the research community grew from the type of research we pursued. When we would first meet at conferences, we would typically ask each other's names before our conversations swiftly veered into discussions about our respective research interests. I enjoyed learning about how and why individuals chose specific projects to pursue. Most of the time, these reasons were vested, personal interests in specific and almost random topics.

It is different in the US. When I went to my first US-based conference in Maine in 2015, a Gordon Research Conference, I was firstly asked my name. Then, I was asked what research *group* I was affiliated with. I did not know how to exactly respond to such a question initially. I was not technically affiliated to a research group in Ireland. I just did research with chemistry laboratory demonstrators and I liked thinking about psychological empowerment literature. These research interests stemmed from a conclusion I arrived at about improving learning in the undergraduate laboratory during my final year undergraduate project. From meeting other American PhD students, I soon began to get a gist of what it meant to be a science education PhD student in the US.

The make-up of chemistry education research in the US consists of prolific research groups, located in universities, led by an Assistant, Associate or Full Professor of Chemistry Education. Sometimes these are within a science department and sometimes in education. These groups identify by their Professor and the type of research they all pursue together as a group. For example, the *Stowe Group* is Professor Ryan Stowe's research group at the University of Wisconsin-Madison and this group researchers the design, analysis, and refinement of high school and college learning environments that help students explain and model phenomena in terms of atomic/molecular interactions. The *Popova Group* is Professor Maia Popova's research group at the University of North Carolina at Greensboro and this group researches the development of organic chemistry students' representational competence. Comprising of researchers at both post-graduate and post-doctoral, these groups work to achieve the shared research visions and goals of the group.

Coming from a small country with a handful of PhD science education research students, let alone chemistry education PhD students with their own individual research agendas, the prevalence of these research *groups* in the US was to be the first chemistry education cultural phenomenon that I experienced in my travels between Ireland and the US. If someone achieves entry into one of these groups towards obtaining a PhD, often the aim and objectives of their PhD are already determined and fully mapped out by their leading Professor. Effectively, they avoid months (or years!) of dabbling in literature trying to find gaps or unique positionings on things. They are surrounded by like-minded individuals who have already developed significant expertise in the very area that they are doing a PhD on. As a result, the PhD projects that are produced from these groups of expertise are exceptional because from day one, they are subject to very high standards of academic integrity and rigor. These groups produce exceedingly good research which has been critiqued at length by their own group members before any viva voce examination occurs.

When comparing the paths to chemistry education PhD in Ireland and the US, I appreciate the autonomy that doing a chemistry education PhD in Ireland afforded me more than anything. I wasn't affiliated to a group of researchers in Ireland, but I still count my lucky stars that I was fortunate enough to have had Dr. Anne O'Dwyer (Lecturer in Science Education, Mary Immaculate College) as my primary PhD supervisor. If I proposed an idea to Anne in the early days of my PhD, she always encouraged me to take my thinking on it a step further. She gave me the space and confidence to pursue a PhD that reflected my own personal teaching and learning philosophies. Together we moulded the project that is now an artefact of our working relationship. I remember being so proud of my project when I finished because I felt it represented the development of my thoughts under Anne's supervision about chemistry education over a period of four years. It represented a body of work that I was afforded total control over what direction it travelled. I could, and did choose to do something different, something that was unique to my background and interests.
(Example of a paper produced from my PhD:
https://pubs.rsc.org/--/content/articlehtml/2017/rp/c7rp00051k)

Granted, not all chemistry education research groups in the US set out prescribed projects for new graduate students to pursue for their PhD. However, from what I witnessed in the US, it was rare for a graduate student to start a chemistry education PhD with a blank canvas. The Irish chemistry education research landscape may be relatively small, but it granted me an academic freedom which I now realise was exclusively priceless.

Evidenced-Based Science Curricula Reform

Figure 1: Professor Melanie Cooper and *the author*

After I graduated with my Chemistry Education PhD, I joined Professor Melanie Cooper's research group at Michigan State University. Professor Cooper is a cornerstone of the chemistry education research world. After being awarded with her Chemistry BSc. in 1975, MSc. in 1976, and PhD in 1978 from the University of Manchester, Professor Cooper took up a faculty position with Clemson University in South Carolina. She became the first tenure-tracked Professor of Chemistry education to be installed in a chemistry department in the US. She is now Lappan-Phillips Professor of Science Education at Michigan State University, where she and her group carry out research on the development and assessment of evidence-based curricula in order to improve the teaching and learning of chemistry within large-enrolment undergraduate chemistry courses. This kind of research, and moreso, the appetite for this kind of research, was to be my second chemistry education cultural phenomenon that I experienced in my travels between Ireland and the US.

There is a pronounced, steely determination and commitment in the US to inform the development of science curricula using evidence-based research. The Cooper Group have spent years continuously informing the development of undergraduate general and organic chemistry curricula based on the research they conduct on student learning in these modules. Starting with their first evidence-based curricula, the general chemistry module *Chemistry, Life, the Universe and Everything* (CLUE) set out to tackle the prevalence of more traditional general chemistry modules that seeks to 'cover' a huge amount of content (Figure 2). Instead, CLUE seeks to progress students' understanding of just three core ideas (Structure, Energy and Properties), by engaging students in scientific practices such as developing and using models, formulating arguments from evidence, and developing scientific explanations (Cooper & Klymkowsky, 2013).

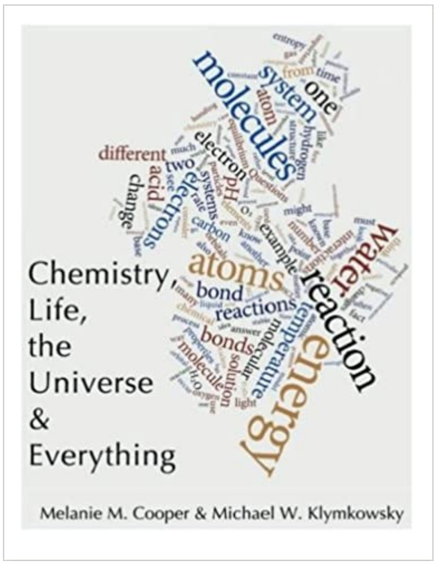


Figure 2 Cover of Chemistry, Life and the Universe & Everything

Several studies evidence the efficacy of CLUE in supporting student understanding and reasoning about a range of chemical phenomena. For example, compared to students taught in traditional courses, CLUE students can use chemical structure to predict chemical and physical properties at least one semester earlier (Underwood, Reyes-Gastelum, & Cooper, 2016); CLUE students are significantly more likely to indicate correctly that intermolecular forces occur between, rather than within small molecules (Williams, Underwood, Klymkowsky, & Cooper, 2015); and finally, CLUE students are significantly more likely to draw Lewis structures and derive the important information contained within Lewis Structures (Cooper, Underwood, Hilley, & Klymkowsky, 2012). Additionally students from a CLUE general chemistry course are better able to reason about acid base reactions, and this improvement is continued through two semesters of a traditional organic chemistry course (Crandell, Kouyoumdjian, Underwood, & Cooper, 2018).

While I was at Michigan State, the organic chemistry version of CLUE (OCLUE) was being delivered. It was during this time that Melanie and her team published the first OCLUE paper detailing its features and underpinning philosophies (Cooper, Stowe, Crandell, & Klymkowsky, 2019). The excitement at the time for this chemistry education revelation was palpable. Attending OCLUE lectures and assisting in the correction of OCLUE mid-term and terminal exams afforded me acute insight into the inner workings of a well-researched, carefully considered organic chemistry course. OCLUE echoes many of the pedagogical tenets of CLUE, however, in addition, there is a more pronounced alignment with the pedagogical tenets set out by the national science education policy; '*Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas*'.(Figure 3)
https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts

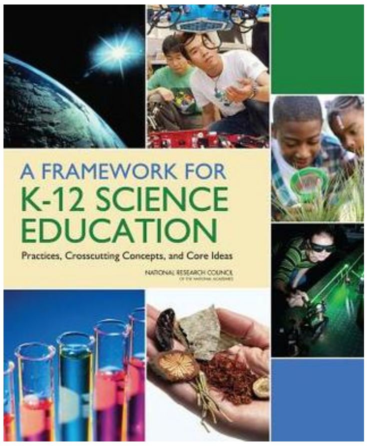


Figure 3: The Framework for K-12 Science Education

The Framework for K-12 Science Education sets out an ambitious pedagogical ambition for science educators to help guide students to reach a series of 'performance expectations' which comprise the Next Generation Science Standards (NGSS). The NGSS is similar in format to a curriculum, but there is a deliberate veer away from the use of 'curriculum' in the NGGS. Instead, the term 'performance expectations' are used to indicate what students should achieve in science for each year of study, from ages 5/6 to 17/18. The Framework's pedagogical ambition, entitled *3-Dimensional Learning for Science Education (3DL)*, seeks to harness the power of integrating three dimensions of science education: disciplinary core ideas, scientific and engineering practices, and crosscutting concepts.

My awe of the NGSS & 3DL Science Education

As someone who went through the process of becoming a science teacher in Ireland, teaching science in Irish secondary schools and an Irish university and eventually coming to think about how we research and learn about science education in Ireland, when I got to grips with the depth, rigor, clarity and structure of the NGSS and 3DL science education in the US, I was quite flabbergasted to say the least. I remember my awe when learning that primary and secondary science curricula (and in some instances, third level science courses too!) in the US are all carefully aligned to build upon students' understanding of just three or four big ideas which are to the core of each discipline. The NGSS sets out exactly what students should be expected to know and do in each domain for every single year of their education – from ages 4 to 18+! These performance expectations carefully build upon each other and connections to other performance expectations across the discipline are clearly noted for teachers. Teachers are supplied with evidence statements for each performance expectation to inform the development of summative assessments, clarification statements for each performance expectation to relieve ambiguity, examples of how students can meet these performance expectations and assessment boundaries to indicate to teachers the depth at which any single performance expectations will be assessed.

An example here would be:
"*Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]*"

Teachers are then provided with a detailed explanation of how these performance expectations build on students' understanding of the core ideas of "Structure & Properties of Matter" and "Chemical Reactions" , how they can engage students in the "Constructing Explanations and Designing Solutions" scientific practice towards reaching this performance expectation and how they can help students to view this science through the cross-cutting concept (lens) of "Patterns".

In the context of the Junior Cycle Science specification, where students are not actually expected to develop any robust understanding of the concept of bonding in the Chemical World strand and the word "vague" was used 78 times in an ISTA report on teachers' response to the new Junior Cycle Science Specification, I was more than impressed by the NGSS and 3DL pedagogy to say the least.

To be very honest, in light of the level of rigour, detail and clarity that has been invested into the development of the NGSS and 3DL science pedagogy, and its positive reception by science teachers, it is surprising and alarming that we ended up with a reformed junior cycle science specification that has been widely criticised for offering *"a dumbed down"* a common level paper with a *"minimal amount of physics and chemistry and almost no questions on experiments"* (https://www.irishtimes.com/news/education/junior-cert-science-science-teachers-slam-new-common-level-paper-1.3921110). The learning outcomes are stated to be "*vague*" without indication of the depth that each should be treated (https://www.irishtimes.com/news/education/teachers-say-junior-cycle-science-curriculum-being-dumbed-down-1.3912762) and that *"Teachers are confused and frustrated and are drowning in a plethora of documentation and meaningless jargon"* (https://www.irishtimes.com/opinion/letters/problems-with-junior-cycle-reform-1.4112423). To add to these frustrations, the drawbacks of implementing a learning outcome specification were all pre-empted by the Hyland report in 2014 (Hyland, 2014).

The Funding

While it is all very well and good for me to be able to point to different curricula and associated approaches, I am cognisant that the science education community in the US is vast, and extremely well-funded. Every year, the US allocates $64 million to research K-12 STEM education, $63 million to research undergraduate STEM education and $35 million to research STEM education at all levels through the National Science Foundation (NSF). That is astronomical funding when compared to the Irish context. By comparison, the equivalent body to NSF, Science Foundation Ireland, allocates no money to science education research or curriculum development.

A critique of Irish funding for SER

Science education research is not a priority for the government of the Republic of Ireland, or its statutory body with responsibility for assigning scientific research funding, Science Foundation Ireland (SFI). The SFI sets out 15 priority areas for research which typically include medical devices, food for health, marine renewable energy and sustainable food production and processing. The 2019 SFI annual report notes that these priority research areas *"reflects the results of the National Research Prioritisation Strategy adopted by government following input from the research community, the enterprise sector and research funding departments and agencies"* (SFI, pg. 83). It is clear from this that science education research is not actually recognised as research in the eyes of SFI, and thus, it is not supported. This concern was raised by Peter Childs as long ago as 2004 (Childs, 2004.) https://www.irishtimes.com/opinion/letters/investment-in-science-education-1.1136940), to no effect.

Further in the 2019 SFI report, just €5 million (from a total of €188 million!) was spent on 47 STEM education projects, which were mostly outreach projects. The SFI is prioritising how many individuals can be *'reached'*, as the report boasts that 3,492 teachers from 299 primary schools received continuous professional development, 620 primary schools received awards and that "*SFI-funded researchers' education and public engagement increased 26% with 2,299 activities reported in 2019*".

Investing in research on improving how students learn science at primary, secondary and tertiary levels of education is clearly not a priority for the SFI or the government. Although it should be noted that a small number of science education PhDs are funded through IRC and previously through IRCSET. One must wonder whether all of the fantastically ambitious science research targets set out by the Irish government will actually be achieved when there is no commitment to researching the improvement of science education. Then again, is it even any wonder that we have ended up with a junior cycle science specification that is being ferociously criticised in the public sphere, with its demands weighing heavily on the hearts and minds of all teachers and students?

Michigan: All things chemistry education aside

Figure 4: The Cooper Research Group, June 2019

Apart from all-things chemistry education, Michigan will always have a special place in my heart. Although the prospect of -42ºC winter days may seem somewhat undesirable now, I do have fond memories of tucking under the Michigan snow blanket for months on end. I will never forget the white-washed landscapes, or the silent gasp of breath I took when I first heard the words "*don't breathe in and don't expose your skin"* during an emergency 6am cold-weather phone alarm. I will never forget watching little drops of condensation forming on the inside handle of my patio door as it froze right through from one side to the other, or throwing a glass of boiling water into the cold air only for it to instantly turn to snow as it fell back down to earth. I will never forget taking a big deep breath at the edge of Lake Michigan (larger half of Lake Michigan–Huron), which in terms of surface area, is the largest body of fresh water in the world.

Figure 5: Michigan State at -32 degrees Celsius!

I will never forget the warm autumn hues of the great Michigan forests or my awe at passing an 80,000-seat stadium on campus every day. I will never forget the hustle and bustle of the sorority and fraternity houses that surrounded campus and all the Greek letters that went with them, or learning that the coach of the Michigan State football team is paid more than the president of the university! I will never forget seeing the first blades of green grass when the snow first started to melt away, or the deafening silence of the university corridors during Spring Break. But more than anything, I will never forget the care and kindness shown to me by Professor Melanie Cooper and her amazing team. They opened my mind to an entirely new dimension of what it means to learn science, and research it. They took me in as one of their own and from the other side of the Atlantic, they continue to remind me that learning a thing or two about chemistry education or chemistry education research was not the only thing I gained from my time in Michigan.

References:

Cooper, M., & Klymkowsky, M. (2013). Chemistry, Life, the Universe, and Everything: A New Approach to General Chemistry, and a Model for Curriculum Reform. *Journal of Chemical Education, 90*(9), 1116-1122

Cooper, M., Underwood, S., Hilley, C., & Klymkowsky, M. (2012). Development and assessment of a molecular structure and properties learning progression. *Journal of Chemical Education, 89*(11), 1351-1357.

Crandell, O. M., Kouyoumdjian, H., Underwood, S. M., & Cooper, M. M. (2018). Reasoning about Reactions in Organic Chemistry: Starting It in General Chemistry. *Journal of Chemical Education, 96*(2), 213-226

Cooper, M., Stowe, R., Crandell, O., & Klymkowsky, M. (2019). Organic Chemistry, Life, the Universe and Everything (OCLUE): A Transformed Organic Chemistry Curriculum. *Journal of Chemical Education, 96*(9), 1858-1872.

Hyland, A. (2014) The design of Leaving Certificate science syllabi in Ireland: an international comparison. Report for the annual conference of the Irish Science Teachers' Association. https://ista.ie/wp-content/uploads/2016/03/The-Hyland-Report-_0.pdf

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC.: The National Academies Press. https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts

Underwood, S., Reyes-Gastelum, D., & Cooper, M. (2016). When do students recognize relationships between molecular structure and properties? A longitudinal comparison of the impact of traditional and transformed curricula. *Chemistry Education Research and Practice, 17*(2), 365-380

Williams, L. C., Underwood, S. M., Klymkowsky, M. W., & Cooper, M. M. (2015). Are Noncovalent Interactions an Achilles Heel in Chemistry Education? A Comparison of Instructional Approaches. *Journal of Chemical Education, 92*(12), 1979-1987.

□

University Chemistry in Ireland 1980-2020

Peter E. Childs
Dept. of Chemical Sciences, University of Limerick, Limerick peter.childs@ul.ie

Introduction

Chemistry at 3rd level in Irish universities has changed considerably over the last 40 years. The number of Chemistry-related courses, number of Chemistry graduates and number of Chemistry PhDs have all increased over that period, along with an increase in the number and percentage of students going on to 3rd level. (A separate article by Marie Walsh in issue #115 looked at the situation in the RTC/IoT sector.) The very first ChemEd-Ireland conference in 1982 looked at the state of chemical education in Ireland at that time and Henry Lyons surveyed chemical education at second and third level (Lyons, 1982). In 1994 I wrote a paper with Julian Ross on Chemical education in Ireland for a European body (Figure 1), which became the European Chemistry Thematic Network (ECTN) (Childs & Ross, 1994). I also wrote articles with surveys of chemical education in Ireland in for *Teaching Chemistry around the World* (Childs, 2010) and for *Irish Chemical News* in 2014 (Childs, 2014). In addition, I have written an annual report on Chemical Education in Ireland for the EuCheMS Division of Chemical Education from 1998 to 2018. These articles enable me to look back over the past 40 years. Box 1 shows the abbreviations used in this article.

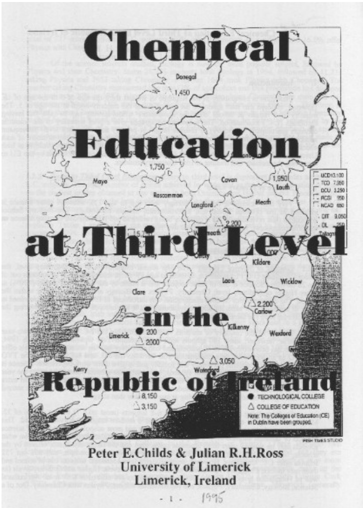


Figure 1: Report published in 1990 for ECTN (Childs & Ross, 1995)

Box 1: Key to abbreviations used

TCD Trinity College Dublin
UCD University College Dublin
RCSI Royal College of Surgeons of Ireland
NUIG NUI Galway
MU Maynooth University
UCC University College Cork
UL University of Limerick
DCU Dublin City University
TUD Technological University Dublin
IoT Institute of Technology
TCE Thomond College of Education
HEA Higher Education Authority
DES Department of Education and Skills
OECD Organisation for Economic Cooperation and Development

General educational scene in Ireland

Ireland has seen major demographic change since 1980: a high birth rate dropped off and then increased again, and is now in decline again. The bulge in numbers is going through second level at the moment, and will have a major impact at third level in the coming years. A high proportion of the population, which has increased since 1980, are in fulltime education, although Ireland spends the second lowest % of GDP in the EU on education (Figure 2).

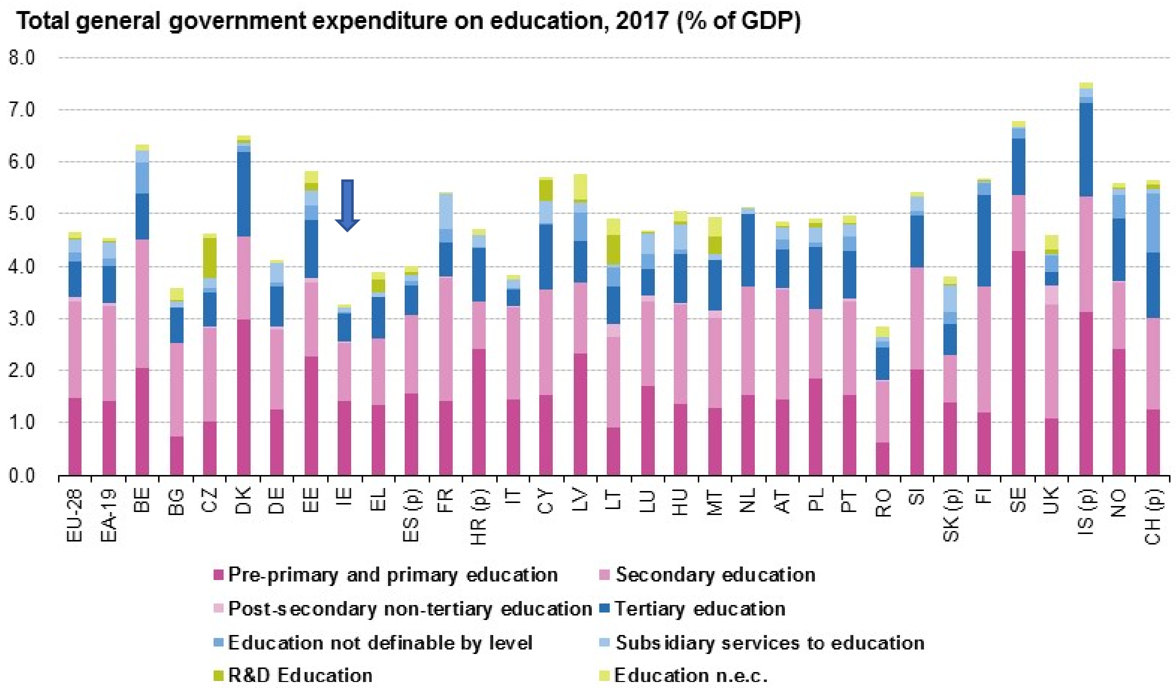


Figure 2: Government expenditure on education in Europe in 2017 (Eurostat)

Ireland has one of the lowest expenditures (see above) as a % of GDP in Europe, just pipping Romania for bottom place! A recent summary of education in Ireland from the EU is given below.

Education and Training in Ireland: impact of EU membership
https://ec.europa.eu/ireland/about-us/impact-of-EU-membership-on-Ireland_en

- EU funding has helped improve education standards in Ireland and created great opportunities for studying abroad through Erasmus +, the EU's study and work abroad programme.
- The EU's financial instrument for investing in people, the European Social Fund (ESF), is contributing €610 million from the EU budget into Ireland's €1.15 billion Programme for Employability, Inclusion and Learning (PEIL) that runs until 2020.
- Since Ireland joined the EU, Irish agencies and State bodies have received almost €6.5 billion in investment from the ESF.
- The EU's Youth Guarantee initiative is providing jobs, training and education for Europe's under 25s. Ireland will receive €68 million under the initiative to increase employment, social inclusion and skills for young people.
- Irish citizens choosing to work or study abroad can have their Irish qualifications recognised throughout the European Union under the European Qualifications Framework.
- In 1973 when Ireland joined the EU just 27,135 Irish students reached third level education. By 2015 that figure had increased to 173,649.
- Around 50,000 students from Ireland have participated in Erasmus + since 1987. A survey carried out by the Higher Education Authority (link is external) in 2016 found that Erasmus+ students coming to study or work in Ireland are responsible for encouraging almost 25,000 visitors here, adding €14 million to the Irish economy.

- According to an Erasmus impact study, a third of Erasmus students have a partner of a different nationality, compared with 13% of those who stay home during their studies. A total of 27% of Erasmus students meet their long-term partner while on Erasmus. The European Commission estimates that around one million babies are likely to have been born to Erasmus couples since 1987.
- Funding of almost €170 million has been allocated to Ireland for Erasmus+ 2014-2020. Over 77% of this will be allocated to education and training, with a further 10% focussing on youth.

For a current assessment of education in Ireland see *Education at a Glance*, 2019 (OECD, 2019).

Table 1 shows the change in numbers in education over the years and Table 2 shows full-time enrolments at third level in 2017. It is clear that the most dramatic change is in third level enrolment, where over 60% of the age cohort now go on to some form of third level education.

Table 1 Enrolments in education in Ireland (DES)

Level/Year	1980	1990	2000	2010	2019
Primary	551,319	543,744	439,560	509,652	567,772
Second	297,747	343,045	345,384	318,522	362,899
Third	40,613	68,165	119,991	161,840	191,324

Table 2: Full time third level enrolments by programme, student type, 2017 (DES)

2017	Irish	International	Total
Undergraduates	144,530	15,293	159,823
Postgraduates	16,183	7,636	23,819
Total	160,713	22,929	183,642

It can be seen from Table 1 that there has been a steady increase in enrolments at third level – up 371% since 1980. This is a massive change compared to the enrolments at primary and second level, which have gone up and down with the birth rate. The bulge going through second level at present will result in a predicted increase by 2030 at third level of between 16 and 27%, depending on the scenario used (Figure 3). This will have massive cost, space and staff implications for third level. At third level in 2017 overall, 12.5% of students were international, but at postgraduate level 32% were international students. I suspect that this percentage will be higher for STEM students. The current Covid-19 crisis will have a major impact on third level due to the loss of funding from overseas students as well as a loss of students, especially postgraduates, who underpin Ireland's research efforts. Ireland has followed other developed countries in becoming increasingly dependent on overseas students to fill the graduate schools, especially in STEM subjects.

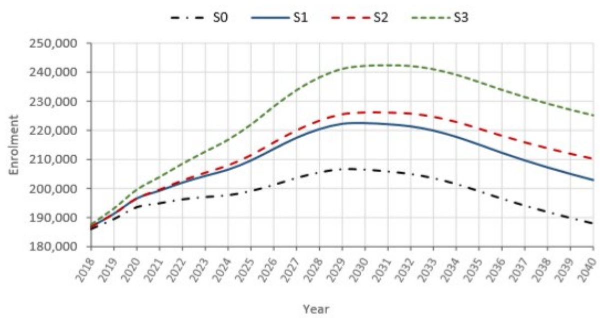


Figure 3: Enrolment at third level under different scenarios 2018-2040 (https://www.education.ie/en/Publications/Statistics/projections/projections-of-demand-for-full-time-third-level-education-2018-2040.pdf)

Changes at third level from 1980 to 2020

Here are some of the main changes that have occurred since 1980:

- Increase in the total third level numbers: 40,613in 1980 to 191,324 in 2019 (Table 1).
- Increase in the percentage going on from school to 3rd level (20% in 1980 to 64% in 2019).
- Increase in the number of Chemistry or Chemistry-related degrees at third level, especially in the IoT sector.
- Introduction of a Common Framework of Qualifications in 2003, with levels 6 to 10 being covered at third level.
- Increases in the number of level 8 (honours) degrees offered by RTCs/IoTs, as well as research degrees (PhDs and Masters.)
- Change from denominated to undenominated (common entry) science degrees, with specialisation later, usually after year 1, in many institutions.
- Introduction of courses with forensic or pharmaceutical in the title to attract students and reflect the job market in the pharmachem industry.
- Increase in the size and research activity of Departments of Chemistry.
- Increase in the annual output of Chemistry Masters' (taught and by research) and PhDs.
- Increase in the number and percentage of non-nationals in research schools.
- Increase in the research funding for postgraduate work, mainly through SFI, and growth in specialised research centres e.g. SSPC in UL, CRANN in TCD.
- Rise in the international research rankings for Irish Chemistry (and related science subjects).
- Overall decrease in rankings of Irish universities in recent years due to reduced funding, although they still rank highly.
- An inflation of grades in universities and IoTs so that much higher percentages are getting 2.1 and 1st class degrees than in earlier years. (see https://www.thejournal.ie/grade-inflation-irish-third-level-4757371-Aug2019/)

In 1980 there were 5 universities in Ireland – TCD and 4 NUI colleges, together with National Institutes of Higher Education (NIHE) in Limerick and Dublin. By 2020 there were 9 universities – in 1989 the NIHEL and NIHED became universities, UL and DCU respectively. In 2019 DIT and IT Tallaght became TUD and RCSI achieved university status. Several consortia of IoTs are in the process of applying for university status. One set of university rankings (by THE) is given in Table 3 below. TCD consistently has the highest Irish ranking in several international rankings, but all 9 universities are in the world top 1000, with 5 in the top 350. This is a major achievement for a small country with low investment in third level education. However, in recent years the top universities have dropped down the league table. The relative rankings differ depending on the criteria used in the different rankings.

Table 3: International ranking of universities
https://www.timeshighereducation.com/student/best-universities/best-universities-ireland

Ireland Rank 2020	WUR Rank 2020	University
1	164	Trinity College Dublin
=2	201-250	Royal College of Surgeons in Ireland (RCSI)
=2	201-250	University College Dublin
4	251-300	National University of Ireland, Galway
=5	301-350	Maynooth University
=5	301-350	University College Cork

7	501-600	University of Limerick
8	601-800	Dublin City University

Five Irish universities make it into the top-ranking Chemistry departments in the world (Table 4) (https://www.usnews.com/education/best-global-universities/search?region=&country=ireland&subject=Chemistry&name=). The top placed one in Ireland is TCD with a world ranking of 343 and a score of 49.1. The top university (MIT) has a score of 100!

Table 4: World rankings in Chemistry

#343 Trinity College Dublin (49.1)
#377 Tie University College Dublin (47.2)
#473 Tie University of Limerick (41.5)
#635 Tie Dublin City University (34.5)
#650 Tie NUI Galway (33.9)

In recent years Ireland has gone up the global rankings overall and in particular subject areas, as shown below, which is a major achievement for a small country.

Table 5: Global scientific rankings (2017)

10th in global scientific ranking
2nd in Animal & Dairy
2nd Immunology
2nd Nanotechnology
3rd Material Science
4th Agricultural Science
5th Chemistry
6th Basic medical research
6th Computer science

In addition, 28 Ireland-based researchers can consider themselves the cream of the crop in 2019 following the publication of this year's Web of Science Group list of highly cited researchers. The list aims to identify scientists and social scientists who produced multiple papers ranking in the top 1pc by citations for their field and year of publication, typically seen as demonstrating great influence among their scientific peers. Globally, 6,216 researchers have been included from 60 nations, with 40% (2,737 researchers) based in the US. The institute with the highest concentration of leading authors is Harvard University with 203 researchers. (https://www.siliconrepublic.com/innovation/ireland-elite-scientists-2019)

Ireland has the highest % of people with third level qualifications in the EU as shown in Figure 4 and Table 6. Ireland has the highest % of graduates in Europe in the 25-64 age range i.e. in the workforce, and in 2017 produced the highest % of S&T graduates (Figure 5). 40% of PhDs were in S&T (Figure 6). The figures in Table 6 show the massive expansion of higher education in Ireland in the last 25 years.

Table 6: 3rd level qualifications (25-64)

1992	2001	2017
17%	24%	46%

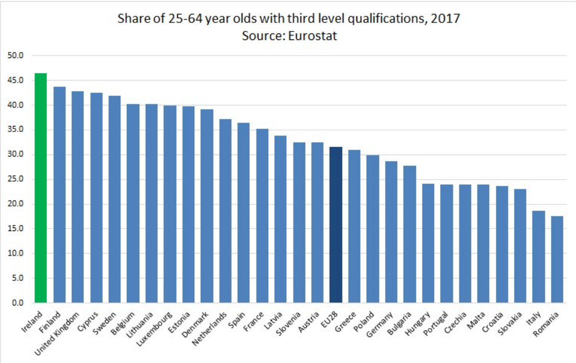


Figure 4: Share of 25-64 year olds with 3rd level qualifications (2017) (Eurostat)

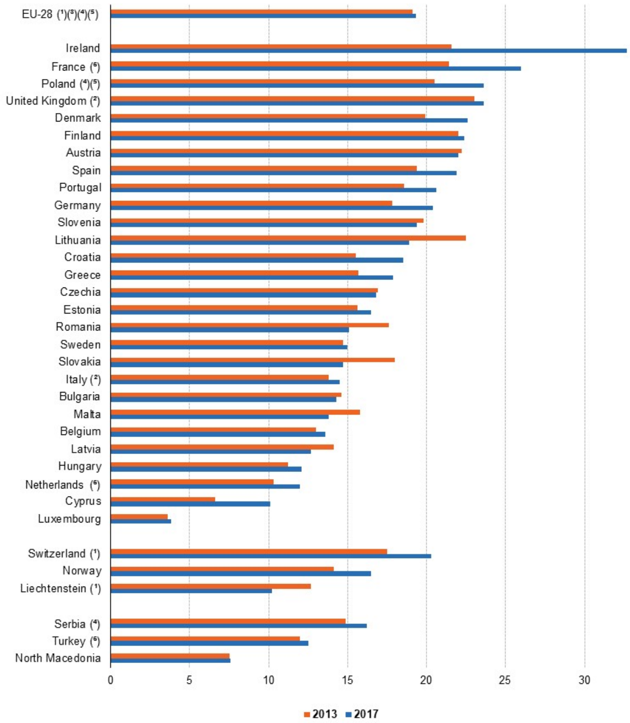


Figure 5: Graduates with science and technology qualifications in 2013 and 2017 (Eurostat)

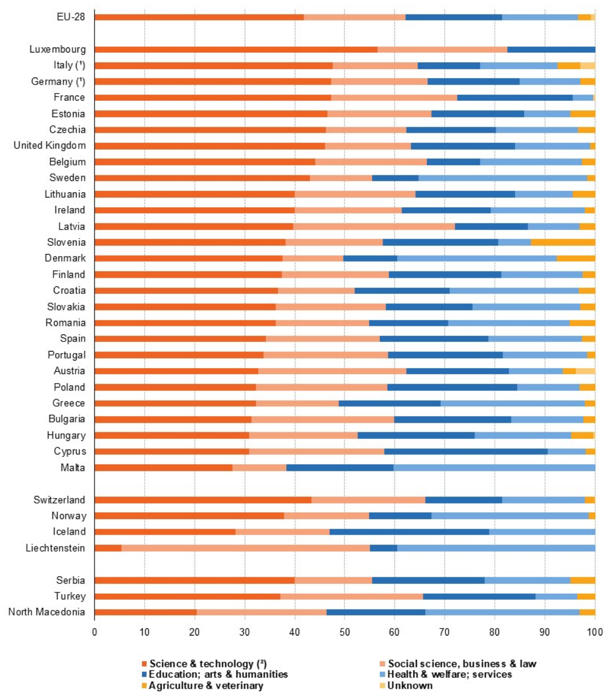


Figure 6: PhDs by field of study 2017 (Eurostat)
https://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_personnel#Science_and_technology_graduates

These data show the development of third level and STEM education in Ireland over the last few years. The availability of well-qualified people has been a major factor in the growth of the high-tech industries in Ireland since 1980, especially the biopharmachemical industry. This industry not only provides good jobs for Chemistry and Biochemistry graduates and Chemical/Biochemical Engineers, but is also at the core of Ireland's economic success and its ability to weather the 2008, and I also hope the 2020 economic recession.

Chemistry Departments in Irish Universities

In issue 115 Professor Tony Pembroke has given a detailed history of the development of Chemistry Sciences at the University of Limerick, as this is the home of *Chemistry in Action!* There are strong and active Chemistry departments at all 9 universities and in Table 7 below the research activity is indicated by the number of postdoctoral fellows, number of postgraduates (which includes masters and doctoral students) and the number of PhDs graduated in 2019.

Table 7: Strength of Chemistry departments in Irish universities

University	No. academic staff	No. of postdocs	No of postgrads	No of PhDs (2019)
TCD⁺	23			
UCD	26	24	105	19
RCSI	8	12	18	3
NUIG	16	21	55	17
MU	13	6	25	4
UCC	24	19	92	5
UL*	28	48	109	21
DCU	18	15	57	10
TUD⁺	24			
Totals	180	145**	461**	79**

* Note that Chemical Sciences at UL includes Industrial BioChemistry, Chemical and Biochemical Engineering and Environmental Science; ** Incomplete figures; $^{+}$ data not returned

From the figures above, it is clear that Chemistry research is in a healthy state at Ireland's universities. In 1987 30 PhDs were produced, in 1994 62 and in 2019 over 79. There was also an increase in the number of postgrads enrolled from 419 in 1994 to over 461 in 2020. (The postgrad figure includes both masters' and PhD students.)

The following tables were supplied by the HEA, courtesy of David Shiels. Table 8 shows undergraduate and postgraduate degrees in the universities and Table 9 in the IoTs from 2008 to 2018. It should be noted that NUIG has no data from 2011 to 2015, so the figures are somewhat incomplete. The IoTs produce more undergraduate awards overall but more honours degrees are produced in the universities. One of the major changes in the IoTs over the past 40 years has been the increasing numbers of Level 8, honours degree courses, so that their output is now comparable with that of the universities (e.g. in 2018, 268 in the universities versus 179 in the IoTs). Research is stronger and has a longer history in the universities and they produce more postgraduate degrees, PhDs and Masters' (taught and by research). There is also a very uneven production of e.g. PhDs in the universities (max. 93, min. 35 per year). This may reflect changes in the available funding for postgraduate work and the size of departments.

One of the indications of the strength of research in Chemistry at third level in Ireland is the annual Postgraduate Colloquium, sponsored by the Institute of Chemistry of Ireland. In 2019 it was hosted jointly by RCSI and TUD. There were 45 student speakers, and a total attendance of 184 from 14 institutions (including Queen's University, Belfast). This is a showcase of Irish Chemistry research.

Table 8: Chemistry Graduates by Sector and Award Type in Universities 2008-2018 (HEA)

Sector/Award Type	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Universities - total	**308**	**279**	**263**	**290**	**259**	**304**	**357**	**360**	**355**	**397**	**360**
Undergraduate	**218**	**168**	**165**	**178**	**157**	**172**	**222**	**235**	**255**	**295**	**268**
Honours Degrees	218	167	165	178	157	172	222	235	255	295	268
Ordinary Degrees		1									
Postgraduate	**90**	**111**	**98**	**112**	**102**	**132**	**135**	**125**	**100**	**102**	**92**
Masters Research	10	10	6	13	6	13	17	8	10	16	8
PhD	62	83	51	83	83	90	93	82	69	45	35
Post Grad Dips.										1	
Postgrad Certs.					10	2				1	
Postgrad Diplomas Pre16/17	3	1	7			1	3				
Taught Masters	15	17	34	16	3	26	22	35	21	39	49

Table 9: Chemistry Graduates by Sector and Award Type in Institutes of Technology 2008-2018 (HEA)

Sector/Award Type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Institutes of Technology - total	**148**	**178**	**148**	**131**	**152**	**181**	**306**	**339**	**368**	**368**	**382**
Undergraduate	**138**	**167**	**138**	**121**	**142**	**166**	**261**	**313**	**350**	**326**	**339**
Certificate										3	
Higher Certificate									65	54	46
Honours Degrees	35	50	72	47	57	83	125	164	164	169	179
Ordinary Degrees	53	50	39	31	51	48	85	95	121	100	114
Undergraduate Certificates Pre16/17	50	67	27	43	34	35	51	54			
Postgraduate	**10**	**11**	**10**	**10**	**10**	**15**	**45**	**26**	**18**	**42**	**43**
Masters Research	2	2	2		2	2		1	2	2	
PhD	6	9	8	9	8	7	8	7	4	2	2
Postgrad Diplomas									4	7	5
Postgrad Certificates							10				10
Postgrad Diplomas Pre16/17				1			6	3			
Taught Masters	2					6	21	15	8	31	26

The gender breakdown of research degrees in shown in Table 10 and of honours degrees in Table 11. These data show a slight excess of males over females for research degrees (53 % in 2018) and an excess of females over males in honours degrees (53 % in 2018) in the universities. There is a larger excess of females over males in honours degrees in the IoTs (61 % in 2018). This reflects the small excess of girls over boys taking LC Chemistry and reinforces the point that Chemistry is the equal opportunity science, compared to Biology (excess of girls) and Physics (excess of boys).

Table 10: Gender Breakdown of Research (Masters Research and PhD) Graduates (HEA)

Sector/Gender	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Universities	**72**	**93**	**57**	**96**	**89**	**103**	**110**	**90**	**79**	**61**	**43**
Female	33	44	29	39	41	53	52	39	38	27	20
Male	39	49	28	57	48	50	58	51	41	34	23
Institutes of Technology	**8**	**11**	**10**	**9**	**10**	**9**	**8**	**8**	**6**	**4**	**2**
Female	7	3	1	3	9	6	4	2	1	3	1
Male	1	8	9	6	1	3	4	6	5	1	1
Grand Total	**80**	**104**	**67**	**105**	**99**	**112**	**118**	**98**	**85**	**65**	**45**

Table 11: Gender Breakdown of Honours Degree Chemistry Graduates (HEA)

Sector/Gender	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Universities	**218**	**167**	**165**	**178**	**157**	**172**	**222**	**235**	**255**	**295**	**268**
Female	107	74	90	92	87	94	113	118	131	147	143
Male	111	93	75	86	70	78	109	117	124	148	125
Institutes of Technology	**35**	**50**	**72**	**47**	**57**	**83**	**125**	**164**	**164**	**169**	**179**
Female	16	32	43	19	36	56	66	85	96	89	109
Male	19	18	29	28	21	27	59	79	68	80	70
Grand Total	**253**	**217**	**237**	**225**	**214**	**255**	**347**	**399**	**419**	**464**	**447**

Grade inflation at third level

Concern has been expressed for many years about grade inflation in third level colleges (as well as at Leaving Certificate level.) Grade inflation describes the increase of top grades being awarded year by year without any major change in the student population. In fact, student numbers have expanded to over 50% of the age cohort, so that we are recruiting students lower down the ability curve than in the past. All things being equal, we would then expect a smaller percentage to get the higher classes of degrees and a longer tail. But at the same time, the results data show that the percentage of students getting higher degree grades (1st and 2.1) has actually increased. With bigger classes and a greater spread of ability, you would have expected the opposite. The most recent article on this was published in ***TheJournal.ie*** in August 2019. The two figures below refer to First class degrees (Figure 7) and 2.1 degrees (Figure 8.)

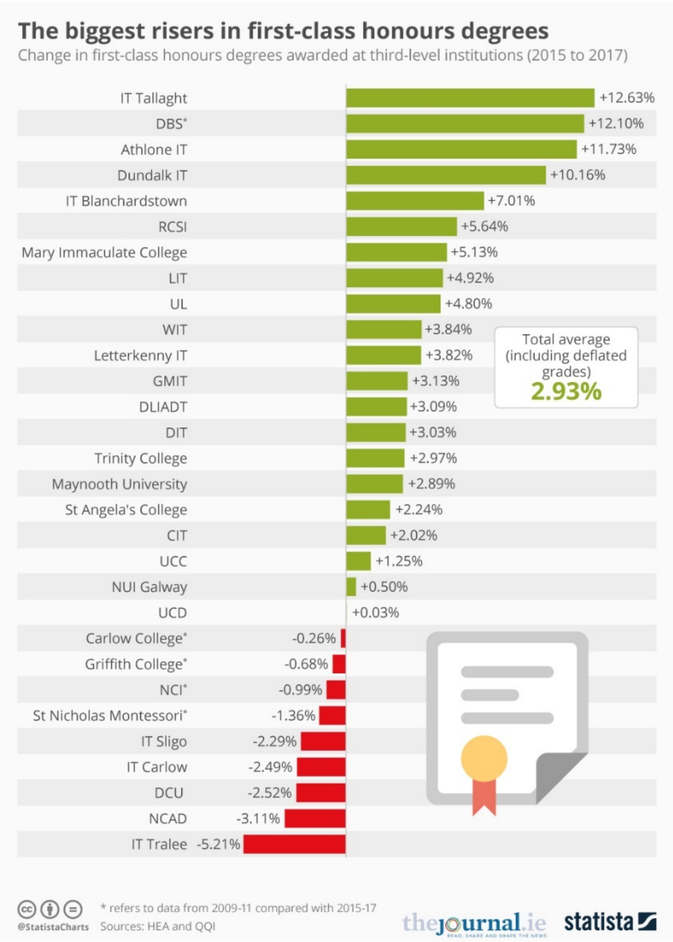


Figure 7: Change in first class degrees 2015-2017 (https://www.thejournal.ie/grade-inflation-irish-third-level-4757371-Aug2019)

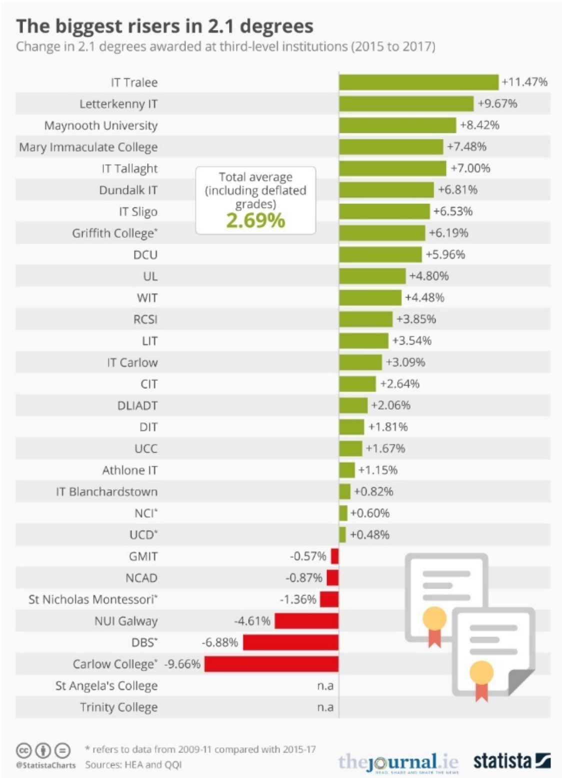


Figure 8: Change in 2.1 degrees (2015-2017) (https://www.thejournal.ie/grade-inflation-irish-third-level-4757371-Aug2019/)

This may seem like a trivial academic problem, but it has implications for the quality of Irish degrees and their reception by employers. The use of external examiners is supposed to ensure equality of standards across the third level system. A similar phenomena of grade inflation has been observed in the UK at both A-level and degree level, and is a matter of concern there also. There is pressure on institutions and academics to reduce standards and raise grades, as numbers of students increase, but this is a worrying long-term development.

Growth in the number of Chemistry courses

One of the major changes in Chemistry education over the last 40 years has been in the number and type of courses on offer. The menu of level 8 honours degrees has greatly expanded, especially in the RTCs, now IoTs. This is evidence in tables 12,13 and 14 below.

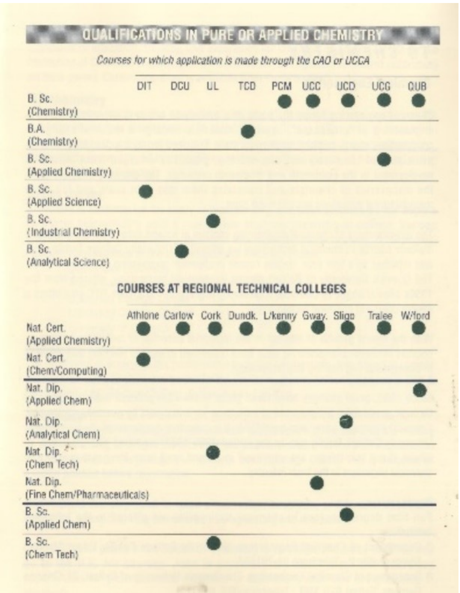
In 1982 at the first ChemEd-Ireland conference, Dr Henry Lyons gave a talk on 'Chemical education in the South' and in it he surveyed the state of third level as well as second level Chemistry education. He gave a table for graduate and postgraduate courses in Chemistry in 1982, which is reproduced below Table 12).

Table 12: Graduate and postgraduate courses in Chemistry, Pure and applied (Lyons, 1982)

College/university	Degrees offered
NUI colleges	
University College, Cork	B.Sc., M.Sc,, Ph.D.
University College, Dublin	B.Sc., M.Sc,, Ph.D.
University College, Galway	B.Sc., M.Sc,, Ph.D.
St Patrick's College, Maynooth	B.Sc., M.Sc,, Ph.D.
Trinity College, Dublin University	B.A. (mod), M.A., Ph.D.
N.C.E.A. awards	
National Institute for Higher Education (Limerick)	B.Sc. in Industrial Chemistry
National Institute for Higher Education (Dublin)	B.Sc. in Analytical Science
Thomond College of Education	B.A. in P.E. with Chemistry
Regional Technical College, Cork	B.Sc. in Chemical Technology
Regional Technical College, Sligo	B.Sc. in Environmental Science
College of Technology, Kevin Street, Dublin	B.Sc. (TCD) Grad R.S.C. (part-time)

In 1990 in the second of two National Chemistry Weeks (held in 1988 and 1990), a table of available Chemistry courses was included (Table 13). There was very little change from 1982 with mostly just one Chemistry course per institution: degrees in the universities and certificates/diplomas in the RTCs (as they were then.)

Table 13: Chemistry courses available in 1990 (Childs, 1990)


QUALIFICATIONS IN PURE OR APPLIED CHEMISTRY

Courses for which application is made through the CAO or UCCA

	DIT	DCU	UL	TCD	PCM	UCC	UCD	UCG	QUB
B. Sc. (Chemistry)					●	●	●	●	●
B.A. (Chemistry)				●					
B. Sc. (Applied Chemistry)								●	
B. Sc. (Applied Science)	●								
B. Sc. (Industrial Chemistry)			●						
B. Sc. (Analytical Science)		●							

COURSES AT REGIONAL TECHNICAL COLLEGES

	Athlone	Carlow	Cork	Dundk.	L/kenny	Gway.	Sligo	Tralee	W/ford
Nat. Cert. (Applied Chemistry)	●	●	●	●	●	●	●	●	●
Nat. Cert. (Chem/Computing)	●								
Nat. Dip. (Applied Chem)									●
Nat. Dip. (Analytical Chem)							●		
Nat. Dip. (Chem Tech)			●						
Nat. Dip. (Fine Chem/Pharmaceuticals)						●			
B. Sc. (Applied Chem)							●		
B. Sc. (Chem Tech)			●						

If we compare these offerings with Table 14, we can see the changes of degree titles and the vast increase in the number of courses and institutions offering honours (level 8) degrees in 2020. In 1980 only TCD and the four NUI colleges were allowed to award degrees; when NIHEL and NIHED became universities in 1989, they were given their own individual degree awarding powers. They were the first new universities since the founding of the State in 1922.

In 1982 the RTCs only offered national the Certificate in Science (Applied Chemistry), validated by the NCEA, and National Diplomas in Science (see Marie Walsh's article in this issue).

In 2003 Ireland introduced a National Qualifications Framework to standardise awards across the educational system (https://www.qqi.ie/Articles/Pages/National-Framework-of-Qualifications-(NFQ).aspx), thus rationalising the awards offered. Certificates were level 6, diplomas became ordinary degrees (level 7) and honours degrees level 8. Masters were level 9 and PhDs level 10. See Figure 9 for the complete range of NFQs.

Figure 9: National Framework of Qualifications

Comments on Table 14: It is clear from the data that courses in the IoTs in general have lower points than similar courses in universities. All students apply to university or IoT through a common system, the Central Applications Office, in operation since 1978. The cut-off points are a combination of demand (popularity) versus the number of places. Students have traditionally preferred to accept offers in universities, although they can apply for up to 10 courses at both degree (level 8) and certificate/ordinary degree (level 6/7). High demand courses like pharmacy have the highest points; courses with fewer places will have higher points. The introduction of a maths bonus in 2012 has increased the points on many courses, as well as increasing the percentage taking honours maths from 15% in 2011 to 31% in 2018. (https://www.thejournal.ie/cao-points-maths-4187925-Aug2018/) Ireland has the advantage compared to many countries in that everyone takes maths to the end of formal schooling, which is a good foundation for STEM courses.

There is also the TCD effect – courses in TCD tend to have higher points, though an exception is the general entry Science course, where UCD has higher points. In general students prefer to study in the universities and thus their points are higher than in the IoTs, for similar courses. The label Pharmaceutical is now more common than Chemistry and applied Chemistry has dropped off the table.

Table 14: Honours Degrees (level 8) in Chemistry or related subjects (2019)
(see http://www2.cao.ie/points/l8.php)

College	Course title	Points 2019
IoTs		
AIT	Pharmaceutical Science	328
CarlowIT	Science (options)	261
CIT	Chemical and Pharmaceutical Engineering	432
	Physical sciences (common entry)	279
	Pharmaceutical biotechnology	388
	Analytical Chemistry + QA	288
DKIT	Science (options)	300
GMIT	Chemical and pharmaceutical sciences	307
	Science (options)	325
	Forensic science and analysis	300
LetterkennyIT	Science (options)	302
LIT	Forensic and Pharmaceutical sciences	335
	Drug and medical product analysis	236
	Biotechnology and biopharma. sciences	379
ITSligo	Science (options)	308
	Pharmaceutical science and drug development	339
	Forensic investigation and analysis	306
ITTralee	Pharmaceutical science (options)	342
WIT	Science (options)	302
	Pharmaceutical science	298
Universities		
DCU	Analytical science	446
	Chemical and Pharmaceutical sciences	488
	Science (common entry)	454
	Science education	424
TUD (DIT)	Science (common entry)	464
	Analytical Chemistry	341
	Science and nanotechnology	312
	Chemical science and medicinal Chemistry	420
TUD (Tallaght)	Pharmaceutical science	261
	DNA and forensic analysis	300
RCSI	Pharmacy	565
TCD	Chemical sciences	499
	Physical sciences	510
	Pharmacy	567
UCD	Science (options)	521
	Chemical engineering (option in Engineering CE)	511
NUIG	Science (options)	400
	Biopharmaceutical Chemistry	510
UL	Chemical and biochemical engineering	456
	Biological and chemical sciences (common)	412
	Science and teacher education (Physical Science)	382
	Science and teacher education (B with P, C or Ag)	478
MU	Pharmaceutical and biomedical Chemistry	452
	Science (options)	308

PhD research and funding

There has been a sea-change in Irish science since 2000. ICSTI (Irish Council for Science and Technology Innovation) recommended big investment in STEM research and this led from 2000 to massive funding in third level facilities through PRTLI (Programme for Research in Third Level Institutions) and then through SFI (Science Foundation Ireland). There was an emphasis on applied science, over and against basic (blue skies) science, and on building a research infrastructure through setting up major research centres, involving collaboration between third level institutions and industry. The centres have been very successful and this investment in research and innovation has resulted in Ireland moving up the international league tables for research and innovation. Many STEM-based companies have been spun out of Irish research since 2000. (Research and innovation in Ireland, https://ec.europa.eu/ireland/news/key-eu-policy-areas/research-and-innovation_en)

A number of meetings and publications have looked at the role of PhDs in the Irish economy, and specifically at Chemistry. (see *The role of PhDs in the smart economy* Forfas 2009, http://www.sciencecouncil.ie/media/asc091215_role_of_phds.pdf

These led about 10 years ago to the introduction of the four-year structured PhD by coursework and research, rather than the previous three-year PhD by research only. The introductory year is now devoted to courses in transferable skills and subject-based courses, worth a total of 30 ECTS. Many of these are run collaboratively between institutions by distance learning.

Research into teaching and learning

I have been involved for many years with the EuCheMS Division of Chemical Education, whose brief is to encourage the teaching and learning of Chemistry in Europe, with a strong emphasis on Chemistry Education Research (CER). The European Chemistry Thematic Network (ECTN) was a very successful EU-funded initiative to link universities across Europe and encourage development of teaching and learning in Chemistry at third level across Europe, through projects and working groups. Several Irish universities were partners in ECTN. A very successful forum for sharing ideas on the teaching and learning of Chemistry at third level, Variety in Chemistry Education, started in York and is still held every year, now jointly with Physics. An Irish version, Irish Variety in Chemistry Education, was launched and the 11th iViCE was held in TUD in April 2019. The iViCE conferences attract about 30 participants but it is noticeable that most of the speakers and attenders come from the IoTs sector. The EuCHeMS Division of Chemical Education runs a biannual conference on Research in Chemical Education, ECRICE, and in 2005 started a European Variety in Chemistry Education conference, Eurovariety (in 2013 this was held in UL.) Over the years there has been regular participation from Ireland at both these conferences. The Chemistry Education Research Team at TUD is probably the strongest group researching third level Chemistry and have won several RSC Higher Education awards. Michael Seery, ex TUD, is now Professor of Chemical Education at the University of Edinburgh and Editor of the influential RSC journal *Chemistry Education Research and Practice*, CERP. All these initiatives are welcome signs of an interest in improving teaching and learning of Chemistry through research, however, they are sporadic and sparse in the chemical education landscape.

Research into the teaching and learning Chemistry at third level in Ireland is less common than research into second level, but the groups at TUD and DCU have done good work in this area. The good attendance at the Irish Variety in Chemistry Education conferences, especially from the IoTs, is encouraging but only a small fraction of Chemistry staff shows any interest in chemical education. Unlike the U.K., where several universities now have Professors of Chemical Education located in the Chemistry Departments e.g. Leeds, Edinburgh, Reading, Southampton, East Anglia. Our own Michael Seery had to leave Ireland for Edinburgh to get such a post. We will know that chemical education is taken seriously in Ireland when such posts are created in Irish Chemistry departments and an evidence-based approach is taken to improving teaching and learning.

Challenges and opportunities in university chemical education

The discussion and statistics above show that Chemistry at university level in Ireland is in a fairly healthy state, and it is much stronger than it was 40 years ago. However, there some challenges and opportunities to identify.

1. Reduced resources and funding together with an increase in student numbers means stretched facilities for teaching and learning. This problem will increase as the student bulge moves into third level, increasing numbers by up to 30%.
2. The danger of dumbing down courses and grade inflation needs to be addressed to maintain the standards and reputation of Irish degrees, in the light of increased student numbers.
3. Increased funding for research has been available since 2000, but often with an applied, short-term focus in a small number of areas. Basic (blue skies) research also needs to be funded.
4. Research schools in STEM subjects are increasingly filled with overseas students (typically 30% or more). Such students are financially profitable for universities and keep research groups functioning, but there is a long-term danger in not recruiting enough national PhD students.
5. The pressure to get grants and publish in prestigious journals, as the main criteria for hiring and promotion, had devalued the role of teaching as a primary function of universities. Good teaching is also a key factor in recruiting students into research groups. Academics see research as their most important function and don't always want to teach, weakening the undergraduate experience.
6. There has been a welcome emphasis on teaching and learning in higher education in recent years, but it would be good to see specific appointments in Chemistry departments of staff dedicated to improving teaching and learning, as is the case in a number of UK universities.
7. Compared to 40 years ago there has been a proliferation of Chemistry and Chemistry-related courses in universities and IoTs, with no overall planning relating to national needs. Competition between universities and IoTs has led to duplication of courses and pressure to fill places. This has meant universities taking weaker students to fill places and IoTs struggling to fill their courses (as evidenced by the points required). Drop-out rates are high in STEM courses, more so in IoTs than in the universities.
8. There is a need for more research into the problems of teaching and learning Chemistry at third level, as has happened in other countries, and for academic staff to take more interest in and apply what has been learned from research to make teaching Chemistry more effective.

At the end of Henry Lyons' article in the Proceedings of the first ChemEd-Ireland conference in 1982, he raised four issues relating to third level Chemistry in Ireland. I asked him to respond to each of these in 2020. (Lyons, 1982).

1. Academic staff receive little if any training for teaching/lecturing and very few have industrial experience.

Very little seems to have changed over the past 40 years - PhD followed by Postdoctoral research leading on to academic careers.

UL and DCU have some staff with industrial experience and there are a few national (IRCSET) and EU (e,g Marie Curie) programmes which promote movement between industry and academia.

Advances in technology have had an enormous effect on teaching and Learning e.g. online courses and novel modes of delivery.

2. Universities and other colleges area experiencing difficulties in replacing outdated equipment and purchasing additional equipment during the current economic recession. (1982!)

This has greatly improved mainly due to initiatives and programmes from SFI and Enterprise Ireland.

3. Academic research and publications seem to gain more recognition for promotion of lecturing staff than teaching, especially in the universities.

As far I know this is still the case and likely to remain so.

4. Up to now there has been little real research in chemical education in Ireland - just surveys and analysis of statistics.

I have no up-to-date or statistical information on this issue, but I suspect that there has been some improvement.

Conclusion

This overview of Chemistry at university level is necessarily incomplete, as not all the statistics were available, but it does give a picture of a very healthy sector. Chemistry departments are thriving at undergraduate level and in research, in terms of funding, facilities and numbers of postgraduate students and postdoctoral researchers. This is due partly to government initiatives like PRTLI and SFI, but also due to success in wining funds from European bodies (e.g. FP7, H2020, ERC). However, the reduction in funding for third level due to the 2008 recession has caused major problems, combined with increased student numbers, and this year the effect of Covid-19, whose knock-on effects can only be guessed at. The conversion of IoTs into Technological Universities will change the higher education landscape, although there is already competition for students and funding between the two sectors. Research in Irish Chemistry departments is strong, as evidenced by the annual ICI Colloquium, but I would like to see more interest and investment in improving the teaching and learning of Chemistry at third level. Teaching is often seen as second-best after research, whereas it ought to be seen as the prime activity of any Chemistry department. The quality of Chemistry graduates is important for supplying research schools but also for employers. A positive view of the undergraduate experience in Chemistry encourages students to continue their careers, but also filters down into second level by providing important role models. Chemistry does not have a gender problem, as there is a small majority of girls in LC Chemistry and women in undergraduate Chemistry courses, and also in Chemistry graduate schools. As with many countries, the percentage of women academics decreases as you ascend the academic ladder, and this is a problem to be addressed. Chemistry is the equal opportunity science and many Irish graduates, male and female, have been very successful in industry and business, in Ireland and overseas, as well as in academia. The history of Chemistry in Irish universities is long and distinguished, back to the 19th century and before, and long may it continue.

References

Childs, P.E., (1990), *Chemistry the creative science*, Limerick: National Chemistry Week

Childs P.E. and Ross, J.R.H., (1994), 'Chemical education at third level in the Republic of Ireland', Limerick: University of Limerick (unpublished paper for ECTN)

Childs, P.E., (2010), 'Republic of Ireland', in *Teaching Chemistry around the World*, ed. Bjőrn Risch, Műnster: Waxmann, 310-332

Childs, P.E., (2014) 'The state of chemical education in Ireland', *Irish Chemical News*, Issue 1, 15-25 Available online at http://www.Chemistryireland.org/docs/news/Irish-Chemical-News-2014-Issue-1.pdf Accessed 27/2/20

Lyons, H.J., (1982), 'Chemical education in the South', *Chemistry Education in Ireland*, Proceedings ChemEd-Ireland 1982, Limerick: Thomond College, p. 20-28

OECD (2019), "Ireland", in *Education at a Glance* 2019: OECD Indicators, OECD Publishing, Paris. DOI: https://doi.org/10.1787/e6f76052-en
https://www.oecd-ilibrary.org/docserver/e6f76052-en.pdf?expires=1583857964&id=id&accname=guest&checksum=DA08F12B5C6E22DA1D1FD21600D4E3D1

Editor's note: I asked several distinguished academic chemists to write this overview and nobody had time to do it. This overview is thus not as authoritative as it might have been, but is a start towards a more comprehensive history of teaching and research in third level Chemistry in Ireland.

Biography

Dr Peter Childs came to Ireland in 1978 to teach Chemistry at Thomond College of Education, TCE (later amalgamated with the University of Limerick). He had previously taught Chemistry at Makerere University, Kampala, Uganda (1970-76), and also worked at the Universities of York and Leeds before coming to Ireland. He started Chemistry in Action! in May 1980 and the ChemEd-Ireland conferences in 1982, both still going strong. He retired in 2009 from teaching Inorganic and Environmental Chemistry at UL, and has continued to edit Chemistry in Action!, supervise research students, organise Teachers' Workshops and be involved in several European projects and in the EuCheMS Division of Chemical Education (1998-2018). He is a former President of the ISTA and of the Institute of Chemistry of Ireland, and was Chair of the EuCheMS Division of Chemical Education from 2002-2008.

□

How science outreach has changed in Ireland over the years

Martin McHugh and Sarah Hayes
SSPC, University of Limerick, Limerick
martinmchugh@ul.ie and sarah.hayes@ul.ie

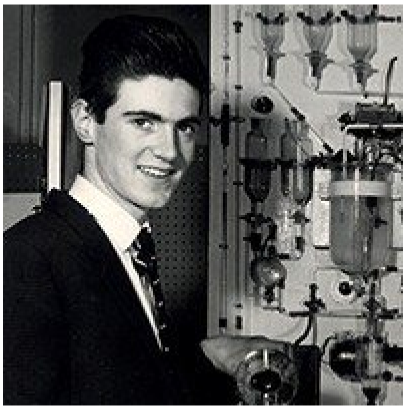
Introduction

In recent years, outreach has woven its way into the fabric of science education. Throughout Ireland, science is no longer bound by the four walls of the classroom. As a subject, science permeates every facet of our lives and outreach provides an outlet for engagement with science at every occasion. Science outreach programmes offer a chance to emphasize the relevance of STEM fields to broader society, while raising awareness about the impact these fields have on people in the community. Today, organisations from universities to industry and schools play a vital role in bringing science to society. However, outreach has not always been the constant presence that it is today. Over the years, the landscape has changed rapidly.

The origins of scientific outreach in Ireland

Rev Dr Tom Burke and Tony Scott, the founders of the BT Young Scientist and Technology Exhibition. https://btyoungscientist.com/awards-students/rev-tom-burke-bursary/

The origins of scientific outreach can be traced back to 1965 with the inaugural Young Scientist's Exhibition (YSE), now known as the BT Young Scientist and Technology Exhibition (Kennedy 2014). The first exhibit was designed to bring American style science fairs to Irish audiences. It was the brainchild of UCD physics researchers Tom Burke and Tony Scott (BT 2020a). Over the years, the event has evolved into the premiere science outreach event in Ireland with 40,000 visitors flocking to the RDS to see the 500 plus student exhibitions over 4 days. Expanding on their success, BT also hosts a Primary Science Fair for younger students (BT 2020b).



John Monaghan, the inaugural winner of the Young Scientist's Exhibition. John's project developed an apparatus to demonstrate various chemical reactions that take place during digestion. https://btyoungscientist.com/about/john-monahan-1/

Science Weeks

The Young Scientist Competition stood alone as a landmark event for scientific outreach for many years. The next phase of science outreach in Ireland began with the inception of a national Science Week. Originally pioneered by Forfás, 'Information Technology and Science Week' took off in 1996 (Ahlstrom 2015). The aim of the week was to raise awareness among the public around the benefits of science to society. A year later in 1997, it was renamed 'Science Week' and a combined 50 events were held between voluntary groups, business, industry and third level institutes (Ahlstrom 2015). Today, Science Week is run by Science Foundation Ireland (SFI). Unrecognisable from its early days, the week is now a promotional engine for science on a regional and national level with 1200 events annually (Newstalk 2019).

Science Week represented a 'big bang' moment for science outreach in Ireland, as regional events started to take off. Festivals of Science are now commonplace throughout science week with a total of 12 in 2019, but the first was established in

1998, the Galway Science and Technology Festival (Murray 2019).

Testing out race cars at the Medtronic stand at the Galway Science and Technology Festival. Over 20,000 people attended the event in 2019. https://www.galwayscience.ie/event/galway-science-and-technology-festival-launch-2019-programme/

The appetite for regional science has continued to grow and SciFest was created in 2006. Developed by science teacher Sheila Porter, the event brings local science fair events to secondary students around Ireland with winners progressing onto the national finals. Working with over 4000 Irish students, it is an inclusive event that has proved to be an excellent steppingstone for the BT Young Scientist and Technology Exhibition (SciFest 2020). Following this lead, ESB Science Blast started in 2019 with the goal of regional science fairs for primary school pupils (ESB 2020).

Adam Kelly with his SciFest Award in 2018. He went onto win the BT Young Scientist in 2019 and in the same year, also won the European Union Contest for Young Scientists. In his research, he created a tool that optimises the simulation of quantum circuits in super computers (O'Sullivan 2018). https://www.irishtimes.com/news/science/adam-kelly-16-wins-scifest-2018-for-quantum-computing-solution-1.3692718

The role of SFI in science outreach

The proliferation of these events has been enabled in no small part by SFI. Annually, SFI opens a science outreach funding called the Discover Programme. This opportunistic fund has ignited the imaginations of scientists and innovators around Ireland. In 2019, €5 million was awarded to 47 projects that ranged from school engagement programmes to museum exhibits and a national science communication conference, SCI:COM (Gorey 2019). In addition to this, SFI has embedded outreach as a core aspect of their 17 national research centres. Initially, a cluster of six centres was established in 2012 with each centre mandated to have an Education and Public Engagement (EPE) officer. Their roles are to bring the science from the centre to the public by conducting events and by training and mobilising the centre's research community (SFI 2020).

Science centres

Most developed countries in the world have interactive science centres going back at least 20 years. Several attempts have been made in Ireland to get such a national Science Centre off the ground. An important private initiative was the opening of Ireland's first science museum, the Science Gallery in Dublin. Hosted by Trinity College Dublin, the museum has welcomed 3 million visitors since 2008 (Science Gallery, 2020). The push has been to establish entertaining and engaging experiences where learning also takes place. This drive led to the opening of Irelands first science centre in 2018, the Explorium. The centre uses state of the art equipment to demonstrate scientific phenomena, particularly those in physics related to sport (Explorium, 2020).

The foyer of the Explorium in Dublin with an exhibit on g-forces where visitors get to ride a bike in a hamster wheel. https://www.rte.ie/lifestyle/living/2019/0313/1036124-digital-dad-reviews-a-family-day-out-at-explorium/

Small is beautiful

With the rapid development of science outreach over the years and the success of larger programmes mentioned above, it is easy to forget that the majority of outreach happens at a smaller scale. School visits, science clubs and open days are still the backbone science outreach in Ireland and this work is often conducted on a voluntary basis. This is especially true in industry and in third level institutes where site and lab tours are a regular occurrence for visiting students. Moreover, SMART FUTURES has looked to formalise this type of engagement by working with professionals who want to deliver career talks in schools (Smart Futures, 2020). This trend in continuing with science shows. Traditionally, they have been a part of university outreach programmes belonging to chemistry departments, however, semi-commercial shows are now operating at large scale events. The immensity of work that is conducted has led to 'non formal' activities now being recognised as a pillar of science education in Ireland. Given this, outreach has become an endeavour that is guided by research. Establishing an evidence base for science outreach along with the continued collaborations between scientists, teachers and researchers have been determined as a key factor for continued success (Davison *et al.*, 2008). Moreover, outreach is becoming a prescribed element to many substantive research projects with institutes such as the European Commission (2015) pushing their vision of 'science for the people, by the people'.


Sport: pages 18-23

IRISH TIMES

Looking back, it is hard to have predicted the journey of outreach in Ireland. The single commonality between then and now is that outreach is still driven by a passion for science and education. The sense of community, exploring the unknown and providing moments of inspiration are motivators for providers and audiences alike. Over the years, scientific outreach has gone from strength to strength and long may it continue. In 1980, the only science outreach was the YSE, a lone flower in a desert, but in 2020 (subject to COVID-19), which itself has put science and scientists in the public spotlight, many flowers are blooming in a fertile landscape.

References

Ahlstrom, D. (2015, November 4). From Small Acorn to Giant Oak Tree… Retrieved from https://www.dit.ie/media/update/04-11-2015/151103_irish%20times_science%20week_siobhan%20daly.pdf

BT (2020a). Exhibition History. Retrieved from https://btyoungscientist.com/exhibition-history/

BT (2020b). The Primary Science Fair @BTYSTE. Retrieved from https://btyoungscientist.com/the-primary-science-fair-at-btyste/

Davison, K., Domegan, C., McCauley, V., & McClune, W. (2008). A review of science outreach strategies north and south: with some recommendations for improvement. Centre for Cross Border Studies.

ESB (2020). ESB Science Blast: What is ESB Science Blast. Retrieved from https://www.esb.ie/acting-responsibly/generation-tomorrow/esb-science-blast

European Commission (2015, May 22). Science to the People! Retrieved from https://ec.europa.eu/digital-single-market/en/blog/science-people

Explorium (2020) Explorium Homepage. Retrieved from https://explorium.ie/

Gorey, C. (2019, December 5). Almost 50 projects get access to €5m in SFI STEM outreach funding. Retrieved from https://www.siliconrepublic.com/innovation/sfi-discover-programme-stem-outreach-2019

Kennedy, J. (2014, January 10) Interview with the first-ever young scientist exhibition winner. Retrieved from https://www.siliconrepublic.com/innovation/interview-with-the-first-ever-young-scientist-exhibition-winner-video

Murray, A. (2019, October 29). Inside the Galway science festival that wows thousands with STEM. Retrieved from https://www.siliconrepublic.com/innovation/galway-science-and-technology-festival-2019

Newstalk (2019, November 11). Join the fight against climate change at Science Week 2019. Retrieved from https://www.newstalk.com/news/science-week-climate-change-922769

O'Sullivan, K. (2018, November 9). Adam Kelly (16) wins SciFest 2018 for quantum computing solution. Retrieved from https://www.irishtimes.com/news/science/adam-kelly-16-wins-scifest-2018-for-quantum-computing-solution-1.3692718

Science Gallery (2020) Science Gallery Homepage. Retrieved from https://dublin.sciencegallery.com/

SciFest (2020) SciFest Homepage. Retrieved from https://scifest.ie/

SFI (2020) SFI Research Centres Outreach. Retrieved from https://www.sfi.ie/engagement/sfi-research-centres-outreach/

Smart Futures (2020). Smart Futures home page. Retrieved from https://www.smartfutures.ie/

□

Biography

Dr Sarah Hayes is Associate Director for Academic Partnerships & Public Engagement at SSPC, the Science Foundation Ireland Research Centre for Pharmaceuticals, based at the University of Limerick, Ireland. Sarah is a former physics and chemistry teacher and completed her PhD in science education in 2012 under the supervision of Dr Peter E. Childs, examining the place of science in the Irish Transition Year. Currently, Sarah works with a broad number of stakeholders including academic, industry, and societal partners to enhance collaboration and develop impactful public engagement projects. She conducts research in the area of informal and non-formal learning in science and is involved in two European projects focused on issues of diversity in science.

Dr Martin McHugh is the education and public engagement manager at Science Foundation Ireland Research Centre for Pharmaceuticals (SSPC), based at the University of Limerick, Ireland. Martin is a former science and biology teacher and in 2017 completed a PhD investigating the impact of video technology on student interest and engagement. Currently, Martin develops medicine and health-themed outreach activities for public groups, and he is active in collaborative research investigations into the impact of informal learning environments on participants. His work also entails working with the SSPC research community by helping them communicate their cutting-edge science to the public through writing and presenting.

SSPC
SYNTHESIS AND SOLID STATE PHARMACEUTICAL CENTRE
Innovation Through Collaboration

The SSPC Education & Public Engagement (EPE) team, based at the University of Limerick, focus their efforts on bridging the gap between academia/industry and lay audiences. The outreach programme is broad and varied, targeting pupils, teachers, parents, grandparents and the wider public. We place a particular focus on working with female pupils, those from a disadvantaged socio-economic background, and those living in geographical areas with little access to STEM research and activities. Over the past few years, the EPE team has developed multiple pharma-themed workshops, produced over 100 media interactions, written 10 peer-reviewed publications through our engagement with EU research projects, the most recent being RACE and ARTIST.

□

Ireland and the International Chemistry Olympiad

Odilla E. Finlayson
CASTeL, School of Chemical Sciences, Dublin City University
Odilla.finlayson@dcu.ie

For the last 25 years, Ireland has participated in the International Chemistry Olympiad (IChO), a world-wide competition in Chemistry for second level students, currently involving 80 countries. To date, Ireland has achieved 2 silver medals, 21 bronze medals and 4 honourable mentions in this competition. This is a remarkable achievement for such a small country and the person who has been mainly responsible for this success, until his untimely passing in 2015, is the late Dr Paraic James of Dublin City University.

Early Days

Ireland's participation in IChO began in 1995, when Dr Odilla Finlayson (School of Chemical Sciences, DCU) and Dr Michael Cotter (then School of Education, DCU) attended the 27th IChO in Beijing, China. At that time, DCU was involved in co-ordinating and running the International Programming Competition – again, a competition for second level students - to promote computer programming throughout second level schools. The Rules of participation in IChO require prospective new participant countries to send observers to two editions of the competition directly before they participate fully as a delegation with team members. Therefore, in 1996, Dr Paraic James accompanied Dr Michael Cotter to the 28th IChO in Moscow, Russia.

Figure 1: Medal at 1995 IChO, Beijing, China

Following these two observation years, key issues arising from Ireland's participation became apparent. Firstly, it was decided that Ireland would participate as all-island team, involving schools from both Northern Ireland and the Republic of Ireland. Secondly, the standard of the international competition was very high – certainly at the level of 2nd year undergraduate University level Chemistry. Therefore, a period of intensive training had to be included to prepare students for this level of competition. The students participating in the selection rounds for IChO are mainly in their final year of study in school and preparing for Leaving Certificate or A-level assessments, and thus there is limited opportunity to select and train teams. Please note that the use of the word 'training' is the word that is used in the international competition – here it means an intensive period of teaching and learning Chemistry involving the students and academic mentors.

Since his first involvement, Paraic recognised the interest and potential of the Irish students. Paraic was a gifted teacher and motivator, as well as an outstanding organic chemist. His talent as an academic shone in his organisation of the selection and training of the student teams; he turned each training day into days of discussion about chemistry, whether it was in the classroom or over the evening meals. His enthusiasm for his subject and the students was clearly obvious to all. For many of these students Paraic's guidance at the outset of their career path was pivotal. What is less easy to see, but even more impactful, is the support he gave many of the students in starting their academic careers, especially in instilling confidence in their abilities – being from a small country does not mean that you cannot compete with the international giants.

While I and others were also involved in giving specialist classes in particular topics, the other key individual who was involved for approximately 15 of those years was Professor Wesley Browne. Wesley worked closely with Paraic in training and selecting the final teams and in mentoring the teams while at the competition. Even though Wesley joined the staff in the University of

Gröningen (Netherlands) in 2003, he continued to be involved in acting as an IChO mentor for Team Ireland. for many years. In recent years, he is now contributing to the Dutch IChO team selection and training. Over the years, former IChO Olympians have also been involved in aiding and selecting the Irish teams, notably Noel O'Boyle (IChO 1997) and Cormac Quigley (IChO 2003).

The first Ireland team to participate in IChO in 1997 in Montreal were:

Noel O Boyle (St Muredach's College, Ballina),
Barry Hughes (St Patrick's Boys Academy, Dungannon),
Dominic Calvan (St Patrick's Boys Academy, Dungannon),
Anthony O' Kane (St Louis Grammar School, Ballymena)

Figure 2: Ireland Team with Mentors at IChO 1997 From left: Noel O'Boyle, Dominic Calvan, Dr Paraic James (Mentor and Team Leader), Anthony O'Kane, Barry Hughes, Michael Cotter (Mentor)

At this competition, Noel O'Boyle was awarded a bronze medal and Barry Hughes received an Honourable Mention. This was remarkable for Noel, Barry and the mentor team in their first year of participation.

IChO Aim and history

The IChO is a chemistry competition for students at second level which:

- aims to promote international contacts in chemistry;
- intends to stimulate the activities of students interested in chemistry by way of the independent and creative solution of chemical problems;
- helps to facilitate cordial relations between young adults of different nationalities;
- encourages cooperation and international understanding.

Countries are invited to send a national delegation, consisting of up to four students and two mentors. A programme of activities is set out that can be typically run over ten days; during this time, the students are tested on their chemistry knowledge and skills in a five-hour laboratory practical examination and also a five-hour written theoretical examination in chemistry. As the programme extends over 10 days, there are plenty of opportunities for the students and mentors to promote 'friendships between scientific workers of different nationalities, co-operation between students and mentors and exchange of pedagogical and scientific experience in chemistry'.

Frequently, the theoretical and practical problems relate to areas of topical interest in the host country, either ongoing research or applied problems. These can further stimulate student interest in chemistry through creative problem solving, requiring a thorough knowledge of many different aspects of chemistry.

The detailed history of IChO can be found at https://www.iuventa.sk/en/Subpages/ICHO/History-of-the-ICHO.alej. In brief, the idea of the International Chemistry Olympiad was developed in former Czechoslovakia in 1968, with the first competition taking place in June 1969 in Prague. The event has been held every year since then, with the exception of 1971. In the early years, the delegations were mostly from the former Eastern bloc countries; however, in 1980 the event took place in Austria with 13 countries participating with 52 students. The UK first took part in 1983 in the 15th IChO hosted by Romania, where 18 countries participated (72 competitors).

By 1997, (29th IChO), when Ireland sent its first complete delegation, 47 countries were participating with teams, giving 184 participants. Over the last 25 years, the competition has continued to grow and in 2019, (51st IChO), 80 countries participated with teams, giving approximately 320 competitors – almost double in size from when Ireland first sent observers!

With the greater number of countries involved and the greater emphasis on preparation in each country, there is a corresponding increase in standards of the competition. All the participating students are ranked based on their individual scores in each of the examinations (practical and theoretical). Gold medals are awarded to the top 12% of students, silver medals to the next 22% of students and bronze medals to the next 32% of students. Honourable mentions are awarded to the top 10% of non-medallist participants. Special awards are also given to the students with best scores in the theoretical and practical examinations.

Team Ireland Success at IChO

At IChO, it is difficult to achieve a medal standing and there have been many years where, in spite of great focus and dedication of the students, Ireland have not achieved that standing. The success of the team members at IChO is to be commended and the list of team members are given in the Table in Appendix 1.

However, there have been some very notable years and it is only appropriate to highlight particular years in this survey. In 1999, Raja Mukherji (Drimnagh Castle Secondary School, Walkinstown, Dublin 12) achieved a silver medal, ranking 27th in the competition; in that year also, Colman Carroll (St Andrew's College, Booterstown, Dublin) and Fiona McFerran (Loreto College, Coleraine, Co Tyrone) were awarded bronze medals. The second silver medallist was in 2006, when Mary-Ellen Lynall (Methodist College, Belfast) achieved this level, ranking 49th in the competition overall.

Figure 3: Ireland Team at IChO 2017
From left: Michael Hong, Diarmuid O'Donoghue, Alicia Huntley and Aaron Hannon

In recent years, the students have again gained awards, notably:
- in 2017 with the award of 3 bronze medals to Michael Hong (Methodist College, Belfast) Diarmuid O'Donoghue (Ashton School, Blackrock Road, Cork) and Alicia Huntley (Regent House School, Newtownards, Co.Down).
- in 2019 with bronze award to Brian Durkan (St. Muredach's College – Ballina, Co Mayo).

Figure 4: Brian Durkan (Bronze medallist) with Mentors Dr Cormac Quigley and Dr Brian Murphy at IChO 2019

So now, how can you and your students get involved?

National Chemistry Olympiad (IrChO)

Over the intervening 25 years since the first participation in IChO, the selection and training process for the final team members has been tweaked and optimised. Here I will outline the current selection process for IChO. The selection currently involves two rounds of competition. For Round 1, each year, all of the 2nd level schools in the country are invited to nominate 2 students in their final year of school (i.e. 6th year) to attend the national competition (IrChO), usually in January/February, in DCU (although in 2020, Round 1 was hosted by TCD). Additionally, students who have been selected in previous years to participate in the selection of teams for the younger age Olympiads (i.e. EUSO and IJSO) are also invited to attend (if they are in 6th year and are studying Chemistry). The Round 1 examination consists of two examination papers in chemistry that are challenging and appropriate for the content covered in Leaving Certificate Chemistry and A-level Chemistry. At the end of Round 1, all the participants are awarded certificates of participation to note their achievement at being nominated by their schools to participate in this event.

The top students are awarded medals as follows:

- 2 Gold Medals – to the top student from, Republic of Ireland and top student from Northern Ireland,
- 2 Silver Medals – to 2nd placed student from Republic of Ireland, and 2nd placed student from Northern Ireland,
- 4 bronze medals awarded to next top four students in merit order.

The medal winners and a number of highly commended students form the panel that then participates in training and a Round 2 selection examination to select the top 4 students who represent Ireland at the IChO that year. The panel participates in 3 days of training where the students are introduced to topics such as spectroscopic analysis, detailed mechanistic processes in organic chemistry, inorganic equilibria studies etc. Finally they take a theoretical and practical assessment as part of Round 2, where the top 4 students are selected. Following their Leaving Certificate or A-levels (as appropriate), the students then take part in up to two weeks of residential intensive training focused on the specialist topics of the particular Olympiad that year.

Each year over 100 students participate in Round 1 of IrChO and to date over 2,500 students have participated. Considering that these students are also focused on their end of school national examinations, their dedication and love of chemistry is evident.

Future and Encouragement

Considering that approximately 1,000 students achieve an H1 in Leaving Certificate Chemistry each year, it would be good to see more students participating in the national chemistry olympiad. Following the competition in 2019, I realised that, having worked with the Chemistry Olympiad since 1995, in conjunction with Paraic and others, it was time for me to step back and encourage new ideas for the future development of the competition. To this end, in 2020, a new committee has been formed to oversee the organisation, running and possible expansion of the Chemistry Olympiad.

The new committee members are:
Dr. Brian Murphy (AIT and Co-Chair), Dr. Carl Poree (TCD and Co-Chair), Dr. Pat O'Malley (DCU), Dr. Cormac Quigley (GMIT), Dr. John O'Donoghue (TCD/RSC), Dr. Odilla Finlayson (DCU) - Advisor to 2020 IChO Committee

The Committee are already considering ideas of how the Olympiad can include more universities and Colleges in running selection rounds, and in additional tuition throughout the year. Unfortunately, this year, in the light of COVID-19, the IChO event in Turkey will now not take place. This is a huge but understandable disappointment for the panel of students who had been selected to take part.

Appendix 1: TRY some problems – practical and theoretical

1. Practical Examination IChO 2019 – see (https://icho2019.paris/en/problemes/problemes-icho-2019/) 5-hr examination

Problem P1. Greening the oxidation of 4-nitrobenzaldehyde
For the last decades, chemists have tried to replace harmful reagents in oxidation processes in order to reduce hazardous waste treatment. In this problem, potassium peroxomonosulfate has been chosen as oxidising agent, because it only produces non-toxic and non-polluting sulfate salts. It is provided here as Oxone®. Furthermore, the reaction itself is performed in a mixture of water and ethanol, which are classified as green solvents.
Your task is to perform the oxidation of 4-nitrobenzaldehyde, to recrystallise the product, to compare TLC eluents and to check the purity of the product using TLC.

Problem P2. The iron age of wine
Iron is an element which can naturally be found in wine. When its concentration exceeds 10 to 15 mg per litre, iron (II) oxidation into iron (III) may lead to quality loss, through the formation of precipitates. It is therefore necessary to assess the iron content of the wine during its production.
Given the very low concentration of iron species, a coloured complex of iron (III) with thiocyanate SCN^- as a ligand is used to quantify the iron amount, through spectrophotometric measurements.

Your task is to determine the total iron concentration of the white wine provided, using spectrophotometry, and to determine the stoichiometry of the thiocyanate – iron(III) complex.

Problem P3. Wine for keeping

Sulfur dioxide, SO_2, is used as a preservative in wine. When SO_2 is added to wine, it can react with water leading to bisulfite ions, HSO_3^-, and protons, H^+. Bisulfite can also be converted to sulfite, SO_3^{2-}, by the loss of a second proton.

These three different forms of sulfur dioxide in water can react with chemicals in wine such as acetaldehyde, pigments, sugars, etc. forming products P. The total concentration of sulfur dioxide is the sum of the concentration of the "free" forms (SO_2, HSO_3^- and SO_3^{2-}) and P.

The preservative concentration is regulated because sulfites and sulfur dioxide can be harmful to some people. In the EU, the maximum total sulfur dioxide content is set at 100 mg L^{-1} for red wine and 150 mg L^{-1} for white or rosé wine.

Your task is to determine the total sulfur dioxide concentration of the white wine provided by iodometric titration.

2. The Theoretical Task: Extract from Theoretical Examination IChO 2019 see (https://icho2019.paris/en/problemes/problemes-icho-2019/)

Problem T3: About silver chloride

Data at 298 K: pKs1(AgCl) = 9.7; pKs2(Ag_2CrO_4) = 12

Formation constant of the complex $[Ag(NH_3)_n]^+$: $K_n = 10^{7.2}$

Potentials against the standard hydrogen electrode:

Standard potential of $Ag^+/Ag(s)$: $E°(Ag^+/Ag(s)) = 0.80$ V

Apparent potential of $O_2(aq)/HO^-(aq)$ (in seawater): $E'(O_2(aq)/HO^-(aq)) = 0.75$ V

Part A: Quotes from a chemistry lesson by Louis Joseph Gay-Lussac

The following quotes from a chemistry lesson by Louis Joseph Gay-Lussac (French chemist and physicist, 1778–1850) deal with some properties of silver chloride.

Quote A: "I will now talk about silver chloride, a milk-white solid. It is easily obtained by pouring hydrochloric acid into an aqueous solution of silver nitrate."

Quote B: "This salt has no taste since it is insoluble."

Quote C: "This compound is completely insoluble in alcohol and even in acids, except in concentrated hydrochloric acid which dissolves it readily."

Quote D: "On the other hand, silver chloride is highly soluble in aqueous solution of ammonia."

Quote E: "Then, we can make silver chloride appear again by adding an acid which reacts with ammonia."

Quote F: "If you take a bowl made of silver to evaporate salty seawater, you will get impure sodium chloride, mixed with a milk-white solid."

1. Quote A: Write the balanced chemical equation of AgCl(s) synthesis.
2. Quote B: Calculate the solubility s of AgCl(s) in water at 298 K in mol L^{-1}.
3. Quote C: In a highly concentrated solution of chloride ions, a well-defined complex of stoichiometry 1:2 is formed. On the following qualitative axis (with pCl increasing from left to right), place in each domain the silver-containing species that is predominant (or exists, for solids). pCl values at frontiers are not expected.

Quote D: When ammonia is added to silver chloride, a well-defined complex of stoichiometry n is formed.

4. Write the balanced equation corresponding to the synthesis of the complex $[Ag(NH_3)_n]^+$ from silver chloride and calculate the corresponding equilibrium constant.
5. Ammonia is added to 0.1 mol of silver chloride in 1 L of water until the last grain of solid disappears. At this moment, $[NH_3]$ = 1.78 mol L^{-1}. Determine the stoichiometry of the complex neglecting dilution effects.
6. Write the balanced chemical equation corresponding to quote E.
7. Assuming that seawater is slightly basic and rich in dioxygen, and that silver metal can reduce dioxygen in such conditions, write a balanced chemical equation corresponding to the formation of the solid mentioned in quote F. A stoichiometric coefficient of 1 will be chosen for dioxygen.

Calculate its equilibrium constant at 298 K.

Part B: The Mohr method

The Mohr method is based on the colorimetric titration of Cl^- by Ag^+ in the presence of potassium chromate ($2K^+$, CrO_4^{2-}). Three drops (~ 0.5 mL) of a K_2CrO_4 solution at about 7.76 x 10^{-3} mol L^{-1} are added to V_0 = 20.00 mL of a sodium chloride solution of unknown concentration C_{Cl}. This solution is then titrated by silver nitrate (Ag^+, NO_3^-) at C_{Ag} = 0.050 mol L^{-1}, which immediately leads to the formation of solid A. A red precipitate (solid B) appears at V_{Ag} = 4.30 mL.

8. Write the balanced equations of the two reactions occurring during the experiment. Calculate the corresponding equilibrium constants.

9. Identify the solids.

Solid A: Solid B:

10. Calculate the unknown concentration C_{Cl} of chloride ions in the sodium chloride solution.

11. Calculate the minimal volume $V_{Ag(min)}$ for which AgCl(s) precipitates.

12. Calculate the residual concentration $[Cl^-]_{res}$ of chloride ions when silver chromate begins to precipitate. Justify why CrO_4^{2-} is a good titration endpoint indicator by comparing two values.

Biography

Odilla Finlayson is Associate Professor of Science Education (Chemistry) in School of Chemical Sciences DCU. She is an active member of the research centre CASTeL, where she has supervised many PhD students in catalysis as well as in science education. As a physical chemist, she is involved in lecturing to undergraduate chemistry students and is also involved in teaching and monitoring pre-service science teachers. She has worked with the many Olympiads over the last 25 years with colleagues both within and outside of DCU, and has served as Country Co-ordinator for Ireland for EUSO (to 2019) and IJSO (to present).

□

Diary

2021

ASE Annual Conference 2021 online in 2021
06 January 2021 - 09 January 2021
https://www.ase.org.uk/events/ase-annual-conference-2021-online-in-january

The 11th International Symposium on Microscale Chemistry
12 - 15 July 2021, Oundle, Peterborough , United Kingdom
https://ismc2021.weebly.com/

10th New Perspectives in Science Education
18-19 March 2021, Florence, Italy
https://conference.pixel-online.net/NPSE/

Eurovariety 2021 will be held in Ljubljana - Slovenia, 7 - 9 July 2021.
http://www.eurovariety2021.si/

Chemistry Education Research and Practice, *Gordon Research Conference*
Coordinating the Production and Consumption of Knowledge on Chemistry Teaching and Learning, July 11 - 16, 2021, Bates College,, Lewiston, ME, USA
https://www.grc.org/chemistry-education-research-and-practice-conference/2021/

2021 ChemEd
25-29 July
University of Guelph, Canada in 2021 (https://chemed2021.uoguelph.ca/) This conference alternates with BCCE.

14th ESERA online conference, University of Minho (Braga, Portugal) from 30 August to 3 September 2021.
https://www.esera.org/news/esera-announcements/854-esera-conference-2021-call-for-proposals

40th ChemEd-Ireland
16 or 23 October (tbc)
Dublin, DCU
Odilla.finlayson@dcu.ie or james.lovatt@dcu.ie

2022

ECRICE 2020 postponed to 11-13 July 2022.
http://www.weizmann.ac.il/conferences/ECRICE2020/excellence-and-innovation-chemistry-teaching-and-learning

ICCE 2022 Cape Town, South Africa 18-22 July 2022
www.ICCE2022.org.za

2020 ICCE (postponed) now 2022 ICCE
18-22 July 2022 in Cape Town, South Africa.
https://www.icce2022.org.za/

BCCE 2020 has been cancelled. The next conference BCCE 2022 will be held in Purdue University.

If you have any news of other conferences please email peter.childs@ul.ie

Escape Room – Teachers Approved!

Marina Stojanovska[1], Vesna Milanović[2], Dragica Trivić[2]
[1] Ss. Cyril and Methodius University, Faculty of Natural Sciences and Mathematics, Skopje, Macedonia
[2] University of Belgrade – Faculty of Chemistry, Belgrade, Serbia
e-mail: mmonkovic@yahoo.com

Abstract

Escape room is novel and innovative method that can be used in teaching in general. Its popularity grows every day. The benefits of applying this approach in chemistry teaching are numerous, concerning both the cognitive and affective side of teaching. Thus, it can be used to develop conceptual knowledge, critical and creative thinking, problem-solving, but also skills needed in everyday life. It trains students to communicate and collaborate, to express and defend their opinions, to make compromises and decisions. Several escape room activities were conducted with chemistry teachers during seminars for professional development in Macedonia and Serbia. The goal was to actively involve teachers in the activity and to get insight into their opinions about the applicability of this approach in chemistry teaching. In this paper five escape room simple paper-and-pencil activities are presented which can be implemented in chemistry teaching.

Introduction

Escape room is a relatively novel concept and it has been used in education in recent years (Dietrich, 2018; Peleg et al., 2019). It is based on game-based learning (Admiraal et al., 2011; Antunes e al., 2014; Burguillo, 2010; Orlik et al., 2005; Russell, 1999; Stojanovska, & Velevska, 2018), and goes beyond that. It involves learning activities aimed to introduce or revise concepts in more attractive and engaging way. This approach fosters creativity and logical thinking. Students are put in a position to solve problems, discuss, defend their arguments, make compromises, and finally make a decision. Escape room puzzles are designed to be carry out by a group, thus increasing students' communication skills, but also other skills needed for their future life, such as collaboration, empathy, teamwork, self-confidence etc. These activities provoke higher-order thinking skills and development of conceptual knowledge and sometimes they can fill the gaps in knowledge or confront some misconceptions. It is understandable that students communicate more freely with their classmates rather than with the teacher. Involving games into the lesson insures both learning and having fun.

Games can be used as a pedagogical tool, which means that they must have some educational content and not be used only as an entertainment. They should be well-prepared and the preparation process is crucial for successful implementation. Preparation time is usually longer than the actual realization of the game, but once prepared games can be used many times with slight modifications. Teachers should also be aware of the lesson time limit and all escape room activities must end before the bell rings, and also leave some time for overall-class discussion.

Carefully prepared game-based activities will surely enable greater students' participation and mental involvement, which will then lead to increased students' motivation and interest of the subject and development of positive attitudes toward chemistry. Hence, educational games and escape room activities can be very beneficial in the classroom providing both mastery of the curriculum and an inspiring lesson.

Having all this in mind, it is important to educate pre-service and in-service teachers and illustrate the applicability of this approach in chemistry teaching. This goal was set for seminars for professional development of chemistry teachers in Macedonia and Serbia during 2019 (Stojanovska, 2019a; Stojanovska, 2019b). The idea was to introduce the escape room approach to teachers by truly involving them into the activity (Figure 1). In this way, they could understand the escape room approach based on their own experience and feel the excitement while playing with their colleagues. Furthermore, this approach is appropriate for any topic, any school subject and any age level. Therefore, it can be integrated into the professional development program of teachers regardless of the teaching subject.

Figure 1. Working atmosphere during the seminars

Escape room puzzles

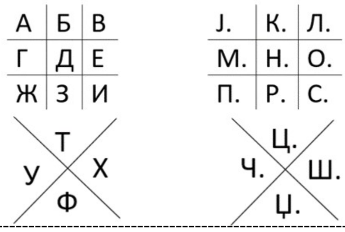
In a typical escape room activity, the participants are locked (or "locked") in a room trying to solve the puzzles in order to escape. The presented puzzles are developed for primary and secondary school students, so it is more appropriate to use the award 'locked in the box' instead of actually locking the students inside the classroom! One thing that can be significant for teachers is the cost for these activities, which in this case is minimal and, additionally, materials can be reused.

During the seminar workshops, teachers were given a handout for each puzzle, either to help them to solve the puzzle or to motivate and encourage them in their work. Puzzles presented at the seminars, together with a brief explanation, teachers' handout, and the final code to the puzzle are given below (Figures 2–6).

	This puzzle can be easily made using the snote application (https://snotes.com). Four words are overlayed in a way they are unreadable. If this puzzle is printed on a piece of paper and rotated at a certain angle, the words are easy to understand. In this particular case, the words are: konferencija (conference), datum (date), aprilski (April), dani (days). This puzzle was used in a game during the conference in Belgrade and these words gave a clear association to participant teachers about the code (the conference was held on 24th April 2019).
a	b
Seminars are an important part of teacher professional development, which is a continuous process – beginning on the first day and ending on the last day of a teacher's working career. It is a lifelong learning process in which the teacher is constantly improving.	244
c	d

Figure 2. Hidden words – the puzzle (a), explanation (b), teachers' note (c), and the code (d)

[redacted]



Students are given a coded message and a legend to be used to crack the code. They should reveal the mysterious text, and then answer the question.

a b

Dear educators,
Use the encrypted message to discover the three-digit code. Think creatively and share creativity. You can't spend creativity. The more you use, the more you have!

680

c d

Figure 3. Coded message – the puzzle (a), explanation (b), teachers' note (c), and the code (d)


THE BEST TEACHERS WORK TOGETHER

CCC - COOL CHEMISTRY COFFEE
ARHIMEDOVA 5
SKOPJE
MAKEDONIJA
1000

CASHIER: MARINA STOJANOVSKA
CUSTOMER: VREDNI NASTAVNICI

PURCHASE:

CEZIUM €325.00
AZOT €63.00
VODOROD €114.00

DDV +90.45% TAX: €454.06

TOTAL: €956.06

PAYMENT METHOD: CREDIT CARD
TRANSACTION #1546010111 -001
DATE:16/02/2019 11:37:48 PM

NO RETURNS WITHOUT RECEIPT

THANK YOU

A fake receipt is created inserting some chemical information among dates, item purchases, names, taxes etc. Students are searching for clues by calculating the atomic or the mass number, the group or the period of the elements, the number of protons, neutrons, electrons, valence electrons etc.

a b

Dear educators,
Welcome to our CCC cafe bar. This is the receipt for your order. No, no, no ... don't worry, we're not asking for money! Use your receipt to discover your three-digit code. Be guided by the rule of cooperation: "Working together increases the chance of winning."

151

c d

Figure 4. Cool Chemistry Coffee Receipt – the puzzle (a), explanation (b), teachers' note (c), and the code (d)

a

Two statements are written on a piece of paper: "I'm a Queen (KrAlICa)" and "I Wonder … What Would I Do Without My King (KrAl)". The text is written in Macedonian, so it is language specific puzzle, but one can use other word-combination to attain the similar effect. Students are expected to use the keyword *without*, thus performing the subtraction operation (*KrAlICa* minus *KrAl* equals *ICa*). Finally, they should use the atomic numbers of iodine and calcium to break the code.

b

In 1869, the Russian chemist Mendeleev wrote the known elements (then 63) on the cards and then ordered them into columns and rows according to their chemical and physical characteristics. To celebrate the 150th anniversary of this important moment in science, 2019 was proclaimed the International Year of the Periodic Table of the Elements (IYPT2019).

c

5320

d

Figure 5. The Queen and the King – the puzzle (a), explanation (b), teachers' note (c), and the code (d)

1. Which of the following pairs **do not** have the same number of neutrons in the nucleus?
A. K and Ca B. Na and Mg C. F and Ne D. Li and Be

2. Two atoms, X and Y, have a total of 12 protons, 14 neutrons, and 12 electrons. The atomic number of Y is three times larger than that of X. In which group (G) and in which period (P) is the element X?
A. G-1, P-2 B. G-2, P-1 C. G-17, P-2 D. G-2, P-7

3. In the third electron shell of one atom there are twice as low electrons than in the first shell. What is the atomic number of the element?
A. 14 B. 11 C. 9 D. 3

	A	B	C	D
Q1	@	☼	♫	♥
Q2	♫	♥	@	☼
Q3	♥	@	☼	♫

@ = 1 ☼ = 2 ♫ = 3 ♥ = 4

a

Three multiple-choice questions are given. Each answer reveals one digit of the code which can be identified using the multiple-choice grid and symbols which are associated with numbers from the legend.

b

Dear educators, *At this chemistry competition you only need to answer three questions. Copying from other groups is not allowed, but you can freely consult the members of your group. After answering the questions correctly, try to discover the three-digit code using the legend. This will allow you to win first prize.* *Good luck!*	431
c	d

Figure 6. Municipal Chemistry Competition – the puzzle (a), explanation (b), teachers' note (c), and the code (d)

Conclusion

The escape room approach is suitable to be used for developing activities for students so they can encounter the chemistry content in a different way than in the traditional classroom. This will lead to increased interest for the subject, but it would be an intellectual challenge for students as well. Furthermore, students will develop essential skills for life, such as collaboration, communication, problem-solving, critical and creative thinking, decision-making etc.

Therefore, the escape room activities can be used to create a positive learning atmosphere in the classroom and "revival" the lessons. Our experiences so far showed that this approach is of great interest to teachers and, of course, to students. Teachers during the seminars were amazed what they could do in their classrooms with just a little effort and almost no money and computers. It is an additional motivation for creating new activities of this kind that will benefit both teachers and students.

References

Admiraal, W., Huizenga, J., Akkerman, S., & ten Dam, G. (2011). The concept of flow in collaborative game-based learning. *Computers in Human Behavior, 27*(3), 1185−1194. doi: 10.1016/j.chb.2010.12.013

Antunes, M., Pacheco, M. A. R., & Giovanela, M. (2012). Design and implementation of an educational game for teaching chemistry in higher education. *Journal of Chemical Education, 89*(4), 517−521. **doi:** 10.1021/ed2003077

Barzilai, S., & Blau, I. (2014), Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences. *Computers & Education, 70*(1), 65−79. doi: 10.1016/j.compedu.2013.08.003

Burguillo, J. C. (2010). Using game-theory and competition-based learning to stimulate student motivation and performance. *Computers & Education*, *55*(2), 566−575. doi: 10.1016/j.compedu.2010.02.018

Dietrich N. (2018). Escape Classroom: The Leblanc Process – An Educational "Escape Game". *Journal of Chemical Education, 95*(6), 996−999. https://doi.org/10.1021/acs.jchemed.7b00690

Orlik, Y., Gil, E., & Hernández, L. C. (2005). The game "Young Scientists" as active science educational tool for extra-curricular work in the school. *Natural Science Education, 3*(14), 47−50. Retrieved from http://oaji.net/articles/2014/514-1393349254.pdf

Peleg, R., Yayon, M., Katchevich, D., Moria-Shipony, M., & Blonder, R. (2019). A Lab-Based Chemical Escape Room: Educational, Mobile, and Fun!. *Journal of Chemical Education, 96*(5), 955–960. https://doi.org/10.1021/acs.jchemed.8b00406

Russell, J. V. (1999). Using games to teach chemistry. *Journal of Chemical Education*, *76*(4), 481–484. doi: https://doi.org/10.1021/ed076p481

Stojanovska, M. (2019a). Seminars for chemistry teachers. *Macedonian Journal of Chemistry and Chemical Engineering, 38*(1), 141–144. (in Macedonian).

Stojanovska, M. (2019b). Transformation of the traditional classroom into an escape room classroom, Book of Abstracts, April Chemistry Teaching Days – 30th Professional Development for Chemistry Teachers and 3rd Methodology of Chemistry Teaching Conference, p. 37. (in Serbian)

Stojanovska, M., & Velevska, B. (2018). Chemistry games in the classroom: A pilot study. *Journal of Research in Science, Mathematics and Technology Education, 1*(2), 113–142. doi: 10.31756/jrsmte.121

□

Chemists you should know: No.7 Jacques Alexandre César Charles, 1746-1823

Adrian Ryder
tutorajr@gmail.com

Early life

The subject of this essay, Jacques Alexandre César Charles, was born on the 12th of November 1746 in the small town of Beaugency, which is situated on the right bank of the river Loire some 115 Km south-west of Paris, in number 15, rue Porte Vendómoise, a house which still stands today. He was the eldest child of his parents Jacques Alexandre Charles and Marguerite Claude Humery de la Boissiere. Jacques Senior was a King's Adviser and Crown Prosecutor in Beaugency. The couple had six children in all but only three sons are named: Jacques the eldest, Charles Jules César, born in 1748, and Joseph Solomon Charles De Talmours, born in 1756. It was typical of the time to ignore any girl children and those who fail to reach adulthood.

Charles Jules, the second son, became Priest of St. Paterne d' Orléans and Titular Canon of the Cathedral there. He died in Orleans on March 22nd 1823. Jacques Jean-Marie Moussalli writes that when the mob invaded King Louis XVI's palace, the Tuilieries, on 10th August 1792, in order to kidnap him, killing any cleric they came across on the way, Charles Jules, fleeing from the killers, was taken in by his brother Jacques. He was hidden beneath a deflated balloon in the laboratory in the adjacent Louvre, where he had quarters and worked by grace of King Louis, who was a dedicated patron of the sciences. On arrival of the mob, Jacques amused them with a number of surprising physics tricks, after which they left to find other amusement.

Joseph Solomon, the youngest son, was born on February 18th 1756 and died on April 21st 1816. He served as a deputy public Prosecutor in St. Dominque, Haiti, and after independence there in 1804, as a lawyer in Parliament, and a notary and merchant in the Bercy district of Paris. He was to marry twice, producing two children from the second union.

Jacques Charles in his working attire

Charles, having completed elementary education in the Beaugency school, went on to secondary education in the Meung-sur-Loire College some five miles away to the north-east. Here he showed himself to be an excellent student dealing easily with new subjects and activities. Virtually no mathematics was done and absolutely no science of any kind. He did turn his hand to music and painting and seemed to enjoy the traditional classical education provided. It is reported that as an exercise he studied the Aeniad of Virgil and was not satisfied until he could recite the entire work by heart.

Franklin's influence

What he did in the immediate years after finishing school is not known and it only on his move to Paris, in 1779, to work in the Ministry of Finance that reliable details of his life begin to emerge. Now aged thirty-three, we see a dramatic change in his life. This can be directly linked to one man, Benjamin Franklin. Franklin, born 17th January 1706 (dying 17th April 1790), was one of the seven founding fathers of American Independence who came from England. He was a remarkable physicist in his own right with a great number of inventions to his credit. He famously showed that lightning was a form of electricity by means of flying a kite during a thunderstorm, the invention of the lightening conductor for buildings. He also invented bifocal spectacles, a new form of stove, the Franklin stove, the flexible urinary catheter, the glass harmonica and multiple plate capacitors. He arrived in Paris in 1776 as the Commissioner from the rebel American states to France, seeking aid in the form of munitions and arms for the revolutionary army. Following the recognition by France of the American Congress in 1778, Franklin was elected Minister Plenipotentary to France and was instrumental in the negotiations which led to the Treaty of Paris in 1785, which ended the revolutionary conflict with Britain.

Benjamin Franklin 1918 commemorative United States postage stamps

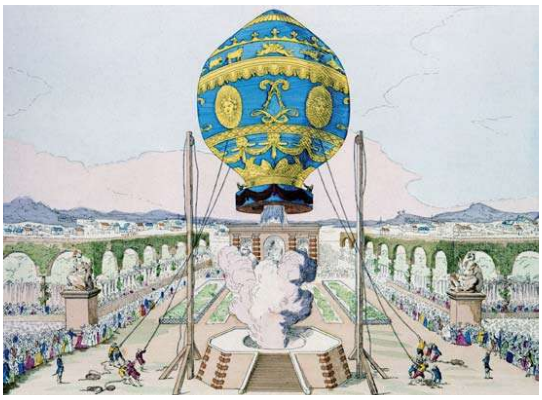
On his arrival in Paris in 1779, Charles became aware of Franklin and immediately decided to get to grips with the science exemplified by him. He attended the Academy of Sciences, which had a long association with the practical side of the sciences rather than concentrating on the theoretical. This suited Charles who repeated, refined and confirmed Franklin's experiments and the electrical findings of others and put together for himself a cabinet of physical equipment and curiosities. His progress in science was such that he gave his first public demonstrations and discourse on the 22nd of January 1781. This was an immediate 'hit' with the public and led to him giving public lectures and demonstrations to large crowds being. Charles was now becoming a 'name' in the scientific area. These lectures and demonstrations led to recognition by King Louis XVI, who was an avid patron of the sciences and later granted Charles living quarters and workspace in the Louvre (then a Royal palace.) Charles's association with the Academy was to last the rest of his life, first as a lecturer and in 1785 as a full professor. He was named a resident member of the Academy on November 20th 1795, later becoming the Academy's Librarian and finally becoming the President of the Academy in 1816.

Aeronautical exploits

On June 4th 1783, in Annonay, a small town 36 miles south of Lyon, some 273 miles from Paris, the brothers Jacques-Étienne and Joseph-Michel Montgolfier (who were paper manufacturers) set aloft the first hot air balloon ever recorded. This unmanned machine had a diameter of thirty-five feet and was made of paper covered with cloth and heated by a straw fire. Some weeks later sketchy news of the successful launch reached the Academy in Paris and Charles was asked to investigate the new phenomenon. With very few details available to him, Charles decided to try the newly discovered hydrogen gas (first made in 1766 by Henry Cavendish in England) to fill a balloon and filled a rubber varnished silk fabrication with the gas. The hydrogen gas was formed using 225 kg of sulphuric acid on over half a ton of scrap iron. The balloon, about thirteen feet in diameter, was able to lift a payload of only 9 kg. On August 27th 1783, the balloon was launched before a large gathering of Parisians at the Champs de Mars (where the Eiffel Tower stands there today). As the balloon ascended it began to blow away northwards. Various spectators, including Benjamin Franklin, mounted their horses and went chasing after the balloon. Some 45 minutes later the balloon descended into a field close to Gonesse, some 10.3 miles North-East of the Centre of Paris, (Charles de Gaulle Airport is now a near neighbour). There the local farmers attacked the strange hissing (due to leaks in the rubberised coating) and strongly smelling (due to sulphur dioxide impurities) beast with pick axes, spades and knives and had torn the beast to pieces before the pursuing horsemen arrived, too late to save but small pieces of the balloon.

The next step in the assault on the air came on September 19th of the same year, when the Montgolfier brothers launched a second hot-air balloon from Versailles, carrying three test animals: a rooster, a duck and a sheep, in order to determine if a living organism could survive the heights reached by the balloon. The chasing group, which went to the spot where the balloon, and animals, landed safely, was headed by Jean François Pilâtre de Rozier, of whom more below.

Meantime Charles and the brothers Marie-Noel and Anne-Jean Robert were designing and building a nine-metre diameter hydrogen balloon to carry a crew aloft. But before the preparations were completed, Rozier and the Marquis d'Arlandes, Francois Laurent, had been learning how to use a tethered hot-air Montgolfier balloon. They finally persuaded King Louis to allow a free, untethered flight and on November 21st they set off on the first free balloon flight in history. The flight lasted just over 20 minutes, landing some ten miles from the ascension point.



The Montgolfier Balloon

Not deterred, Charles and the Roberts got their hydrogen-filled balloon ready on the first of December.

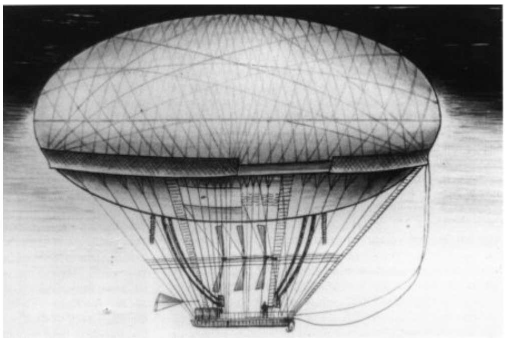
The Charliére Balloon
Contemporary illustration of the first flight by Jacques Charles with Nicolas-Louis Robert, December 1, 1783. Viewed from the Place de la Concorde to the Tuileries Palace(destroyed in 1871)

Thus Charles and Nicholas-Louis Robert entered the basket of the balloon, and to the awe of the crowd assembled in the Jardin des Tuileries, estimated at 400,000, took off at 1.45pm in the first gas-filled balloon ascent in history. Having reached an altitude of about 550 metres, they landed at sunset in Nesles-La Callée, 22 miles away, after a flight of two hours, five minutes. The horseback chasers arrived as the balloon descended and held the retaining ropes. Nicholas Robert got out of the basket and even though some of the hydrogen gas had escaped, the lightening of the load by Robert's getting off, allowed Charles to ascend again.

Painting of Charles's solo flight

The balloon rapidly rose to a height of some 3,000 metres, allowing Charles to see the seting sun again. He now suffered from severe ear pains and so he vented some of the gas and descended gently to the ground in safety in the dark, thus becoming the first person to make a solo balloon flight in any form of balloon. It should be noted that the balloons were such a spectacle and novelty that hundreds of those watching donated a crown each, to cover the cost of making and filling the hydrogen balloon.

Charles and the Roberts now went on to construct an elongated craft, which had steering and a proposed propulsion method using oars.



The oar-driven balloon

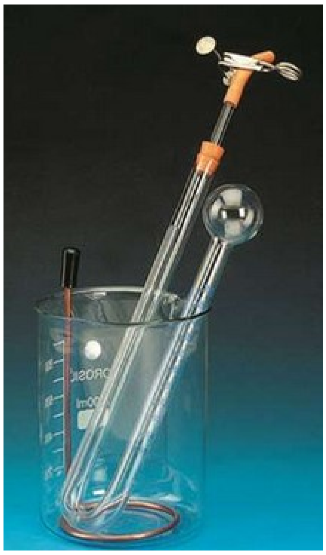
The craft had a number of individual gas-cells, to minimise the loss of hydrogen. On July 15th 1784 the Robert brothers, together with an extra two crew members, M. Collin-Hullin and the Duke of Chartres, Louis Phillippe II, set off and reached an altitude of about 4,500 metres. So efficient were the gas-cells that the Duke had to slash some to allow gas to escape so that the craft could descend after about 45 minutes. While the steering was somewhat successful, the use of oars for propulsion proved an abject failure.

Charles himself, after his solo experience, never again took flight but continued to advise and support the flights of others. In this regard he invented a valve line, to allow gas to be released from the balloon, rather than having to slash the balloon material.

As final notes on the emergence of balloon flight, it is noted that the Robert brothers with M. Collin-Hulin ,took the craft to the air on September 19th 1784. After flying for 6 hours 40 minutes, they landed 186 km away in Beuvry near Béthune. This was the first flight of over 100 km. On a more sombre note, de Rozier, who had made the first free flight in a hot-air balloon, attempted to cross the English Channel from France. (Jean-Pierre Blanchard, a Frenchman, and Dr John Jeffries, an American had previously, on the 7th Jan.1785, flown from England to France. On the 15th June 1785 they took off from Boulogne-sur-mer in a hybrid hydrogen and hot air balloon. Shortly after going aloft they encountered contrary winds and a sudden decompression of the balloon saw the vessel crash near Wimcreaux in the Pas-de-Calais area, killing both occupants. De Rozier thus has the unfortunate reputation of being on the first manned balloon flight and being the joint first to be killed in a balloon accident. This was, however, not to deter many others - ballooning was now firmly established. The modern hybrid gas and hot air balloon is named the Rozier balloon in his memory.

Scientific Investigations

With the excitement of the first gas balloon over, Charles returned to the more mundane work of experimentation and teaching at the Academy. Thinking about the effect of temperature on gases, in 1787 he conducted a series of experiments on five gases held in J-tubes such as illustrated in the photograph below.

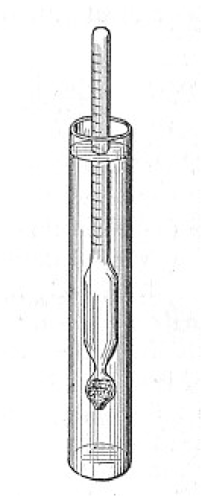


Apparatus similar to that used by Charles

The five tubes were filled to the same level, with carbon dioxide, hydrogen, oxygen, nitrogen and air respectively, using mercury as a stopper, and the tubes were heated to 78 degrees centigrade in a water bath. The effect of pressure was eliminated by having the mercury level in both arms of the tube at the same height. All five gave the exact same increase in volume. Having satisfied himself that the expansion of a gas was proportional to the temperature, he left the work, having reported, as he did habitually, to the others in the Academy and did not publish his findings. It was left to Joseph Louis Gay-Lussac (6/12/1778 – 9/5/1850) to take over and produce the exact correspondence between volume of a mass of gas at constant pressure with temperature in 1802. The correlation is described as $V1/T1 = V2/T2$ where T1 and T2 are in degrees Kelvin and the pressure is kept constant. Gay-Lussac published his work but unselfishly gave the credit for the idea to Charles, and the equation is known today as Charles's Law.

Charles developed the constant weight hydrometer, which one is used to seeing in the laboratory, shown below on the right. It replaced the hydrometer on the left, a constant volume hydrometer, which uses small weights added to the over liquid pan to keep the mark on the upper tube at surface level and uses the formula:

Mass of hydrometer + added masses divided by the mass of hydrometer equals the specific gravity of the liquid divided by the specific gravity of the original liquid used to give the graduated mark on the hydrometer. This was developed by Daniel Gabriel Fahrenheit (24 May 1686 to 16 Sept. 1736).



Two types of hydrometer

Jean Baptiste Biot (1816) gives details of two hydrometers invented by Charles, a thermometrical (Vol.1 p.414) and the balance hydrometers shown below using a modern electronic balance.

The balance hydrometer

Nicholson hydrometer

Charles adapted the Nicholson hydrometer by allowing the bottom weight to be swivelled vertically and allowing for material of density less than water to be placed below the hydrometer causing an uplift, from which it was possible to determine the density of the material.
(Note: a further development of the balance hydrometer is reported by this author in Chemistry in Action! No. 108, Summer 2016.)

In 1780 Charles captured images using paper impregnated with silver chloride a fore-runner of photography. Unfortunately the images were not stable and were rapidly lost. Joseph Nicéphore Niépce (7 Mar. 1765 – 5 July 1833) was to take Charles's work further, resulting in the permanent capture of an image in 1825.

Charles went on to invent a reflecting goniometer and to remove the difficulties associated with the use of the Gravesand Heliostat. A 'Megascope', an instrument for the magnification of large objects is also his invention. He had been involved in the extraction of the element boron, contemporary with Humphrey Davy, who is credited with the first isolation of the element.

Fully and happily established at the Academy, Charles felt the need to settle down and he married Julie Françoise Bouchaud des Hérettes (4 July 1784 – 18 Dec. 1817), a Creole woman from St. Domingue in Haiti, in his brother's church at St. Paterne on the 25th July 1804.

Julie Charles

Jacques Charles in Court Dress

Julie's mother died and her father brought her to Paris at the age of nine. Here he took to drinking and ruined himself financially. Luckily for Julie an uncle took her under his wing. But at the time of her marriage she was described as an unhealthy beauty with a paleness revealing a faltering health. She has received immortality as the famous 'Elvire du Lac' in Alphonse de Lamartine's work. Lamartine (21 Oct. 1790 to 28 Feb. 1869) met her in October 1816 on the shore of Lake Bourget, while he was recovering from illness at the spa of Aix-les-Bains and formed an intense admiration for her. This infatuation was to be of brief duration as Julie was then in the early stages of pulmonary tuberculosis, which claimed her life the following year. It can hardly be a co-incidence that Charles's brother, Joseph Solomon, had just returned from Haiti after independence there, and that Charles and Julie now met probably through Joseph's acquaintance with those who had worked in Haiti. Jacques and Julie produced no children, perhaps due to the 38-year age difference on marriage, Jacques being then 58, while Julie was a mere 20-years old.
Charles outlived her by five and a half years and died in Paris on April 7, 1823.

Streets in La Rochelle, Olivet and La Chapelle-Saint-Mesmin have been named in his honour.

References

Un enfant illustre de Beaugency, by Claude-Joseph Blondel, L,Académie D'Orléans, Numero 4, December 2003. Deterville, Paris.

Traité de physique experimentale et mathématique, Tome 1, 3, jean Baptiste Biot, 1816

https://en.wikipedia.org/wiki/Jacques_Charles

http://chemistry.bd.psu.edu/jircitano/charles.html

https://wikivividly.com/wiki/Jacques_Charles

http://www.websterworld.com/websterworld/scitreas/j/jacquescharles518.html

https://www.ghcaraibe.org/bul/ghc121/p2709.rtf

□

Elementary Chemistry

An occasional feature where we look at the newsworthy chemistry of the elements.

What colour is hydrogen?

Hydrogen is a colourless gas is the usual answer to this question. But there is a lot of talk today about green hydrogen and blue hydrogen. ***What are they?***

Green hydrogen is hydrogen produced without any use of fossil fuels or emission of CO_2; thus it is made from water by electrolysis using renewable energy from wind or solar power, so that no fossil fuels are involved. We also have blue, brown, grey and even turquoise hydrogen (see diagram below).

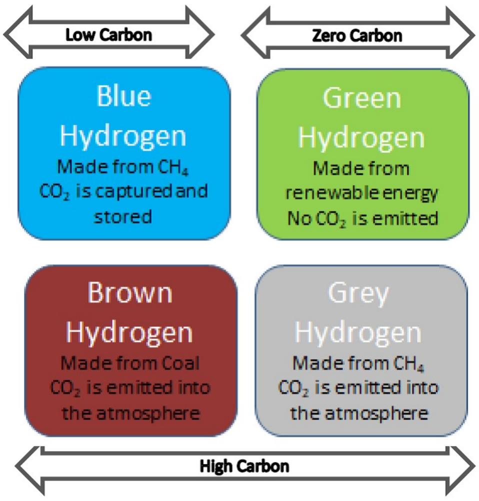
Blue hydrogen is made from methane (a fossil fuel) but the CO_2 produced is captured and stored, so that it does not contribute to climate change (Carbon Capture and Storage, CCS).

Grey hydrogen is made from methane but the CO_2 by-product is emitted into the atmosphere, and

Brown hydrogen is made from coal with CO_2 emission.

It is worth noting that methane has a much greater greenhouse warming potential (GWP) than carbon dioxide, so in one sense, turning methane into carbon dioxide is some gain.

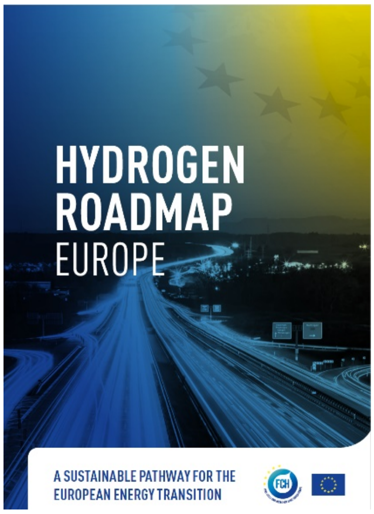
Turquoise hydrogen is the newest colour: this involves methane being converted into hydrogen and carbon using molten metal, which needs to be heated by renewable energy.



Source: **https://www.cedigaz.org/clean-hydrogen-building-large-scale-supply-chains/**

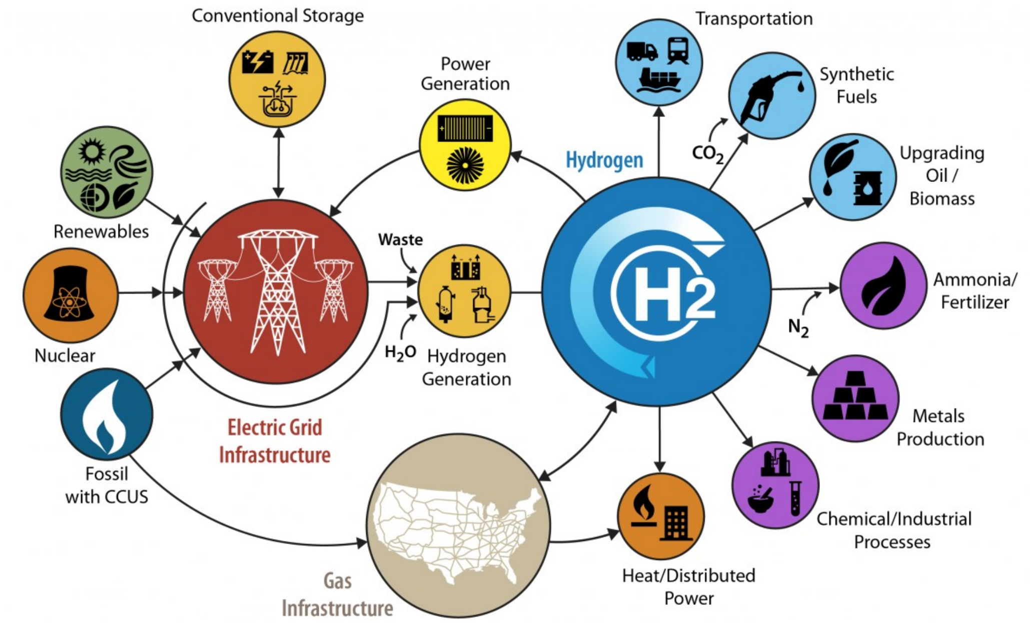
The production of hydrogen (~ 70 mt pa), today is dominated by grey hydrogen (71%, brown hydrogen 29%) and very little green or blue hydrogen is produced. However, there is renewed interest in the hydrogen economy (first proposed in 1970!), using surplus solar energy to produce hydrogen, which can be stored and shipped as an energy storage medium. The long-term plans of the EU for CO_2 reduction include use of green hydrogen, and it is being talked about in Ireland.

Hydrogen gas can be burned directly or mixed with natural gas. The old town gas made from coal was a mixture of hydrogen and carbon monoxide. Hydrogen can be turned directly into electricity using fuel cells, which allows it to be used in cars, trucks and trains. It can also be converted by a process called methanation into methane. All conversions involve energy loss and using hydrogen as a fuel only makes sense if there is surplus energy e.g. from renewables or nuclear power, which can be stored as hydrogen for future use. There are already pilot projects of hydrogen buses, and hydrogen trains are planned, with the advantage over batteries that the range is bigger and refuelling is faster. It may be that the long-awaited hydrogen economy is still just around the corner, but much closer than it was. There are plans to make green hydrogen from solar energy in Australia and other countries, which liquid hydrogen being shipped to end-users.



The EU has a target of 10 mt hydrogen by 2020 (mt = million tonnes) and in 2019 published the EU Hydrogen Roadmap. (**https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf**)

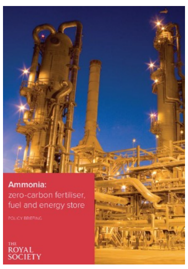
See also **www.hydrogenireland.org**.



American plans to integrate hydrogen into their energy and chemicals infrastructure (Source: https://www.energy.gov/eere/fuelcells/h2scale)

Green ammonia

Ammonia, mainly for fertilizers, is made by the Haber-Bosch process from natural gas, with CO_2 as a by-product. This is thus grey ammonia. However, there is a lot of interest in producing green ammonia, using green hydrogen produced by electrolysis rather than using methane as the hydrogen source. Ammonia has a higher energy density than liquid or compressed hydrogen, and is easier to liquefy and transport. Indeed there is already a global distribution system for liquid ammonia for fertilizer manufacture. Thus green ammonia has been identified as a way of storing renewable energy and transporting it. Ammonia can be burned directly to liberate energy or even run an engine, or converted back into hydrogen gas. Ammonia production is responsible for 1.8% of global CO_2 production.



The Royal Society published a report in Feb. 2020 on *Ammonia: zero-carbon fertiliser, fuel and energy store.* (**www.royalsociety.org/green-ammonia**)

"The production of green ammonia has the capability to impact the transition towards zero-carbon through the decarbonisation of its current major use in fertiliser production. Perhaps as significantly, it has the following potential uses:

• As a medium to store and transport chemical energy, with the energy being released either by directly reacting with air or by the full or partial decomposition of ammonia to release hydrogen.

• As a transport fuel, by direct combustion in an engine or through chemical reaction with oxygen in the air in a fuel cell to produce electricity to power a motor.

• To store thermal energy through the absorption of water and through phase changes between material states (for example liquid to gas)."

Watch this space for more news of green hydrogen and green ammonia.

See also: *Green Hydrogen: Could It Be Key to a Carbon-Free Economy?* https://e360.yale.edu/features/green-hydrogen-could-it-be-key-to-a-carbon-free-economy#:~:text=Green%20hydrogen%2C%20which%20uses%20renewable,%2C%20aviation%2C%20and%20heavy%20manufacturing.

□

Chemlingo: heavy metal poisoning

Peter E. Childs

The heavy metals, so-called, are those metals like lead, mercury, cadmium and others near the bottom of the Periodic Table, and should also include the noble metals like copper, silver and gold. These metals are notorious for being poisonous and have given rise to recognised medical conditions. In this article we will look at the names of some of them. A general name for metal poisoning is *metallosis*. A grey-blue colouration of the skin in exposed areas due to ingesting silver compounds is known as *argyria*, from the Latin for silver, *argentum*, from which we get the symbol Ag. Silver precipitates out in the skin as silver sulfide or selenide, and these decompose in sunlight to give silver, which produces the grey-blue colour. Taking in gold salts like aurothiomalate as medicinal drugs can lead to a similar condition called *chrysiasis*, from the Greek *chrysos* meaning yellow flower, as in chrysanthamum. Gold is deposited in tissue and causes the blue-grey coloration. These effects are hard to reverse.

A more familiar metal poisoning is *plumbism* (from Latin *plumbum*, Pb) due to lead poisoning, which is still an issue in towns due to old lead water pipes. It used to be known as painter's colic, when many paints had a lead base (now banned), for example, red lead used to protect steel from corrosion. Lead poisoning is also known as *saturnism*. Lead poisoning has widespread effects on the body, on the brain and nervous system.

Advert for lead paint, 1920s

The other notorious heavy metal poison is mercury, and its effects are known as *hydraryria* from the Latin for mercury, *hydrargyrum*, Hg. This was also known as Hatter's Disease, because of the use of mercury salts in producing top hats in the 19th century. It is also called Minimata disease after an outbreak of mercury poisoning in Japan, due to industrial pollution of the estuary there.

The Mad Hatter in Alice in Wonderland

Cadmium and nickel can also cause poisoning, as can copper. But that's another story.

□

Chemicals in the news

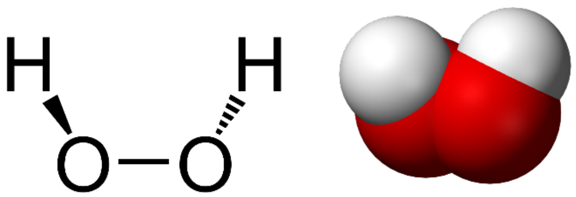
Hydrogen peroxide, H_2O_2

Hydrogen peroxide, H_2O_2, has had a bad press with its connection to several terrorist bombings. Before that it was known mostly for its connection to peroxide blondes, as it is a bleaching agent.

Honey has been known since ancient times to have healing properties when spread on wounds. This seems rather unusual but there is a scientific explanation. When the bees turn nectar into honey, they add an enzyme called glucose oxidase. This works slowly to break down glucose producing as a by-product hydrogen peroxide. Hydrogen peroxide is an antiseptic (as it oxidises and kills bacteria), so the honey is bactericidal and so helps wounds to heal.

Hydrogen peroxide decomposes to give oxygen gas, and this is accelerated by light, so must be stored in dark bottles with vented caps. Its concentration is often given either as % or as the number of volumes of oxygen produced from 1 cm^3. 20 volume (6%) hydrogen peroxide will produce 20 cm^3 of oxygen gas from every cm^3. The more concentrated the hydrogen peroxide the more reactive it is and usually in school we use 10 or 20 volume. **It is important not to mix up % and volume measures.** High concentrations of hydrogen peroxide have been used as the oxidiser in rocket fuels (see below.)

Structure and bonding



What a difference an O makes! Replacing one hydrogen in water by OH turns it into an unstable, strongly oxidising molecule. Pure H_2O_2 has a density of 1.45 g/cm^3 and boils at 150°C (and decomposes). It is pale blue in colour in the pure state and is a hydrogen-bonded liquid. Each oxygen has two lone pairs and it has a skewed structure, with the hydrogens offset from each other, so that the lone pairs are as far away from each other as possible. Its chemical reactivity is due to the long, weak O-O due to repulsion from the lone pairs (similar to the reactivity of F_2, also with a weak bond). All peroxides, which contain the O-O group, are very reactive and oxidising. The O-O bond breaks to give two free radicals, very reactive species on the look out for electrons to grab3. Organic peroxides are especially unstable.

Hydrogen peroxide and flying bombs

The V1 pulse jet flying bob was developed at Peenemunde, on the Baltic coast. It needed to get to flying speed before the pulse jet would work and so it had to be launched from a steam-powered catapult. This catapult was powered by the reaction between concentrated hydrogen peroxide and solid potassium permanganate.

$2\ KMnO_4 + 3H_2O_2 \rightarrow 2MnO_2 + 2KOH + 2H_2O + 3O_2$

"As the Argus pulsejet engine couldn't produce effective thrust until the flying bomb was up to flight speed, the V-1 was launched off a 48 meter (157 foot) long ramp using a steam catapult system, designed by the Walter company. The ramp contained a slot fitted with a dumbbell-shaped piston, and the flying bomb sat on a simple trolley that was linked to the piston. The piston was held in place with a shear pin.

A cart containing a reaction chamber and tanks of with hydrogen peroxide (H_2O_2) and granules of potassium permanganate ($KMnO_4$) catalyst was connected to a chamber at the base of the ramp whose other end was plugged by the piston. When the hydrogen peroxide was pumped over the potassium permanganate, it was converted into large quantities of hot steam that built up pressure against the piston. When the pressure built up to a certain level, it broke the piston's shear pin and the trolley rapidly moved up the ramp."
http://www.axishistory.com/index.php?id=1362

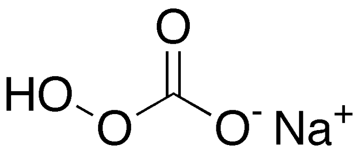
History of hydrogen peroxide propulsion

http://www.peroxidepropulsion.com/article/2

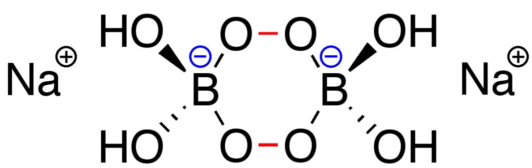
Aqueous solutions of $KMnO_4$ have been used together with T-Stoff (i.e. 80% hydrogen peroxide) as propellant for the rocket plane Messerschmitt Me 163. In this application, it was known as Z-Stoff. This combination of propellants is sometimes still used in torpedoes.

Laundry bleaches

Hydrogen peroxide is used to make sodium percarbonate and sodium perborate which are used in solid bleaching agents or as additives to detergents used for home laundry. The key feature of each is the peroxide link, O-O. The products often say 'oxygen bleach' on them, but they only work effectively over 60ºC. For lower temperature use an activator must be added.



Sodium percarbonate



Sodium perborate

You can do a nice iodine-thiosulfate titration to measue the % of bleach in commerical products. A weighed sample of bleach is used to liberate iodine from acidified potassium iodide solution. This can then be estimated by titration against standard thiosulfsate solution, using starch as an indicator near the end-point.

Some demonstrations using hydrogen peroxide

Cannon fire demonstration:

Pour 30 cm^3 20 vol (6%) (or 5 cm^3 30% (100 vol) hydrogen peroxide plus 25 cm^3 water) and 20 cm^3 ethanol into a large evaporating basin. Light the ethanol which will burn with a colourless flame. Now sprinkle some crystals of potassium permanganate into the flame. There will be a series of sharp cracks (cannon fire) as the $KMnO_4$ reacts with H_2O_2 to produce oxygen and heat, which causes small explosions with the ethanol. The reaction subsides as the $KMnO_4$ is used up but can usually be initiated again with fresh $KMnO_4$. The reaction will be more vigorous with more concentrated H_2O_2. Use a safety screen and have a white tile ready to quench the flame.

Source:
http://media.rsc.org/Classic%20Chem%20Demos/CCD-83.pdf

Elephant's toothpaste:

Pour 5 cm^3 30% (100 vol) H_2O_2 into a large measuring cylinder and add a few squirts of some washing up liquid. Sprinkle in some $KMnO_4$ crystals. The reaction liberates heat and oxygen gas, which forms a foam and rises up and over the top of the measuring cylinder. Put the measuring cylinder in a plastic bowl to catch the overflow. This makes it easy to clean up.

The reaction can also be done using KI solution, solid MnO_2 and fresh liver as catalysts. The rate of the reaction will increase with the concentration of H_2O_2.

This is a versatile and interesting demonstration which can be used to show: effect of concentration of H_2O_2 on reaction rate; illustrate heterogeneous (MnO_2), homogeneous (KI solution) and enzyme catalysis (liver); illustrate the difference between fresh and denatured liver due to enzyme deactivation. Use a glowing splint to show that the bubbles contain oxygen. By adding food colours to the initial mix, you can colour the foam different colours.

If you use 6% H_2O_2 this could be done in boiling tubes by students, inside a large beaker to catch the overflow.

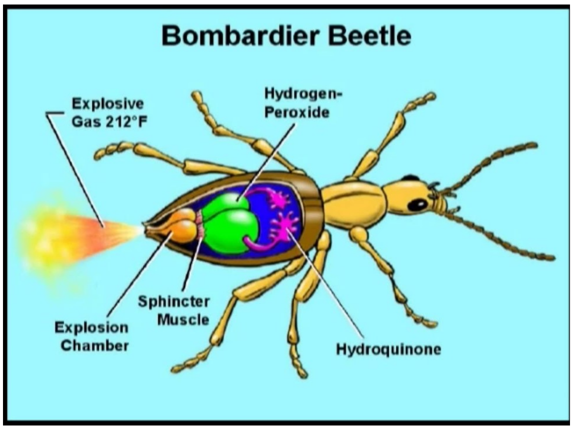
A variation of this is 'instant cappucino': Pour some 30% H_2O_2 into a large beaker, add some washing up liquid and sprinkle in some solid $KMnO_4$. The mixture foams up and a brown colour is left at the top (MnO_2), so it looks like cappuccino.

Glow sticks:
Hydrogen peroxide reacts with certain di-esters, such as phenyl oxalate ester (cyalume), to produce chemiluminescence; this application is most commonly encountered in the form of glow sticks. Two solutions are contained in a sealed plastic tube. When the inner glass phial is broken by bending the stick, the solutions mix, react and cold light is emitted. The addition of fluorescent dyes gives light sticks of various colours. Light sticks can be used to show the effect of temperature on reaction rate: moving an activated light stick from cold water to hot water increases the brightness as the reaction speeds up. This process is reversible.

Joke: Two men went into a bar. 'I'll have a glass of H_2O' said the first. The second said, I'll have H_2O too.' He drank it and died.

Chemical warfare

Chemical warfare is not confined to humans. The bombardier beetle uses hydrogen peroxide to create a burning, chemical spray.



"The spray is produced from a reaction between two chemical compounds, hydroquinone and hydrogen peroxide, which are stored in two reservoirs in the beetle's abdomen. When the aqueous solution of hydroquinones and hydrogen peroxide reaches the mixing chamber, catalysts facilitate the decomposition of the hydrogen peroxide and the oxidation of the hydroquinone. Heat from the reaction brings the mixture to near the boiling point of water and produces gas that drives the ejection. The damage caused can be fatal to attacking insects. Some bombardier beetles can direct the spray in a wide range of directions."
https://en.wikipedia.org/wiki/Bombardier_beetle

□

Information page

Sponsors

The sponsors whose logos are featured on the outer back cover mostly give donations of between €250 to €1,000 per year to enable the production and distribution of *Chemistry in Action!* free of charge to Irish Chemistry teachers. Some of these sponsors have been supporting the magazine since the first issue, and have helped to ensure its continuance over the last 40+ years. Their help is much appreciated.

*****

Contributions wanted!
Contributions are always welcome to *Chemistry in Action!* providing the material is of interest to second-level chemistry teachers. Articles, experiments or demonstrations, teaching tips, book and AV reviews etc. are all welcome.
Send one hardcopy + diagrams and a copy on disc (or by email as a Word document) when submitting material.
You can contact the editor by email at: peter.childs@ul.ie or one of our assistant editors.

*****

Internet version

The most recent back issues plus some TY Science modules and other resources are available at: www.cheminaction.com
For information contact the web editor, Maria Sheehan at mariasheehan400@gmail.com

*****

Editorial correspondence

If you want to communicate with the editor for any reason, please use the following information:

Dr.Peter E. Childs
Hon. Editor
Chemistry in Action!
University of Limerick,
Limerick, Ireland.
E-mail: peter.childs@ul.ie

Communications in writing/e-mail are preferred not phone calls!
You can also send contributions to one of the assistant editors:
Marie Walsh marie.walsh@lit,ie
Maria Sheehan
mariasheehan400@gmail.com
Sarah Hayes sarah.hayes@ul.ie
Anne O'Dwyer anne.odwyer@mic.ul.ie

*****

TY Science Modules

We have discontinued selling these modules as postage got too expensive. At present 6 of them are available online, free of charge, at our website: www.cheminaction.com

*****

In the next issue #117:

Proceedings ChemEd-Ireland 2020

Gemstones Part 2
by Adrian Ryder

Acknowledgements

The Editor would like to thank the President of the University of Limerick for encouraging the publication of *Chemistry in Action!* and for the use of university facilities in its production, printing and distribution. A special thanks to Marie Walsh for her invaluable assistance over many years in producing *Chemistry in Action!,* and to the other assistant editors. The financial help of the companies and bodies, whose logos are given below, is gratefully acknowledged, as they make it possible since 1980 to produce and distribute *Chemistry in Action!* free-of-charge to Irish chemistry teachers.