Chemistry In Action!

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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**.

Cover design: George Fitzgerald, Mobius Design
Cover photo: Sparkling chemistry at the demonstration workshop (Photo: Oisin McHugh Tru Media /SSPC)
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Editorial #114

CinA!s 40th birthday

Chemistry in Action! was launched in May 1980 at the Institute of Chemistry of Ireland's annual Congress in Sligo. Spring 2020 will thus mark its 40th birthday and we hope to hope to have a special issue with articles looking back over the past 40 years. However, if you are chemistry teacher and have been reading it at some time in the last 40 years, you might like to send in your own comments. I think a lot has happened in 40 years in almost every aspect of Irish life and not least in education.

The deadline for material is the end of January 2020. Looking back in my files over the last 40 years I found a collection of limericks and a competition to get teachers or their students to write science-based limericks. I would like to do this again for the 40th issue – there are no prizes apart from publication of the best ones in issue 115.

A new era?

This year sees the first cohort of the new junior science courses entering either Transition Year (TY) or the LC programme. The majority are now doing TY and so we will have to wait a year to see the full impact that the new, reduced junior science course will have on LC science uptake and performance.

There is a big question over whether this batch of students will be adequately prepared to start the LC programme, both in content and learning style. They will have done less science in each of the main areas and will have been taught in a different way. Ideally the LC science courses should have been revised already so that students could make a seamless transition from the junior to senior cycle. However, this does not seem to be likely in the near future. This idea of transition is the theme for the 2020 ISTA Conference, which is earlier than usual – Feb. 7-10 and is in Dublin again.

The conference theme is:
From Junior Cycle Science to Leaving Certificate Biology, Chemistry and Physics: Issues and Challenges.

Does one size fits all?

In shoes and clothes one size does not fit all. The move to a common level course and examination in Junior Cycle Science implies that one size does fit all when it comes to education. This is clearly not the case as any parent or teacher will tell you. Children vary widely in their ability and interests. In the past teachers had problems teaching Higher and Ordinary level students together. Trying to fit a course and an examination to all students, over the whole ability range, inevitably means aiming at the lowest common denominator. It also exposes the weakness in Irish curriculum development that everything is controlled by one body, the NCCA, which has not shown itself very responsive the criticism e.g by the ISTA and the Hyland Report on the new LC science specifications. No other body is allowed to design or approve or offer a school course or introduce a new syllabus. If this were true in the UK, which is isn't, we would never have had the Nuffield science courses or the Salters courses, or 21st Century Science. These were all the product of what we might call private initiative, funded by charitable bodies, and competing in the marketplace with other syllabi for students. Even then teachers and schools have a choice of multiple science syllabi from four examination boards, giving schools great freedom to tailor their subject offerings to their own needs. Ireland has missed the chance to get a context-based science course, like those available in the UK, USA and Germany, among others. In 2000 the NCCA did propose such a course in Physical sciences to replace Physics & Chemistry, but it has never been heard of since (see p. 8). If this option for developing new courses were open in Ireland maybe schools would have had the option of offering Project Maths or the former Maths syllabus, or both, rather than having no choice but to take what was offered.

Gender and STEM choices

There is a continuing debate over why boys have a stronger preference for STEM courses at third level and hence STEM careers. The evidence suggests that it is not due to innate ability but to other influences. On pp. 9&10 we note two important recent reports on this issue. One based on Irish CAO and LC data and the other based on PISA data on 300,000 students from 64 countries.

Peter E. Childs
Hon. Editor

Guide to issue #114

I hope you will find plenty to interest you in this issue, which continues to feature the International Year of the Periodic Table (IYPT) – p. 34-38. I hope you have or will take the opportunity to promote science and chemistry through the Periodic Table. The Periodic Table is not just for 2019, of course, but is the central idea in Chemistry.

There is quite a bit in the Education News section, especially the two papers looking at gender and STEM choice (pp. 9&10). We also have the annual report on chemical education produced for the EuCheMS Division of Chemical Education (p. 12) and some personal views on the new Junior Science course and curriculum development (p. 18).

On p. 6 we have an analysis of the 2019 LC results in science and CAO first preferences, which used to be an annual feature. Continuing the science education theme, we have an interesting article from Rachel Mamlok-Namaan, the new chair of the EuCheMS Division of Chemical Education, on Professional Learning Communities for science teachers in Israel (p. 22). There is also an article from Ingo Eilks and his group from Bremen on the use of graded learning aids in inquiry-based teaching (p. 28).

An interesting European project called RACE, Raw Communications and Engagement, is described on p. 43, followed by two articles by postgraduate students describing their research, produced as part of the project (p. 46 & 48).

I hope many of you have enjoyed Adrian Ryder's articles on famous scientists – in this issue he features the Henry family (p. 51). Adrian has also started a series on gemstones and their colours, as this is one of his hobbies (see p. 58). Colour and chemistry is a fascinating topic, with lots of everyday applications (see also p. 66 for Colour and Complexation.)

Muireann Sheehan completed her PhD on chemistry misconceptions in 2018 and as part of the project she produced a website for student teachers called SubAtomic. This is full of useful resources on the topic of chemical misconceptions and it is now available for anyone to use (see p. 56) for details.

The great limerick competition

To mark the 40th birthday of *Chemistry in Action!* I would like to publish some original science-themed limericks in issue 115 (Spring 2020). Getting your classes to write poetry is a great way to stimulate their interest, to bring the arts into science, and to make them think about the scientific ideas. If you like the idea set it as a competition in your school, maybe for Science Week 2020, and send the nest ones in by January 2020. There are no prizes apart from the honour of being published!

This issue also features another TEMI idea (p. 39) on melting ice cubes. The idea behind TEMI is to use a scientific mystery or discrepant event, or a demonstration presented as a mystery, to get students thinking and suggesting answers, which can be followed up in enquiry activities. We'd be interested to hear from teachers who were involved in the TEMI project, or attended one of many TEMI workshops, about whether they have used the approach and how successful (or not) it has been.

Education News and Views

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

First common level science paper

June saw the first cohort of students taking the common level Junior Science paper based on the new specification and shorter course. The comments by teachers after the paper were not generally very positive as the common paper was thought to be too easy and not challenging enough for brighter students. It remains to be seen how this will affect LC science enrolments and how many students will drop out when they realise the greater demand of the LC courses. (See p. ** for more comment on this issue.)

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2020 ISTA conference

The **ISTA Annual Conference 2020** will take place in the **Explorium, on Saturday 8th February 2020.** The conference will open on Friday 7th February in the Conference Hotel with a keynote speaker - details to be confirmed. The change from the previously advertised data is due to all the flux in the Science Education landscape and the Sustainability of Science Education in Ireland. The theme this year is ***From Junior Cycle Science to Leaving Certificate Biology, Chemistry and Physics: Issues and Challenges.***

All conference participants will also have the unique opportunity of trying out some of the activities in the Explorium - a great place for school tours of all ages.

Conference Hotel: **Clayton Hotel**, Leopardstown, Dublin, D18 NR24

Registration and more details will be online via a conference website later: **www.istaconference.com**

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ChemEd-Ireland 2019

Saturday October 19th.
Technological University Dublin
Claire.mcdonnell@dit.ie

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Changes in EuCheMS DuvChemEd

Dr Odilla Finlayson (DCU) took over this year as the Irish delegate to EuChems Division of the Chemical Education, with Dr Sarah Hayes (UL) as the alternate delegate. They replaced Dr Peter Childs (UL) who was the Irish representative for the last 20 years.

At the Council meeting held in July in Prato, Italy conjunction with Eurovariety, Dr Rachel Mamlok-Namaan, Israel, took over as Chair from Dr Iwona Maciejowska, Poland. Dr Odilla Finlayson (Ireland) was elected as secretary. The next sponsored conference will be ECRICE to be held in the Weizmann Institute, Israel from July 6-8 2020.

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First science education lecturers at UL

The University of Limerick has a strong and long record in science education, producing science teachers since the 1970s. It has had a Professor of Science Education for some time, now Merrilyn Goos and formerly Sibel Erduran, who heads up EPI*STEM. Until now there have been no formal appointments in science education. UL has now appointed two lecturers in Education with specialism in science Dr Aishling Flaherty and Dr. Stephen Comiskey.UL is also launching a Professional Masters in Education (Science) in September, a two-year, full-time course.

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RSC Higher Education Teaching Award 2019

Dr Barry Ryan of Technological University Dublin has won the RSC HE Teaching Award for 2019. As part of the award he will give a lecture tour. Three previous winners have been from Ireland, including two more from Dublin Institute of Technology (now Technological University Dublin).

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RSC Inspirational Member award

In May 2019 Dr Michael Seery was given a special award by the RSC as an Inspirational Member for dedication to the diversification of the programmes for both the Chemical Education Research Group and the Edinburgh and South East Scotland Local Section.

New Editor for CERP

In January 2019 Michael also took over as Editor of CERP (Chemistry Education Research and *Practice).*

Chemistry Education Research and Practice is delighted to announce the appointment of Michael Seery as our new Editor. Michael takes on the editorship from Keith Taber having served *CERP* as Associate Editor since 2016.
Paul MacLellan
http://blogs.rsc.org/rp/2019/01/24/new-editor-michael-seery/?doing_wp_cron=1567699672.5584380626678466796875

I am really delighted to have been appointed as the new Editor of Chemistry Education Research and Practice. *I have long been a fan of the journal, since coming across an article in it at the beginning of my career as a lecturer in chemistry. The discovery that there was a journal dedicated to supporting and promoting best practice in chemistry education was a very pleasant surprise! Since then I have been involved with the journal in various guises, being a member of the advisory board, a guest editor for a special issue on technology in chemistry education, contributing my own articles, and since 2016, being Associate Editor of the journal.*

The support of the Education Division mean that CERP *is free to access and demonstrates the Society's commitment to supporting the research into, and practice of, chemistry education. As I take on the role of Editor, it prompts thought about the direction of the journal and where my own focus lies. Discussions with the Associate Editors of the journal – Ajda Kahveci and Scott Lewis – led us to consider some particular aspects that we wish to focus on. These motivations grew out of considering the value of the journal to the reader. First, we intend to continue to grow the capacity of* CERP *in reviewing the state of our field, so as to be a useful point of reference both for those new to the field as well as those who are experts in it. Second, there is an onus on those of us sharing our work to ensure it is conducted and reported to the highest standards, and the journal will continue the work championed by previous editors in expecting and showcasing the very highest quality in education research methods. And third,* CERP *is unique in the RSC suite of journals as it is a journal with two audiences – those who are experts in the field, publishing education research – and those who are experts in using outcomes of that research in their practice. The journal then has (at least) two categories of reader, and we will continue to develop strategies to ensure value and use to both researcher and practitioner.*

I have no hesitation in stating that taking on the new role is a daunting prospect. The founding editors of the journal, Stephen Breuer and Georgios Tsaparlis, created something really unique and worked hard to grow the journal to the point that it became included in Thomson Reuters Citation databases. They were succeeded by Keith Taber, who has left a long legacy of editorials informing on research methods, and grown the journal substantially in its scope and reach. Keith was also a wonderful mentor to me as Editor, and I have learned an enormous amount from him during my term as Associate Editor. CERP *is also extraordinarily fortunate in the reviewers who give their time to us – the quality of their reviewers is something that is often commented upon.*

Therefore it is with the readers, my editor colleagues, former editors, and reviewers in mind, that I endeavour to work to continue to grow and develop this wonderful journal. I look forward to your submissions!

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2019 Leaving Certificate Results

The 2019 LC Results were released on August 13th this year and the full details can be accessed at www.sec.ie website.

The graph of the % uptake of LC science subjects 2006 to 2019 is shown below. Physics with Chemistry is excluded as it is less than 1% (see Table 2)

In 2019 56,071 (54,440) students took the LC with 2,716 (2,709) taking the LC Applied (2018 figures in brackets). It is expected that the LC numbers will increase in future years with population growth, as the bulge works its way through the school system.

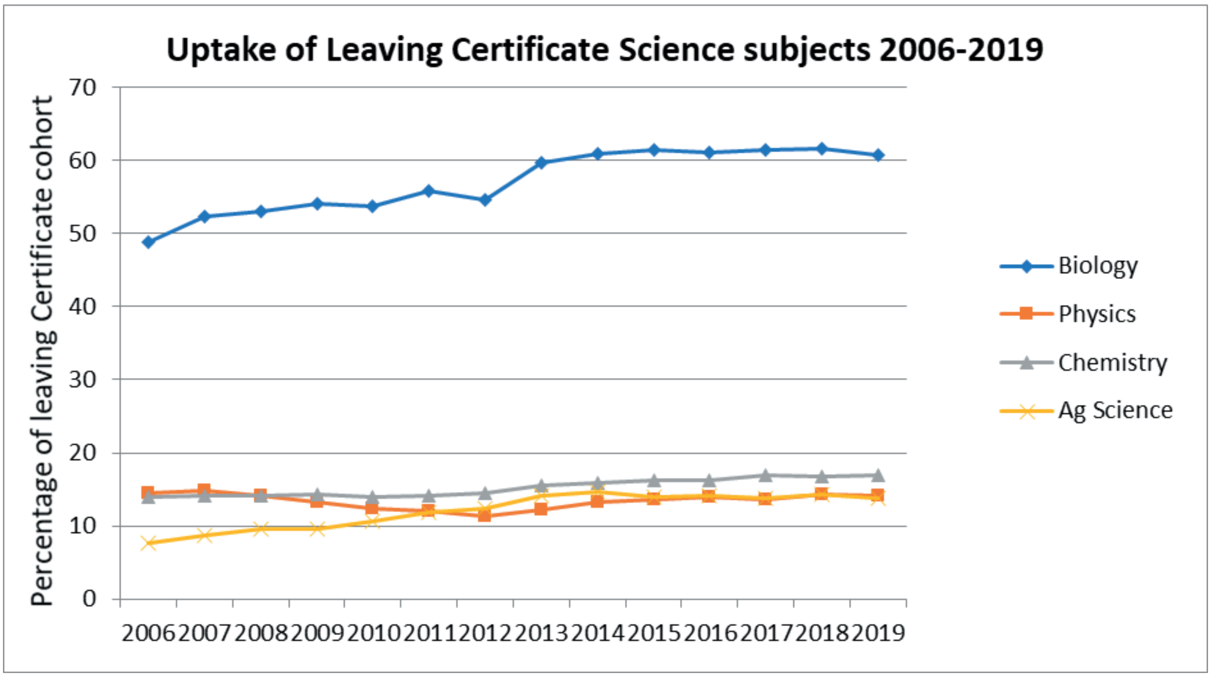

Figure 1: % taking LC science subjects 2006-2019

Table 1: LC science statistics 2004-2019- % of cohort taking each subject (Source: SEC)

Year	Biol	Phys	Chem	AgSc	P+C
2004	43.5	14.8	13.1	5.5	1.4
2005	46.9	14.7	13.6	6.3	1.3
2006	48.8	14.4	13.9	7.7	1.1
2007	52.3	14.8	14.1	8.7	1.1
2008	53.1	14.2	14.2	9.5	1.2
2009	54.1	13.3	14.3	9.6	1
2010	53.7	12.4	13.9	10.6	0.8
2011	55.8	12	14.1	11.9	0.9
2012	54.7	11.4	14.5	12.3	0.76
2013	59.7	12.2	15.45	14.05	0.8
2014	61	13.3	15.9	14.7	0.8
2015	61.5	13.6	16.2	13.9	1.2
2016	61.2	13.9	16.3	14.1	1
2017	61.5	13.6	17	13.7	1.05
2018	61.6	14.3	16.8	14.3	0.95
2019	60.8	14.2	16.95	13.8	0.96

Biology continues to be the dominant science subject, although its % uptake is down slightly. Chemistry retains second place at just under 17% uptake and is still holding its market share steady. In the last two years physics has increased its numbers and now takes third place again for the first time since 2012, just pipping Ag. Science. These data can be seen in Table 2.

Table 2: LC science statistics 2019 (Source SEC)

Subject		**HL**	**OL**	**HL+OL**	**% total LC**	**G:B ratio**
Biology	Boys	10,049 (37.1%)	3,622 (51.4%)	13,671 (40.1%)		
	Girls	17,014 (62.9%)	3,424 (48.6%)	20,438 (59.9%)		
	Total	27,063 (79.3%)	7,046 (20.7%)	**34,109**	**60.8**	1.49:1
Chemistry	Boys	3,411 (41.4%)	656 (52.0%)	4,067 (42.8%)		
	Girls	4,833 (58.6%)	606 (48.0%)	5,439 (57.2%)		
	Total	8,244 (86.7)	1,262 (13.3%)	**9,506**	**16.95**	1.34:1
Physics	Boys	4,714 (71.6%)	1,112 (81.8%)	5,826 (73.4%)		
	Girls	1,869 (28.4%)	247 (18.2%)	2,116 (26.6%)		
	Total	6,583 (82.9%)	1,359 (17.1%)	**7,942**	**14.2**	0.36:1
Ag.Science	Boys	3,692 (55.9%)	831 (72.9%)	4,523 (58.4%)		
	Girls	2,913 (44.1%)	309 (27.1%)	3,222 (41.6)		
	Total	6,605 (85.3%)	1,140 (14.7%)	**7,745**	**13.8**	0.71:1
Phys+Chem	Boys	264	52	316		
	Girls	200	22	222		
	Total	464	74	**538**	**0.96**	0.70:1

Girls are the majority in biology (3:2) and increasingly in chemistry (4:3), whereas boys dominate physics (3:1) and to a lesser extent ag. science (3:2). The uptake of the combined physics with chemistry course continues to be small and given the outdated syllabus and small numbers, one wonders why it is still offered. The SEC should either offer a new course or replace perhaps with a combined science course to follow on from junior science. This might attract students who now take biology as their main or only science subject.

This year sees the first cohort of the new junior science courses entering either Transition Year (TY) or the LC programme. The majority are now doing TY between the junior and senior cycles and so we will have to wait a year to see the full impact the new, reduced junior science course will have on LC science uptake and performance.

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First preferences for Level 8 courses

SUBJECT	2019	2018	+/-
Education	5,301	5,185	2%
Arts	7,481	7,832	-4%
Humanities (except languages)	3,149	2,276	38%
Languages	887	716	24%
Interdisciplinary programmes and qualifications involving arts and humanities	65	113	-42%
Social and behavioural sciences	5,167	4,753	9%
Journalism and information	234	512	-54%
Business and administration	9,562	9,918	-4%
Law	2,759	2,698	2%
Biological and related sciences	3,024	2,855	6%
Environment	296	237	25%
Physical sciences	1,091	1,093	0%
Mathematics and statistics	557	508	10%
Interdisciplinary programmes and qualifications involving natural sciences, mathematics and statistics	971	873	11%
Information and communication technologies (icts)	3,920	3,836	2%
Engineering and engineering trades	4,023	3,607	12%
Manufacturing and processing	406	404	0%
Architecture and construction	2,155	2,130	1%
Agriculture	471	399	18%
Veterinary	886	935	-5%

SUBJECT	2019	2018	+/-
Interdisciplinary programmes and qualifications involving agriculture, forestry and veterinary	479	576	-17%
Health	12,829	13,146	-2%
Welfare	2,488	2,449	2%
Personal services	2,192	2,324	-6%
Hygiene and occupational health services	111	113	-2%
Transport services	46	33	39%
SPECIALIST GROUPS			
Primary education	2,870	2,893	-1%
Secondary education	2,110	1,882	12%
Dentistry (including dental nursing and hygiene)	372	354	5%
Medicine	2,876	2,918	-1%
Nursing and midwifery	5,410	5,751	-6%
Pharmacy (including pharmacy technician)	448	376	19%
Art, design and media (techniques and production)	2,689	2,669	1%
Veterinary medicine	483	504	-4%
Physiotherapy	724	723	0%

70,550 Level 8 applications 2019

69,521 Level 8 applications 2018

+1,029 Difference

40,928 Level 6/7 applications 2019

41,743 Level 6/7 applications 2018

-815 Difference

Applications for Physical Sciences (which includes chemistry) are constant but those for environmental science are up by 25%, and Biological Sciences by 6%. Secondary education is up by 12%.

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What happened to the Physics & Chemistry course?

The Physics & Chemistry combined courses has not changed for over 40 years! Take-up each year is very small and it is only offered by a few small schools. Theoretically it offers a students a chance to study elements of Physics and Chemistry, rather than a full subject. The syllabus is badly out-of-date and out of line in its format and presentation to the current LC science courses, which were revised in the early 2000s. Clearing out my old files I came across the NCCA draft Physics & Chemistry syllabus, with a recommended title Physical Science, published for comments in August 2000 i.e. nearly 20 years ago. Nothing as far as I know ever happened to this syllabus and it was never implemented. I remember commenting at the time that this was a worthwhile attempt to modernise the syllabus but also to take a new approach to syllabus design. It has the four-column syllabus we are familiar with, but instead of being presented as a Chemistry section and a Physics section, it is presented as 7 units. These are:

Unit 1: Atomic structure and the Periodic Table
Unit 2: Waves and Light
Unit 3: Material Science
Unit 4: Medical Physics
Unit 5: Science of the Environment
Unit 6: Telecommunications
Unit 7: Astrophysics

I like the practical, applied and social aspects of several of these topics, although 4 are clearly Physics and only three Chemistry. It might have been more equitable to include an eighth unit focused on Chemistry.

What a lost opportunity to revive this subject and make it more attractive to students! The presentation is similar to modern context-based courses like the Salters courses in the UK and this was and is a welcome innovation. If it were revised today, I would probably include Nanoscience as a unit, which brings in both Physics and Chemistry. If this had been introduced when the other revised courses were introduced (2000 and 2002), I would expect that the uptake of Physical Science would now be higher than the unreconstructed Physics & Chemistry course. There is still a strong case for introducing it and most of the work has already been done.

There is also a case for providing a new LC Science course, including elements of Chemistry, Biology and Physics. This would provide students and schools with an alternative to the current courses and would suit students who only want one, broadly-based Science course and do not want to specialise. Such a course could be taken with Agricultural Science (as is the case with Biology), but not with the other single sciences. A similar structure to the embryonic Physical Science could be envisaged, with 7 or 8 context-based units, with at least 2 focusing on each of the three core sciences, and 1 or 2 units which were deliberately interdisciplinary. Needless to say, such a new course should follow the existing model of a detailed syllabus and not the NCCAs proposed undetailed specifications for the new LC science subjects. Learning outcomes alone do not make a teachable course; often it is said that 'less is more', but in reality 'less is less'.

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It's not just for boys! Understanding Gender Differences in STEM

Judith M Delaney & Paul J Devereux
WP19/05
February 2019
Economic and Social Research Institute,
University College, Dublin
https://www.ucd.ie/economics/t4media/WP19_05.pdf

This is an interesting and timely report on the effect of gender on subject choice in relation to STEM subjects based on CAO applications (2015 and 2017) and the corresponding LC grades.
"We find that differences in overall Leaving Certificate achievement between boys and girls have a negligible effect on the STEM gender gap. While there are systematic gender differences in subject-specific grades with boys doing better in mathematics and girls doing better in most other subjects, we estimate that male comparative advantage in STEM (as measured by Leaving Certificate subject grades) explains only about 3 percentage points of the 22-points gender gap. We find that boys and girls use different decision-making strategies when deciding whether to choose STEM with boys tending to look at their (intra-individual) comparative advantage in mathematics and English, while girls are more likely to decide based solely on their mathematics ability. We also find that comparative advantage plays a larger role for higher achieving students.

Leaving Certificate subject choices are much more important than grades in explaining the STEM gender gap. Differential subject choice in school may partly arise due to availability as boys' schools are more likely to offer STEM-friendly subjects for the Leaving Certificate. However, the gender gaps in Leaving Certificate subject choices are just as large in mixed gender schools, suggesting differential availability is not a major factor. Overall, we attribute most of the explained STEM gender gap to differences in subject choices between boys and girls in secondary school. Even two years before college entry, there are systematic gender differences in decision-making that lead to boys being more likely to choose STEM subjects in college." (p. 6-7)

Table 3 from p.14 shows the subjects taken by boys and girls, overall and in mixed schools. There is little difference between the overall data and those from mixed schools. Girls favour Biology (78% to 54%), Chemistry (20% to 17%), but not Physics (7% to 24%) or Ag. Science (11% to 16%). The report also has data on how many schools offer each subject, based on LC entries. 100% of schools offer English, Irish and Maths, as well as Biology. Girls have less chance to do Physics, Ag, Science and Applied Maths, but the same chance of doing Chemistry.

Schools offering STEM subjects

Subject	Boys	Girls
Biology	100%	100%
Chemistry	92%	93%
Physics	91%	84%
Ag. Science	69%	61%
App. Maths	55%	38%

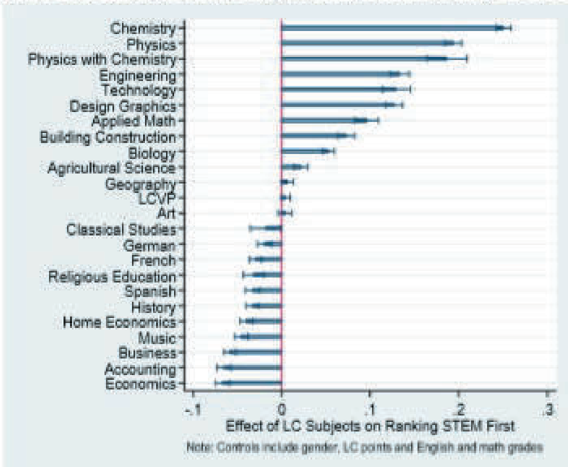
Table 3: Leaving Certificate Subjects Studied by Gender

	Overall		Mixed Schools	
	Male mean	Female mean	Male mean	Female mean
Irish	0.89	0.92	0.88	0.91
English	1.00	1.00	1.00	1.00
Math	1.00	1.00	1.00	1.00
History	0.25	0.19	0.25	0.18
Geography	0.48	0.40	0.47	0.40
Physics	0.24	0.07	0.23	0.06
Chemistry	0.17	0.20	0.16	0.18
Biology	0.54	0.78	0.52	0.78
Physics with Chemistry	0.01	0.01	0.02	0.01
Agricultural Science	0.16	0.11	0.18	0.15
Applied Math	0.06	0.02	0.06	0.02
French	0.47	0.59	0.43	0.59
Spanish	0.11	0.14	0.12	0.14
German	0.14	0.16	0.14	0.14
Economics	0.14	0.07	0.10	0.06
Accounting	0.14	0.12	0.11	0.10
Business	0.32	0.31	0.28	0.30
Art	0.11	0.22	0.10	0.25
Music	0.08	0.17	0.09	0.17
Home Economics	0.04	0.37	0.06	0.41
LCVP	0.24	0.30	0.29	0.36
Design Graphics	0.18	0.03	0.20	0.04
Engineering	0.15	0.01	0.22	0.02
Building Construction	0.24	0.02	0.30	0.04
Technology	0.04	0.01	0.04	0.01
Religious Education	0.02	0.02	0.02	0.03
Classical Studies	0.01	0.01	0.01	0.01
Observations	72,865	80,453	46,336	45,096

The probability of studying STEM subjects increases with Maths grade but decreases with English grade i.e. good results in Maths favour the take-up of STEM, but good results in English have the opposite effect.

The authors also looked at which subjects favoured STEM (Figure 2, p.20). These results are interesting in that they show that studying Chemistry, followed by Physics and Physics with Chemistry, have the biggest effect on choosing STEM subjects. Biology has a much smaller effect as does Ag. Science.

Figure 2: The Effect of Leaving Certificate Subjects on Ranking STEM First



This is an important study and should be carefully studied.

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Girls’ comparative advantage in reading can largely explain the gender gap in math-related fields

Thomas Breda and Clotilde Napp

PNAS July 30, 2019 116 (31) 15435-15440; first published July 15, 2019
https://www.pnas.org/content/116/31/15435

This is another important paper on the factors affecting subject choice between boys and girls. It was based on the sample of 300,000 students in 64 countries in the last PISA study (2012). It looked at the comparative importance of reading and maths between boys and girls. Here is the abstract of the paper.

“Gender differences in math performance are now small in developed countries and they cannot explain on their own the strong underrepresentation of women in math-related fields. This latter result is however no longer true once gender differences in reading performance are also taken into account. Using individual-level data on 300,000 15-y-old students in 64 countries, we show that the difference between a student performance in reading and math is 80% of a standard deviation (SD) larger for girls than boys, a magnitude considered as very large. When this difference is controlled for, the gender gap in students’ intentions to pursue math-intensive studies and careers is reduced by around 75%, while gender gaps in self-concept in math, declared interest for math or attitudes toward math entirely disappear. These latter variables are also much less able to explain the gender gap in intentions to study math than is students’ difference in performance between math and reading. These results are in line with choice models in which educational decisions involve intraindividual comparisons of achievement and self-beliefs in different subjects as well as cultural norms regarding gender. To directly show that

intraindividual comparisons of achievement impact students' intended careers, we use differences across schools in teaching resources dedicated to math and reading as exogenous variations of students' comparative advantage for math. Results confirm that the comparative advantage in math with respect to reading at the time of making educational choices plays a key role in the process leading to women's underrepresentation in math-intensive fields."
It would seem that because girls are better in reading at age 15 than boys, that they tend to prefer non-STEM subjects with less Maths content, whereas the reverse is true of boys.

Here is a comment from *Physics World* (19/7/19) quoting Thomas Breda, the lead author of the study.
"Our interpretation is that students make comparisons of achievement in maths and reading to reach conclusions about their ability in a given field and to make educational decisions," says Breda. "A girl that is good at maths but even better at reading may feel less confident in maths and may favour humanities because she perceives herself as a verbal person."

The researchers claim that these differences "can explain up to 80% of the gender gap in intentions to pursue maths-studies and careers". They add that the contrast in reading and maths ability between 15-year-old girls and boys "is likely to be determined by earlier socialization processes".
https://physicsworld.com/a/girls-reading-ability-drives-the-science-gender-gap-claims-study/

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Pioneers of Science Education (PoSE)

PoSE is a series of article by Dr Peter Childs in the ISTA's journal SCIENCE. So far the series has covered:
1. Maria Edgeworth
2. Richard Dawes
3. James Wilson
4. Thomas Huxley
5. Br James Dominic Burke
6. Henry Armstrong
7. W. Mayhowe Heller
(current issue)

I hope you recognise several or all of these names. Several of these people have had a connection to Ireland. The education systems of Ireland and the U.K. were closely involved until 1922, and many ideas in science education have and continue to pass to and for across the Irish sea. I have a few ideas for further Pioneers of Science Education but I am always open to suggestions.
PEC

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Annual Report on Chemical Education in the Republic of Ireland 2018-2019

Compiled by Odilla Finlayson (DCU) and Sarah Hayes (UL)
ROI delegates to the EuChems Division of Chemical Education

SUMMARY

The most significant development in the last year has been the completion of the first full cycle of the new Junior Certificate Science course and this being examined for first time. The new course is shorter than the previous one, and includes coursework, and inquiry-based foci in addition to a terminal examination. The course aims to strike a balance between traditional learning of science and incorporating argumentation and scientific literacy. There have been mixed responses from teachers and pupils to the new course, with some teacher unions believing that the course does not adequately prepare students for Leaving Certificate Physics and Chemistry. Others welcomed the 'topical' and relevant nature of the examination paper, with references to climate change, depletion of iridium for mobile phone use, and research on the gut microbiome and stress-related disorders.

The other significant development in Chemical Education in Ireland was the decision to cancel the practical component of the revised Leaving Certificate programme. Main reasons cited for this decision were cost and logistical problems such as difficulty in recruiting examiners, the need to bring all school science laboratories up to similar standards, and fitting practical examinations into a crowded timetable for examination students. The Leaving Certificate Chemistry syllabus is currently being reconsidered.

POLICY DEVELOPMENTS

From September 2018, the first students will begin studying the **Leaving Certificate Computer Science and Physical Education** courses. Both subjects are being introduced to an initial group of schools, before both are rolled out nationally in 2020 to all schools who wish to teach them. The impact of these new subjects on update of other subjects at Leaving Certificate level will be interesting to monitor.

In October 2018, Science Foundation Ireland (SFI) and the Department of Education and Skills (DES) launched a study asking businesses across the country to **assess their science, technology, engineering and maths (STEM) engagement with schools**. This study is part of the STEM Education Implementation Plan launched in 2017 and aims to identify and encourage robust and sustainable partnerships between schools, business and industry, public sector bodies, research organisations, further and higher-level institutions, and the Arts.

In March 2019, (https://www.education.ie/en/Publications/Corporate-Reports/Strategy-Statement/action-plan-for-education-2019.pdf) CUMASÚ Empowering through learning - Action Plan for Education 2019 was launched. Actions planned during 2019 include:

- **Progressing implementation of the STEM Education Policy Statement 2017- 2026** and the Implementation Plan 2017-2019, including developing a work plan to increase the numbers of women participating in STEM

  through:

  - Develop a work plan as part of a coordinated response to increase the numbers of **females participating in STEM**, including the establishment of a females in STEM subgroup
  - Develop a work plan in relation to the **integration of Arts** education into all STEM learning experiences
  - Develop a **framework in relation to STEM partnerships** between Business/Industry and Schools to include an agreed set of mutually beneficial guidelines in relation to engagement

- Implement a **STEM advertising campaign** aimed at learners, teachers, school leaders and parents in order to increase participation levels in STEM subjects

The Action Plan also highlighted the action to commence a **review of the draft Leaving Certificate subject specifications** for Biology, Chemistry and Physics, including a new coursework assessment component
New University – in January 2019, the 4th University in Dublin (TU Dublin), was launched, combining DIT, IT Blanchardstown and IT Tallaght. TU Dublin, Ireland's first Technological University, where 'career-focused students, dedicated staff and academic excellence in science, the arts, business, engineering and technology converge to create the leaders of tomorrow'.
Ranking of Irish Universities has changed little over the year with the QS university rankings showing little sign of reversing their decade-long decline. (Table 1). Challenges of larger class groups are now critical factors in the Irish university sector. However, it should be said that a small country like Ireland does well to have 5 universities in the top 500 and both DCU and UL rank within the top 100 under 50 years old.

Table 1: QS ranking of Irish Universities (2018 - 2020)

HEI	2018	2019	2020
TCD	88	104	108
UCD	168	193	185
NUIG	243	260	259
UCC	283	338	310
DCU	391	422	422
UL	501-550	511-520	521-530
NUIM	701-750	701-750	701-750

STEM Research in Irish universities is in a healthy state due to the funding from Science Foundation Ireland (SFI) as well as funding from the EU. (www.sfi.ie) Minister for Training, Skills, Innovation, Research and Development announced a national investment of €3.6 million through SFI Discover Programme, to fund projects dedicated to educating and engaging the public in science, technology, engineering and maths (STEM). Through its SFI Discover Programme, it aims to develop a highly- engaged and scientifically-informed public. 41 diverse initiatives are supported by this year's programme with continuation funding for a further 11 projects. Some STEM initiatives that were funded in 2019 (and specifically targeted towards engaging girls and women in STEM, highlighted in Chemistry in Action) were:

- **SOPHia: Science Outreach to Promote Physics to Female Students (UL)** - a project that aims to encourage female students to take up physics as a Leaving Certificate Subject.
- **STEMChAT – Women as catalysts for change in STEM education (UL)** – looks at the recruitment of female undergraduate STEM Champions and industry mentors who will facilitate informal workshops with school students and parents, predominantly in disadvantaged areas.
- **Strength in Science (NUIG)** – The development of cross-curricular resources for science and PE teachers that are linked with the Biology, Physics and PE curricula that will increase girls' interest in both learning science and participating in exercise
- **Engaging Girls in CS - Code Plus (TCD)** – Female-only coding workshops facilitating a cohort of female speakers working in computing, to deliver career talks in girls' schools. Tech companies will host visits for teenage females.
- **Girls in DEIS Schools: Changing Attitudes /Impacting Futures in STEM (UCD)** - Students will engage with STEM by exploring the lives and impact of several female STEM pioneers, both historical and contemporary.

- **Let's talk about STEM: supports for girls' early science engagement (DCU)** - Parents and educators will participate in workshops to consider evidence on the role of language in differentially motivating girls' and boys' interest in and persistence with scientific learning

Female-only STEM Professors initiatives - In Nov. 2018 Minister of State for Higher Education, Mary Mitchell O'Connor, announced the Government's intention to create up to 45 new posts to boost women's representation in senior academic positions. In Irish universities, 50% of lecturers are women but only 24% of professors are women. This initiative, whose details are still to be worked out, aims to redress the balance and break the glass ceiling. The percentage of women in higher academic posts varies between institutions and between disciplines.

CURRICULUM DEVELOPMENTS

The new junior science course has been examined for the first time in in June 2019. The new course is shorter than the previous one (200 versus 240 hours) and includes an element of coursework and an emphasis on inquiry-based learning.

Specifications for the new Leaving Certificate science courses in Biology, Chemistry and Physics proposed the inclusion of a practical based assessment, assessing elements of the specification that were not possible to asses in the written paper. However following a pilot project run by the State Examinations Commission in 2018 and also a change in the Minister of Education and Skills, in Dec 2018 the Minister of Education announced that the practical exams in the new LC science subjects (biology, chemistry, and physics) as proposed by the NCCA, would be shelved due to cost and logistical problems. *"Instead, he has asked the curriculum advisory body to explore the option of a coursework assessment - such as a project - in biology, chemistry and physics, similar to what happens in some other subjects. Students would complete the coursework during the school year, under the guidance of teachers, and it would be marked by an examiner appointed by the State Examinations Commission (SEC).*

The NCCA , the body responsible for curriculum and assessment, examining the feasibility of integrating a coursework assessment component into the Leaving Certificate Chemistry / Physics / Biology specification. NCCA has also been requested to review the specification in light of the time that has passed since its development, including recent developments associated with the introduction of the new *Framework for Junior Cycle (DES, 2015)*, such as the implementation of the new specification for Junior Cycle Science. This group will hopefully generate a new specification for 2020!

OUTREACH AND INFORMAL LEARNING

Major national science events for school included:

- **BT YoungScientist &Technology Exhibition** in January 2019 - 3,773 students from 374 schools across the island of Ireland competed
- **Scifest** has again expanded this year, with 86 schools running SciFest@School Fairs 2018/19 and Regional events at 16 centres around the country. Winners from the Regional events then participate in the National Final.

Ireland has continued to participate in the **Science Olympiad** events with success:

- At IJSO (International Junior Science Olympiad in December 2019, Borswana, where Ireland secured two Bronze medals
- At EUSO (European Union Science Olympiad) in Portugal in May, where Ireland teams secured a Gold medal and Silver medal; this was the best ever performance by an Irish team at EUSO.
- At IChO (International Chemistry Olympiad) in Czech Republic and Slovakia in July 2018. Irealnd team travelling to IChO in Paris July 2019.
- The Irish Science Teachers Association Senior Science Quiz took place in the Tercentenary Hall in Trinity Biomedical Sciences Institute on Saturday November 24, 2018. Fifty teams of Leaving Certificate students representing 20 counties across Ireland participated. Almost 1100 Leaving

Certificate students took part in the Regional Finals held during Science Week and the top 150 LC students were invited to the BioPharmaChemical Ireland sponsored National Final.

Every year in Ireland Science Week and Chemistry Week just so happen to fall back to back, which gives our Irish RSC members plenty of opportunities to promote the chemical sciences. This year was no exception with dozens of Irish RSC members organising and collaborating on events nationwide to showcase chemistry to school students and the general public.
Careers in Chemistry: This annual event is run by our Irish Education Coordinator, John O'Donoghue, in partnership with the School of Chemistry at Trinity College Dublin. This year the event showcased the diversity of chemistry careers with frank and honest discussions from experienced chemists. Nearly 400 senior secondary school students spent their day with an eclectic array of chemists – including a politician and sports star – as well as researchers and industry professionals.

EDUCATIONAL STATISTICS

Chemistry continues to hold its position as the second most popular LC science subject (Figure 1), taken by approx. **17%** of students although Biology attracts almost 63% of all students taking Leaving Certificate. Physics and Agricultural Science have similar uptakes of 14.1% and 14.5% respectively. The gender split in each of the science subjects is interesting with **Chemistry** tending towards equal participation - (**55.5% Female**), Biology (60.1% Female), Agricultural Science (40.5% Female) and Physics (27.5% Female). In comparison to 2017, 2018 showed a slight increase in female participation (0.5% chemistry and 1% in Physics)

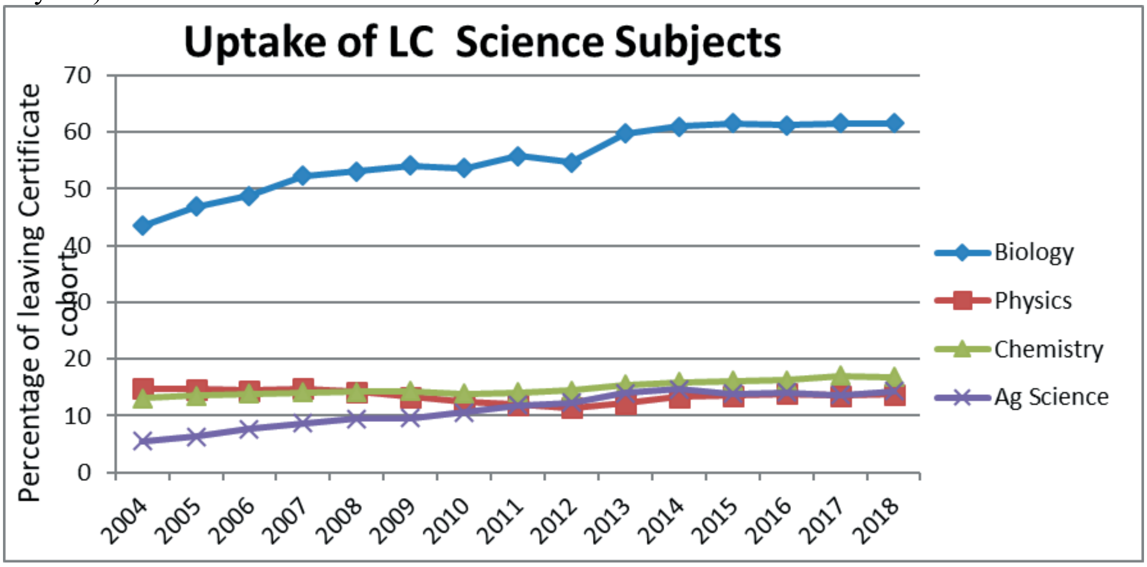

Figure 1: Leaving Certificate science uptake 2004-2018

It will be interesting to monitor the uptake of these subjects with the introduction of Computer Science as a Leaving Certificate subject from September 2018.

COURSES AND WORKSHOPS

Irish chemistry teachers are well provided with conferences, courses and workshops, and these are listed below, including those provided by the Professional Development Service for Teachers (PDST), which provides induction courses for new teachers and CPD workshops. There are additional courses, seminars and conferences for those involved in chemistry education in Higher Education also.

- Chem-Ed Ireland, Dublin, Oct. 2018 (annual)
- BASF Teacher's Workshop, Cork, June 2018 (annual)
- Boyle Summer School Lismore, Waterford, June 2018 (annual)
- Chemistry Demonstration Workshop, Limerick, July 2018 (annual)
- ISTA Annual Conference, Dublin, April 2018 (annual)
- Irish Variety in Chemistry Education, Dublin, April 2018
- SMEC 2018, Dublin, June 2018 (biannual)

- Methods for Research in Science Education (MORSE), Dublin, November 2018
- Irish Universities Chemistry Colloquium, Belfast, 2018
- 43rd Institute of Chemistry Ireland Congress, Athlone, May 2018

AWARDS

Institute of Chemistry of Ireland Awards

The ICI Boyle Higgins Gold Medal and Lecture Award (2018) was awarded to **Professor John M. Kelly**, TCD, whose lecture was entitled *Giga-seconds Exciting Chemistry – Time and the Photochemist.* **This award is made for an outstanding and internationally recognised research contribution to the advancement of chemistry by a chemist of any nationality working in Ireland or by a chemist who is an Irish citizen working overseas.**

The ICI Boyle Higgins Gold Medal and Lecture Award (2019) was awarded to **Professor Suresh Pillai,** IT Sligo, whose lecture was entitled '*Materials in the Nanoscale; From the Laboratory to Industries'.*

The ICI Annual Award for Chemistry (Eva Philbin Lecture Series) (2018) was awarded to **Professor Anita Maguire**, SSPC, UCC, whose lecture title was *'Using Hazardous Reagents Safely – Go with the flow!'* This award is made to an Irish or international chemist of repute who will present lectures on their field of work, across the country that are open to the general public as the purpose of the award is to promote the benefits of chemistry to the widest audience.

The ICI Postgraduate Award (2018) was awarded to **Ms Adele Gabba**, working under the supervision of Professor Paul Murphy (NUIG). She will give her award lecture at the forthcoming 71st Irish Universities Chemistry Research Colloquium, June 2019. This award is for a registered PhD student in any Chemistry discipline working in an Irish Higher Education Institution who has demonstrated excellence in research through publications and a commitment to supporting and promoting Chemistry within their University.

SFI Outstanding Contribution to STEM Communication

SFI awards to recognise an outstanding contribution to the popularisation of science, and recognises an individual who raises public awareness of the value of science to human progress, were awarded to:

Dr Niamh Shaw, Blackrock Castle Observatory and Cork Institute of Technology – an Irish engineer, scientist and performer. She presents the human story of science, creating theatre shows, public events and contributions to media with this focus.

Dr John O'Donoghue, RSC Chemistry Education Coordinator at the School of Chemistry, Trinity College Dublin – where he develops and empowers third level students to engage with schools and the general public. His Spectroscopy in a Suitcase programme has visited schools in every county, showing the real-world applications of chemistry, and his career events have provided students with dozens of valuable science role models.

RSC Awards

Dr Barry Ryan, Irish Chemistry Lecturer in TU Dublin was awarded the RSC's Higher Education Teaching Award;

Chemical Sciences Technical Team at Dublin City university was awarded the RSC Higher Education Technical Excellence Award;

Dr Michael Seery, formerly of TU Dublin (DIT), now of University of Edinburgh, was awarded the RSC's Inspirational Member Award.

PUBLICATIONS

Chemistry in Action! magazine, started in May 1980, has gone to two issues a year (down from three) and mainly electronic publication from issue 110 due to postage costs and this makes it more widely available. In addition, a new website with current and back issues has been launched (www.cheminaction.com).

Irish Chemical News, the journal of the Institute of Chemistry of Ireland, is now produced electronically (http://www.chemistryireland.org/html/ichemnews.html).

SCIENCE magazine is the journal of the Irish Science Teachers Association (ISTA). A new series on Pioneers of Science by Dr Peter Childs was started in 2017.

ESERA proceedings published (available at https://www.esera.org/publications/esera-conference-proceedings. (Finlayson, O.E., McLoughlin, E., Erduran, S., & Childs, P.E. (Eds.) (2018). Electronic proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education. Dublin, Ireland: Dublin City University. ISBN 978-1-873769-84-3).

The Book of ESERA 2017 selected papers from Dublin 2017 will be available during summer 2019.

CHEMICAL INDUSTRY AND CAREERS

Good news for chemistry and for chemistry graduates.

The Irish trade figures for 2018 were very good and the economy is showing strong growth, led by the chemicals and pharmaceuticals sector (https://www.cso.ie/en/statistics/externaltrade/goodsexportsandimports/). Of the total of €140,835 million exports, €86,100 million were chemicals, 61.1%. The net trade balance in chemicals was €66,280 million. The chemicals export figure has grown from €66,385 million to €86,100 million since 2016 alone, a rise of 29.7%.

Chemicals, referred to here as the pharmachemical sector, plays a pivotal role in the Irish economy. It accounts for over 60% of goods exported from the country. It employs more than 30,000 people, and supports a further 26,000 indirect jobs. More than half of the workforce are university graduates. In Ireland the industry is dominated by pharmaceutical companies engaged in either Active Pharmaceutical Ingredient (API) manufacture or/and also dosage form manufacture. As a centre for manufacturing biopharmaceuticals, Ireland is second only to the United States. Recent investments amount to just under €4 billion – the majority from US-based companies including Bristol Myers Squibb, Alexion, Regeneron and Eli Lilly. (https://www.chemlandscape.cefic.org/coun try/ireland/). In recognition of this Science Foundation Ireland re-funded SSPC, the SFI research centre for pharmaceutical manufacturing for a further 6-year term. The SSPC is hosted by the University of Limerick, in partnership with UCC, NUIG, UCD, DCU, TCD, RCSI, MU and WIT, and is a truly national centre. SSPC actively engages with pharmaceutical and biopharmaceutical companies both in Ireland and globally, and has an active Education and Public Engagement team working with teachers, parents and pupils to promote and engage in chemistry.
(reproduced from report in *Chemistry in Action!* 113, Spring 2019)

CONCLUSION

Overall chemistry remains in a healthy state at school with uptake continuing close to 17%, and the demand for third level courses continues. The chemical, pharmaceutical and biopharmaceutical industry continues to thrive in Ireland, and overall other STEM related industries continue to create employment to the extent that sourcing sufficient numbers of graduates can be problematic.
The recognition of the need for diversity in STEM continues to grow, with the government funded initiatives aiming to support this throughout the pipeline, from school to professorial level in Higher Education.

The new Leaving Certificate (LC) Chemistry course (along with Physics and Biology courses) was due to start in 2019, but has not met this deadline, although it was intended that they would follow on from the new junior science course. A report on the pilot of the new practical assessment for these LC science courses has been was published, indicating broadly positive results, but the decision not to pursue practical assessment was made due to potential for mounting costs and significant logistical issues.

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NOTE: Dr Odilla Finlayson (DCU) took over this year as the Irish delegate to EuChems Division of the Chemical Education, with Dr Sarah Hayes (UL) as the alternate delegate. They replaced Dr Peter Childs (UL) who was the Irish representative for the last 20 years. Each year a report on chemical education is produced and these will now be published in *Chemistry in Action!*

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STEMming the tide: reflections on curriculum development in Ireland

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There has been much debate recently about the place of History and Geography as core subjects in the new junior cycle programme. Only Maths, English and Irish are core subjects and are allocated 240 hours; all other subjects are optional and have 200 hours (a reduction of 40 hours from the previous programme.) No-one seems to have raised the stronger case for Science to be a core subject. Despite the powerful rhetoric promoting STEM subjects from government and industry, the fact that Science has been downgraded in hours and is still an optional subject has not been highlighted. There is a strong case for Science to be made a core subject with the same time allocation as the other three core subjects.

Science in the junior cycle feeds directly into five leaving certificate subjects – Agricultural Science, Biology, Chemistry, Physics, and Physics with Chemistry, and indirectly into the technology subjects and Home Economics. **No other subject has so many other courses depending on it.** Not doing Science at junior level thus undermines science and technology at LC level and although over 90% take it at present, more boys than girls take it. The reduced hours and greater choice of courses will further undermine its position. In terms of subject preference, we have **steM** rather than **STEM**, as only Maths is favoured by being compulsory. The economic argument for Science requires enough students to take LC science courses, especially the minority physical sciences (<16% of the LC cohort). This is the economic argument for making science compulsory, in order to make sure that there is an adequate STEM pipeline.

The second argument in favour of Science being compulsory is that everyone in modern Ireland should have a basic level of scientific literacy. If everyone took Science in the junior cycle this would ensure a minimum exposure to science for the whole school population, whether they take a LC science subject or not. This is also the cultural argument because of the importance of science and technology in modern life.

The next important issue to address is whether the new science specification is fit for purpose, as we come to the end of its first cycle and the first cohort is about to take the first examination in June 2019. Although there was a written consultation and a conference before the new specification was introduced, the concerns of teachers and other interested parties were not listened to by the NCCA. They did listen to teachers' request for a terminal, externally-moderated examination rather than teacher-based assessment. However, they did not listen or respond to other major concerns about the new specification.

What are the main concerns about the new science course?

1. The loss of 40 hours (240 to 200 hours, -16.5%), thus downgrading the subject (along with other non-core subjects).
2. The omission of important core topics in each of the main sciences: Biology, Chemistry and Physics. For example: bonding in Chemistry, the human skeleton in Biology, and Light and Magnetism in Physics.
3. The presentation of the specification as only a series of general learning outcomes, without any detail of depth of treatment or suggested practical work. (This differs markedly from the previous course and from best international practice in curriculum/syllabus design.) This means that individual teachers (or schools) must decide the detail required, depth of treatment, nature of practical work etc. This will militate against a uniform student experience of science across the country.
4. A common, final examination with only one level and sample papers which were only released at the start of the 3rd year of the course, not at the start of the course. Sample papers are vital for telling students and teachers what is expected of

them, the style of questions and depth of treatment required. A common paper tries to be the best of all possible worlds and is likely to be too hard for some and too easy for others. It may become a paper aimed at the lowest common denominator of ability.

5. The introduction of new topics for which teachers were unprepared at the start of the course, despite CPD courses, such as the Nature of Science and Earth and Space.
6. The inadequacy of CPD courses for teachers in duration and depth to prepare to teach the new course with its new approach (skills-based rather than content-based) and new topics.
7. An emphasis on skills over content, though in reality content must provide the framework for relevant skills in any subject.
8. No mandatory experiments or activities so it is left to individual teachers whether to do practical work or not, and what activities to do. There is thus no common framework of practical work for all schools.

After three years of implementation are these concerns justified? Talking to or surveying science teachers is the best way to find out if curriculum reform is working and what are the main issues. Listening to and taking on board and responding to science teachers' concerns, as expressed through their subject association (in this case the Irish Science Teachers Association, ISTA), seems to be something the NCCA and its subject committees do not seem to be very good at. The ISTA has recently done an important survey of its members, with a sizable response, to find out what teachers think about the new course and this was published in May 2019. So what things are science teachers so concerned about?

1. The reduction of hours to cover the course, including the new topics.

2. The loss of core topics in the three main sciences, so that students are much more poorly prepared than before for the unchanged and more difficult LC science subjects.

3. The vagueness of the science specification's learning outcomes, without any detail, depth of treatment or indication of suitable practical work. Teachers are left floundering and trying to decide for themselves what to teach, or more commonly, using the textbooks to define the syllabus. Teachers do not know what they are supposed to teach and textbooks become the arbiters and interpreters of the specification. This means essentially, that everyone does what is right in their own eyes and each teacher and/or school ends up teaching a different science course. Teachers are left trying to decide **what** to teach when their job should be to decide **how** to teach.
Professor Ainé Hyland in her report for the ISTA on the proposed new LC science specification (Hyland, 2014) showed that a syllabus based only on general learning outcomes is not the best international practice. The same conclusions hold for the junior cycle Science course.
(Ainé Hyland, (2014), *The design of Leaving Certificate science syllabi in Ireland: an international comparison.* Dublin:ISTA. Available at: https://ista.ie/wp-content/uploads/2016/03/The-Hyland-Report-_0.pdf Accessed 10//5/19)

4. The sample papers were late (beginning of third year) so this was the first time teachers were able to compare what they had been teaching and the type of questions being asked. The fact that there is no common syllabus as each teacher/school is deciding the detail of what to teach and the common examination paper (covering the whole ability range), will inevitably mean a paper aimed at the lowest common denominator or at the middle – too hard for many and too easy for many. To challenge the brightest students to take science subjects and become STEM professionals, they need to be stimulated and challenged by the course and by the examination. Many teachers think the sample papers are too easy as they are trying to appeal to everyone.

5. Teachers also expressed dissatisfaction at the duration of CPD courses provided on the new topics and new approach to teaching.

6. The lack of coordination between the new course and the LC science subjects, which are unchanged and are taught in the same way as before, and particularly the gap between the two cycles, which is now bigger than before. Students will not have covered basic topics in the core sciences and if these are taught in the LC cycle then this will eat into the existing syllabuses. In effect, it has shifted content from the junior to the senior cycle. There is also concern that students' practical work and laboratory skills will be poorer than before, again creating problems for LC science teachers.

7. There is some evidence that the omission of mandatory practical work has reduced the amount done in some schools. Practical work is expensive, time consuming and requires laboratories and resources, and preparation by teachers (in the absence of technicians). It is easier and cheaper to teach from the book rather than in the lab. Some teachers in some schools will inevitably revert to the situation before mandatory experiments, when practical work was an optional element of teaching science.

These are serious matters and based on past performance, the concerns will not listened to or used to revise the specification. If this happens then the defects of this new curriculum will affect the careers of many students. At a time when STEM subjects are being highlighted for their long-term importance to Ireland's economic growth and the development of a knowledge economy, the very foundation of STEM education is being weakened. Most students will now experience, though not all, a watered-down science course, which does not prepare them for LC science courses. There was already a gap between the junior and senior cycles in science; now this gap will be larger and more significant. Students will be entering the senior cycle without any knowledge of some basic topics in Biology, Chemistry and Physics and LC teachers will have to try and fill this knowledge vacuum as well cover the existing LC courses.

The big emphasis in the new junior cycle programme is on key skills but skills cannot replace technical skills (subject knowledge and practical skills) but should rather support them. The so-called soft skills (also known as transferable skills and 21st century skills), e.g. critical thinking, creativity and communication, can only be developed and used in the context of subject knowledge. This point is made very well by Tom Bennett (2014).

"The truth is that skills are based entirely on knowledge; they are the appropriate demonstration of knowledge. There is no false dichotomy here. There is no 'skills or knowledge'. Skills are knowledge in context.

Many abilities are called skills, such as analysis, creative thinking and so on, but these faculties are nothing without knowledge."

(Tom Bennett (2014) 'Knowledge v skills: The debate at the heart of teaching'. *TES* 10/1/14 26-30)

The introduction of the new science specification illustrates all that is wrong in curriculum reform in Ireland. As it stands it is not fit for purpose but it could easily be rectified to take account of teachers' views and thus improve the course and students' first experience of formal science, and provide a better foundation for LC sciences.

Here is how it could be reformed in time for the 2019 or 2020 cohort. This would require setting up a new syllabus task force, including science teachers and science educators.

1. Make Science a core subjects and increase its hours back to 240 hours.
2. Make sure that the core topics in Biology, Chemistry and Physics are included as a foundation for the LC sciences.
3. Expand the general learning outcomes into more detailed specific outcomes (as in the old syllabus), indicating depth of treatment and the detail required.
4. Give teachers specific guidance as what practical work they should do for each part of the course.
5. Restore a two-tier final examination to cater properly for the whole ability range and to provide more challenge for higher ability students.
6. Make sure that the new course is designed to match and provide a framework, in both skills and knowledge, for sunbequent LC sciences.
7. Provide enough relevant and targeted CPD courses to equip science teachers to teach the new topics properly and also to

teach the old topics emphasising skills development.
8. Consult and listen to teachers again before the final approval of a new syllabus (specification).
9. Reintroduce a mandatory list of experiments and activities as a minimum requirement.

Although such changes would require some time to design, they could be done within the year, and even implemented into second and third year courses for existing cohorts. They would need a revision of textbooks to align them more closely with the revised specification but would avoid the ambiguity and vagueness present at the moment.

I fear that the current reform and particularly the revised LC science specifications, which repeat the failings of the new junior science specification, particularly in the lack of detail of teachers, will actually undermine rather than strengthen the drive to promote STEM subjects and careers in the future. It may well result in fewer students taking LC science courses, especially the physical sciences, and thus impact on take-up of third level STEM courses. Instead of stemming the decline of science uptake, especially among girls, I fear that the new courses, with their downplaying of subject knowledge and competence, will actually result in the STEM tide going further out. It is surely significant that it is mainly educationalists who praise and support the new approach in the junior cycle, and not science teachers and scientists?

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How not to do science curriculum reform

- Don't consult or listen properly to science teachers or to their concerns.
- Develop curriculum reform top-down rather than bottom-up so that teachers have the least say.
- Change the LC course before the JC course (as has been done in the past).
- Don't make sure that the JC and LC courses match up in content and approach so that students can move easily from one level to another.
- Rush out the syllabus or specification in an incomplete, half-baked form to meet political or other targets.
- Downplay technical skills (subject content and practical skills) in favour of generic skills.
- Don't give substantial CPD prior to starting the new course but leave it until it has already started and then give the minimum amount.
- Don't produce sample papers along with the syllabus and before the course is launched, in order to ensure that teachers know how the content will be assessed.
- Don't provide a syllabus (specification) with enough details on depth of treatment and specific learning outcomes, so that teachers don't know what they should teach, and instead have to try and unpack and interpret the specification individually.
- Don't give guidelines on suitable practical work to accompany learning outcomes so that teachers don't know what is expected of them.
- Don't provide the additional resources needed to implement a new course effectively.
- Don't revise the specification in the light of teachers' feedback based on their experience of implementing the syllabus.
- Don't learn from experience and do repeat the process for the next curriculum revision.

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Professional Learning Communities (PLCs) of Chemistry Teachers

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Abstract

Creating teachers' professional learning communities (PLCs) is an effective bottom-up way of bringing innovation into the science curriculum and professional development. The models of PLCs are based on principles of learning that emphasize the co-construction of knowledge by learners, who in this case are the teachers themselves. Teachers in a PLC meet regularly to explore their practices and the learning outcomes of their students, analyze their teaching and their students' learning processes, draw conclusions, and make changes in order to improve their teaching and the learning of their students. It was found that participation in a PLC influences teaching practice, so that teachers become more student-centered. Moreover, the teaching culture improves as the community increases the degree of cooperation among teachers, and focuses on the processes of learning rather than on the accumulation of knowledge. This enables students to be innovative, creative, and critical. In addition, trust is developed among the participants, which enables them to discuss and analyze their students' cognitive and affective problems, misconceptions, and learning outcomes.

Teachers' professional learning communities (PLCs) – theoretical framework

Creating teachers' professional learning communities is an effective bottom-up way of bringing innovation into the science curriculum and professional development. The models of professional learning communities are based on principles of learning that emphasize the co-construction of knowledge by learners, who in this case are the teachers themselves. Teachers in a professional learning community meet regularly to explore their practices and the learning outcomes of their students, analyze their teaching and their students' learning processes, draw conclusions, and make changes in order to improve their teaching and the learning of their students. (Tschannen-Moran, 2014). The concept of PLC arose in the field of education in the context of workplace-based studies conducted in the 1980s, that addressed teachers whose professional relations were characterized by continuous striving for improvement, focused on student learning, and who collaborated and explored their work. Such relationships differ from the norms used in the teaching found in a more individualistic culture, which typically characterizes schools as a place of work (Lortie & Clement, 1975).

In 1982, Little conducted an anthropological study of six primary and secondary schools in four counties in the western US. He found that schools with norms of collaboration, collegiality, and research could respond better to the pressures of external changes and educational initiatives. This finding was reinforced by Rosenholtz (1989), who combined surveys and interviews with 78 primary schools. She distinguished "rich" and "poor" schools with respect to learning. The learning-rich schools were more likely to establish norms of cooperation and continuous improvement.

Newmann (1996) argued that a professional community of teachers offers a supportive environment in which teacher learning can occur. For example, the Center for Organizing and Building in Schools at the University of Wisconsin conducted systematic research on 24 primary, junior high, and high schools in which structural and organizational changes were carried out, with an emphasis on the quality of instruction in mathematics and social sciences. It was found that aspects of a school's professional community that include common norms and values, a focus on student learning, reflective dialogue, transformation of teachers' practice in public classes, and a focus on collaboration, are linked to robust teaching and support for teacher learning.

In a series of articles based on analysis of the NELS:88 databases, Lee, Smith and Corninger (1997) argued that more organized schools produce higher levels of teacher satisfaction, positive student behavior, problem-solving pedagogy, and understanding and learning in mathematics and science. *"Our results indicate that when there is a professional community of teachers - when teachers are taking responsibility for the success of all their students - more than learning is occurring"* (Lee *et al*., 1997, p. 142).

Shulman (1997), in his lecture at the Mandel Institute in Israel, spoke enthusiastically about the idea of both teacher communities and student communities. Shulman argued that since a single teacher can never possess perfect knowledge of pedagogical content, we must continue to create conditions in which a teacher can collaborate with other teachers and be part of a community of teachers facing difficult teaching challenges. In other fields, no one expects a single professional working alone to solve an important problem, because complex, real-world problems require "distributed expertise"—the sharing of highly specialized professionals in dealing with common challenges.

Bryk, Gomez and Grunow (2010) identified professional communities, along with a work culture oriented (Markic, *et. al.,* 2016) toward improvement and access to professional development, with elements of "professional capacity" associated with improvements measured in primary school achievement in Chicago over a period of 6 years in the 1990s. A recent study by Kraft and Papay (2014) reinforced this important insight. These researchers used a measure for the professional environment that was composed of the responses of teachers to a survey in North Carolina combined with a national test in mathematics and elementary school reading. They found that teachers who work in a supportive environment, compared to those who work in a less supportive one, have increased effectiveness over time.

PLC workshops for chemistry teachers were initiated in Israel 2 years ago. These workshops were supported by the Ministry of Education and sponsored by the Trump Foundation, the Weizmann Institute of Science, and the National Center of Chemistry Teachers at the Weizmann Institute. The workshop operates on a cascade model: a leading team of researchers guides a group of teachers who will lead communities of teachers in regional communities "professional learning communities close to home" (see Figure 1).

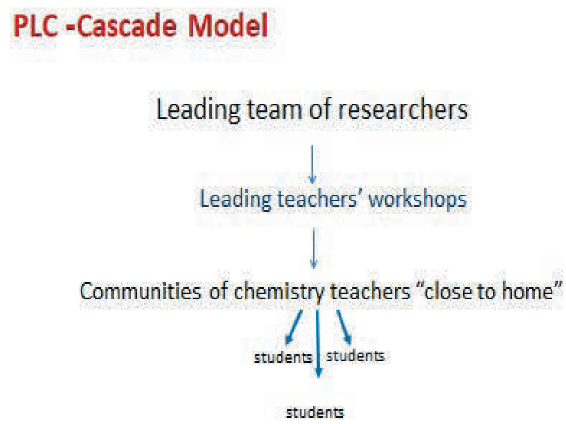

Figure 1. The PLC cascade model (Mamlok-Naaman, Eilks, Bodner & Hofstein, 2018)

A leading team of researchers guides a group of teachers who will become leading teachers, and coordinate regional communities of teachers, "Professional learning communities close to home". So far, there are eight regional communities of chemistry teachers in Israel, consisting of Jewish and Arab high school teachers. Each "Professional learning community close to home" is coordinated by two leading teachers who participate in the PLC workshop. The Tira community of chemistry teachers, will serve as an example of a community "close to home".

Tira "Professional learning community close to home"

15 teachers of the "Tira Professional learning community close to home" (TPLCCH) met once in three weeks, coordinated by 2 leading teachers. Each meeting consisted of:

- An opening activity aimed at creating social and personal relationships among the members of the group, as well as openness and trust to strengthen the cooperation among members of the community, and enable them to gain a sense of ownership.
- "Our corner" – one or two teachers share an experiment or an interesting activity with their colleagues—a short, stimulating and thought-provoking activity that can be applied in the classroom. It can be an experiment, a demonstration, a discussion question, an interesting video clip, or a technological innovation in education.
- A discussion referring to a content and pedagogical subject, e.g., diagnostic questions, misconceptions, unclear questions, or alternative assessment methods.
- Sharing lesson plans regarding new curriculum materials.
- A reflection by each teacher at the end of the meeting, referring to the meeting's topics.

The teachers develop activities and pedagogical teaching strategies with the leading team of researchers (a "bottom-up" approach) and implement them first in their own classes, before they disseminate them among the communities of teachers in their regions. Following are three examples of major activities.

Diagnosis of students' ideas and difficulties.

Teachers are usually surprised to find out that their students have learning difficulties and misconceptions. Therefore, diagnosis of students' misconceptions is a very important activity. During the meetings, the Tira community teachers reflect upon their teaching methods, and discuss how to use different strategies to cope with these difficulties, how to implement the change and then collect and analyze their students' assignments. Major misconceptions have been encountered in topics such as Bonding and Structure, Acids and Bases, Energy, and Equilibrium.

The following example is based on a study conducted by Ben-Zvi Eylon and Silberstein (1986). The study consisted of three stages: (1) a diagnostic investigation of students' views of structure in chemistry, (2) development and implementation of a program designed to prevent some of the misconceptions identified in the first stage, and (3) an evaluation of the new program. The diagnostic investigation of students' views of structure in chemistry consisted of a questionnaire administered to eleven 10^{th}-grade classes in different high schools in Israel (about 300 students, average age 15 years). All students had studied chemistry for at least half a year. The question relevant to the atomic model was:

A metallic wire has the following properties: (1) conducts electricity, (2) brown colour, and (3) malleable. The wire is heated in an evacuated vessel until it evaporates. The resulting gas has the following properties: (4) pungent odour, (5) yellow colour, and (6) attacks plastics.

i) Suppose that you could isolate one single atom from the metallic wire.
Which of the six properties would this atom have?
ii) Suppose that you could isolate one single atom from the gas. Which of the six properties would this atom have?

Most of the teachers at TPLCCH who disseminated this question among their students reported that their students could not differentiate between macro and sub-micro concepts. The interventions which they decided upon in order to cope with the misconceptions consisted of: using models; computerized interactive programs; video clips; games, etc. The process of dealing with the misconceptions which were diagnosed, was based on the Action Research rationale (see below).

Lesson plans referring to sustainable education

A few lesson plans shared at the TPLCCH, dealt with issues of sustainable development, as suggested by the two leaders of the community. Issues of sustainable development have been suggested as a way to contextualize chemistry learning for relevant chemistry education (Eilks and Hofstein, 2014). If this is implemented from an SSI-based perspective (Eilks *et al*., 2013), controversial issues from the sustainability debate can be used to motivate chemistry learning within the context of a societal perspective. The issue of alternative fuels can be used as an example (Mamlok-Naaman *et al*., 2015).

In recent years, a group of teachers in Israel developed a lesson plan that was called "Can used oil be the next generation fuel?" (Ezra *et al*., 2012). This lesson plan focuses students' learning on traditional and alternative fuel sources. The students learn about the advantages and disadvantages of each of the different suggested technologies: fuels from crude oil, recycling of used oils, or producing biodiesel from vegetable oil.

The lesson plan uses a structure that starts with the SSI, involves learning about the content behind the issue, and then turns to questions of evaluation and reflection on the issue from different perspectives and in the foreground of the societal discourse. The lesson plan starts with exposing students to information about the world's energy crisis and its consequences. Discussion of this information activates prior knowledge and raises questions to be answered. The idea that teachers should convey to their students is that sustainable mobility is a worldwide problem and not just a scenario for the science classroom. Furthermore, there are several proposed solutions to this challenge, but these solutions often introduce new problems.

Students undertake different activities to investigate and compare the different fuel types in order to decide on various options for providing fuels for mobility. In one activity, the students are asked to inquire into the chemistry of the use of different fuel types, one of which is biodiesel. Comparative activities require students to select criteria such as enthalpy of combustion values or the release of emissions. The teacher then introduces the student to an experiment that compares the energy released by the combustion of different fuel types. By measuring the mass of the fuel needed to increase the temperature of a certain volume of water by 30 degrees Celsius, students can compare the caloric values of different fuels. They can also investigate the level of pollutants emitted from the burning fuels with a special board called the "Ringelmann scale," which determines the concentration of soot particles produced by the flame. Students are then asked to decide which is the best fuel. Before making a final decision, there is an attempt to involve students emotionally and from an ethical perspective by creating a conflict regarding the use of biodiesel. This activity is based on viewing pictures that highlight the use of crops for fuel instead of using them as a food source for the world's ever-growing population. Students' decisions should be based on arguments, but first there should be agreement within the group about the assumed meaning of the term "best fuel." This discussion leads to understanding that a thorough comparison requires more criteria beyond the limits of chemical behaviour. These criteria include price, environmental behaviour, production methods, and societal impact. An open discussion about which technology has the most promising potential for sustainable development is used to end this lesson plan.

Within this lesson plan, the students learn about an authentic sustainability issue and the complexity of its solution. On the one hand, they learn that there is no "best fuel" nor any "best solution" to many sustainability problems. On the other, they learn that making use of used oil or biofuels is not "the ideal solution." Other ways might better protect the environment because less waste is produced and fossil resources are saved. However, the students also learn how complex such evaluations are and how many dimensions need to be taken into consideration before an overall decision can be made.

Action Research activities

During the meetings, the teachers at TPLCCH conducted Action Research activities, referring to issues which bothered them. The teachers dealt with content issues as well as pedagogical issues such as: "Can we change students' attitudes toward science by integrating relevant, everyday issues into their science curriculum?" The activities consisted of: (1) identifying the general problem and their own research question, (2) planning the research including the development of the research tools, (3) data collecting and analyzing, (4) implementing, (5) data collecting and analyzing, and (6) evaluating and reflecting. The various stages are presented in Figure 2.

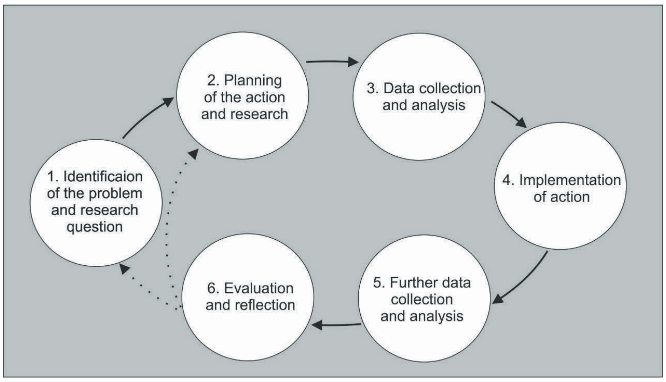

Figure 2. The various stages of Action Research (Mamlok-Naaman, Eilks, Bodner & Hofstein, 2018)

Action Research is regarded either as a practitioner-oriented inquiry into teachers' work and their students' learning in the classroom (Feldman & Minstrel, 2000) or as the development of new teaching strategies oriented towards teachers' and students' deficits or personal interests (Eilks & Ralle, 2002). According to Feldman (1996), the first goal of action research within such a framework is not to generate new knowledge - whether local or universal - but rather to improve and change classroom practices. Nevertheless, this point may be viewed differently depending on the action research mode chosen and depending on the objectives negotiated within the group of practitioners and researchers (Eilks & Ralle, 2002). In the end, the development of individual practices and generation of results of general interest can be understood as two sides of the same coin, with both having equal importance.

A further objective of the Action Research activities was to enhance the chances of creating a professional community of chemistry teachers (Mamlok-Naaman & Eilks, 2012). The participants in the Tira community had many opportunities to enhance their social skills through collaboration and cooperation with their peers. They shared ideas, consulted with each other, and maintained good social and professional relations with the others. The PLC meetings enabled them to consult with each other and exchange information and ideas as often as they wished. The cooperation between the teachers in the group was fruitful and helped promote their teaching strategies, as well as their professional development (Laudonia *et al.*, 2015).

Evaluation of the PLC workshop

Data were collected for two years from a variety of sources: video records of the teacher-leaders' PLC meetings; reflection questionnaires; E-mail correspondences; interviews; portfolios; additional data from questionnaires sent to teachers in the "Professional learning communities close to home", as well as to their students.

The data analysis revealed that the PLC workshops were accompanied by an evaluation study that consisted of questionnaires and interviews. To date, the teachers who have participated in the PLC workshops for chemistry teachers have claimed that the professional community environment improved their self-efficacy and enhanced their ability to share teaching difficulties with their colleagues. The teaching culture improves, as the community increases the degree of cooperation among teachers: trust, ownership, and friendship (Tschannen-Moran, 2014). They said that during the meetings, a feeling of trust was developed among the participants, which enabled them to discuss and analyze their students' cognitive and affective problems, misconceptions, and learning outcomes. In addition, the fact that they could share ideas, lesson plans and interesting experiments was an asset in itself. They were encouraged to develop ownership of innovations in education, becoming more student-centered in their teaching (Mamlok-Naaman *et al.,* 2018).

The PLC community has an impact on teaching practices, and served as a perfect environment for preparing and encouraging teachers to conduct changes - towards gaining pedagogical content knowledge in conveying important issues in education, and preparing the future citizen in a mixed cultural society, focusing on the processes of learning rather than the accumulation of knowledge, in order to enable students to be innovative, creative, and critical.

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Biography

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Students' use of graded learning aids for inquiry learning

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Abstract

Problem-based and inquiry learning is suggested to be an essential component of contemporary chemistry education. At the same time, chemistry teachers in many countries face increasing heterogeneity among their students. Heterogeneity concerning practical work encompasses experimental skills or problem-solving competence, and also differences in conceptual understanding and linguistic skills. Thus, there is a growing need for supporting aids for practical work, e.g. tools that provide additional information on how to conduct and understand an experiment. This article discusses the idea of differentiated and graded learning aids to support inquiry learning. It describes experiences made in a non-formal experimental learning environment on the chemistry of water and reflects on how students perceive practical work with differentiated and graded learning aids.

Introduction

The project "Chemistry, Environment, Sustainability – Non-formal Learning Environments for All Students" aims at developing and implementing practical non-formal learning environments for lower secondary chemistry students. The learning environments are jointly implemented in out-of-school laboratories located at different universities across Germany, namely in Bremen, Saarbrücken, Nuremberg and Karlsruhe. The focus lies on the development of experimental work that challenges the whole range of students, from higher achieving students to those with disadvantaged educational biographies. The intention of the learning environments is to allow all students to master self-regulated inquiry work for more autonomous learning. For this purpose, the project is based on a complex concept for differentiation in practical inquiry learning [1].

One strategy to allow students autonomous learning in our project is the use of graded *cue cards* to help students mastering their tasks and to become more independent learners [2]. Cue cards provide written or/and visual prompts to organize, structure and sequence cognitive activities to solve multistep tasks [3]. The main benefit of the cards is providing the students cues for important steps or the order thereof. The cards serve as a flexible support helping students to maintain autonomy within challenging tasks. Concerning practical, inquiry work the cards can provide chances to approach inquiry problems in an open manner, but to also allow lower achieving students to solve the problems with more guidance and structure, if needed. They can provide help by involving different steps from initial questions to the full solution of the task.

In this article, we describe the use of differentiated learning aids in the form of graded cue cards and we discuss how the learning aids were perceived by students of grades 5 and 6 (10-12 years old) in the case of a practical learning environment on the chemistry of water.

Graded learning aids

Graded learning aids for practical work can have different foci. One focus is information helping students to identify potential steps of an experiment in a logical order. A first learning aid can help to activate prior knowledge about the chemicals or equipment to be used. A further learning aid might suggest the first experimental step or an unsorted sample of different steps. Finally, a third learning aid can present a proposal for a correct procedure to do the experiment that gives learners the chance to do the experimental task successfully. Better students might solve the given problem by the means of open inquiry without help or even a first prompt, whereas lower achieving students can use the aids to perform the tasks by structured or confirmatory inquiry learning. The learning aids do not need necessarily to be text-based. Students with low linguistic capabilities might benefit more from pictorial information than texts. Figures 1 and 2 give examples of corresponding learning aids for experiments of the dissolution of solid substances in water and filtering. The final aid in both cases can also be used for students' self-assessment.

Experiment: Solid substances in water  **Procedure**	**Help for conducting the experiment 1:** For the experiment you may use: **Materials:** • 5 test tubes • test tube rack • spatula • test tube plugs **Chemicals:** • flour • pepper • salt • sand • sugar • water
Experiment: Solid substances in water  **Procedure**	**Help for conducting the experiment 2:** Steps to conduct the experiment: (Attention: The order is not correct!) • *Shake the test tubes.* • *Fill the test tubes half-full with water.* • *Close the test tubes with the plugs.* • *Observe, whether the substances dissolve or not.* • *Give each one spatula of the five solid*
Experiment: Solid substances in water  **Procedure**	**Help for conducting the experiment 3:** The order of the experimental steps is: Fill the test tubes half-full with water. • *Give each one spatula of the five solid substances in each a test tube.* • *Close the test tubes with the plugs.* • *Shake the test tubes.* • *Observe, whether the substances dissolve.*

Figure 1. Graded learning aids for conducting the experiment "Which solids dissolve in water?" (front and backside)

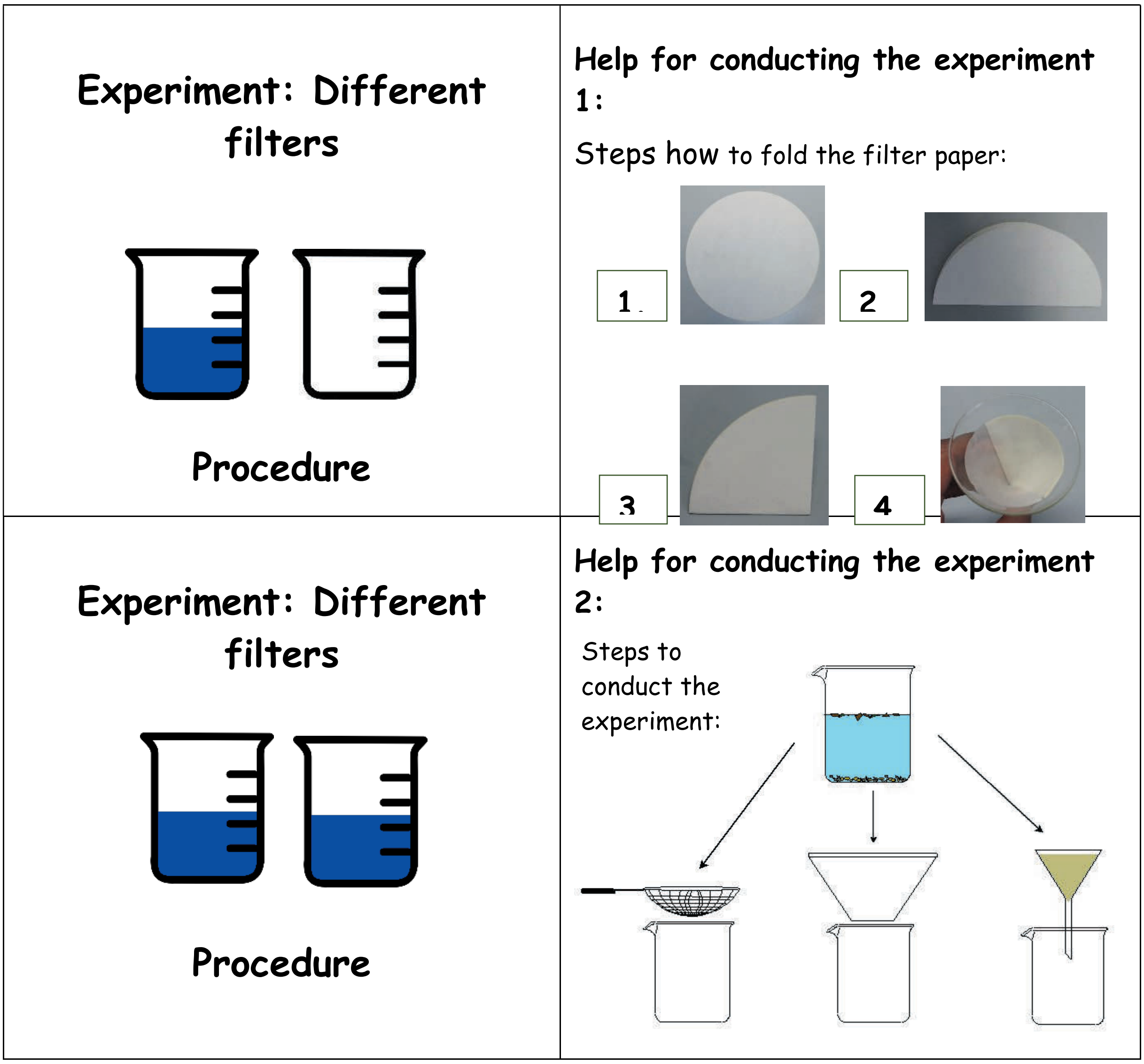
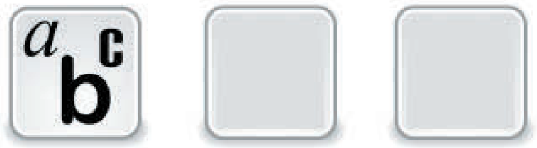


Figure 2. Graded learning aids for conducting the experiment "Different filters" with pictorial information

It might not only be the experimental skills which hinder the learners to solve an experimental task autonomously. Other graded learning cues might focus on conceptual understanding or linguistic issues. The aids for conceptual understanding can provide support graded from a phenomenological-descriptive level, via a verbal explanatory level, up to a submicroscopic or formal level. The language-specific learning aids support comprehension by giving language-sensitive and language-activating hints. Figure 3 shows a three-step learning aid for linguistic support. For each type, several cards can be offered to take into account different aspects of the experimental instruction. The number and foci of the cue cards depend on the type and difficulty of the task and the chances to break it down into single issues.

The learning aids can be printed in different colours, cut out and laminated so that only the front with the name of the experiment, the symbols for the focus and the number of the aids are visible. The learning aids can be offered with the back side up as a stack next to the experiment. The symbols help in recognizing which help is available and what kind of support is given.

Experiment: Cleaning up after the party



Observation

Help to describe the observation 1:

You can use these words for solving the task:

confetti, soap, water surface,
water skin, tear, contract,
to the edge of the glass, beaker

Experiment: Cleaning up after the party

Observation

Help to describe the observation 2:
You can use these parts of sentences:
(Attention: It is not the correct order!)

The skin on the water tears	…on the surface of the
The confetti swims…	…to the fringe of the water surface.
The confetti moves…	…and contracts because of the soap.

Experiment: Cleaning up after the party

Observation

Help to describe the observation 3:

This is a suggestion for how to formulate the observation:

The confetti swims on the water surface. The skin on the water tears apart and contracts because of the soap. The confetti moves to the fringe of the water surface.

Figure 3. Example of a graded learning aid for language understanding. The emphasis is on the support in describing the observation of an experiment on the surface tension of water.

Experiences with the use of graded learning aids in chemistry practical work

The perception of the differentiated and graded learning aids was evaluated incorporating three perspectives. The student´s perspective was evaluated with a feedback questionnaire with 30 questions (Likert type), one person of the teaching staff took notes as a participating observer, and a passive observer focused on how the learning groups used the learning aids. The survey was carried out in 9 learning groups from different comprehensive schools from the Northwest of Germany (grade 6, age range 11-12, N = 159). All the schools are located in urban environments with each a high number of students with first or second generation migration backgrounds. Generally, the learning groups were very heterogeneous in terms of achievement and linguistic capabilities. All the learning groups visited the out-of-school learning environment "Exploring and improving the quality of water" for three hours. 12 different experiments were offered. Subsequently, data from the three perspectives were triangulated to construct meaning.

The evaluation showed that only a few students had worked with graded learning aids prior to the visit of the out-of-school learning environment. During the visit of the learning environment the learning aids were used by many students (75% completely or partially agreed to have used them). The students particularly used the learning aids for the conduct of the experiment. Nevertheless, most students first tried own approaches before they started using the cue cards.

Almost all students liked to have the chance to conduct experiments without a prescribed procedure (91% completely or partially agreed). The learners liked the autonomous inquiry learning approach with more open tasks. Only a few learners (26%) used the graded learning aids in each of the experiments. When the learning aids were used, the students generally decided together (in their group) to use them (61%). Many of the small groups discussed the use of the learning aids before deciding to use them. Some learners (29%) even indicated that they had used the learning aids only because other group members wanted it. More than two-thirds of the students (70%) stated that they decided to use a learning aid only if they had no idea how to continue with the experiment. This is in line with the feedback that only few students (24%) had a look into the learning aids because they were simply curious about their content. The observations also showed that learning aids were rarely used early, and that only very few learners looked at the final learning aid right from the beginning.

The format and the design of the learning aids (graded and marked with symbols) were positively perceived by a large part of the students (87%). Almost all learners liked that the first cue card did not contain the complete solution of a task (89%). Approximately half of the students indicated that they always took the first learning aid, used it for the process of inquiry learning and then used the following cards, in case (51%). The individual feedback showed an overall conscious handling of the learning aids even if these are quite young students. Teachers often express the fear that the students could fall back early on given solutions in helping cards and thus challenging their thinking-skills might be hindered. The students´ reflection showed that in only a few cases did the students read the first cue card and then immediately took the second one (19%). Often, students read the card aloud before it was discussed how to continue further work.

Just a few students mentioned difficulties with the use of differentiated and graded learning aids. A large part of the learners (87%) stated that the cue cards helped them in finding solutions. They perceived the use of the aids in small learning groups without having to ask the teacher for support as positive. The assignment of the aids to the tasks in the experimental instruction seemed to be clear by the design (name and symbol).

With regard to the effectiveness of the learning aids, it can be said that many of the learners assessed them as motivating them for independent experimental work (65%) and as supporting them for inquiry learning (63%). More than half of the students (58%) felt supported in understanding the scientific basis of the experiments by the learning aids. About half of them used the learning aids to understand the linguistic issues related to the instructions (53%).

Conclusion

Wieczorek and Sommer [4], in Germany, already showed that students like graded learning aids for experimental work and that the aids are of potential value to promote independent learning.

They wrote that graded learning aids are particularly suitable for self-directed experimental learning in heterogeneous groups. Also in Germany, Stäudel, Franke-Braun and Schmidt-Weigand [5] described how graded learning aids enable an uninhibited learning experience. These findings are supported by those described on this case study. It is suggested that differentiated and graded learning aids can have a positive influence on inquiry learning and student autonomy in experimental work. The learning aids have potential to challenge and support communication among the students in small group work, and to promote discussion about ideas about how to conduct the experiments. The learning aids allowed teachers to create more open approaches to experimental inquiry learning and helped almost all students to conduct inquiry experiments on their own.

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Biographies

Dr Fiona Affeldt finished her PhD in Chemistry Education in 2018 at the University of Bremen, Germany. Since then, she is working as a teacher for chemistry and biology at a comprehensive school in Bremen.

Dr Silvija Markic obtained her PhD in Chemistry Education from the University of Bremen, Germany, in 2008. After working in school and at the University of Bremen, she became a professor for science education at Ludwigsburg University of Education in 2017.

Dr Ingo Eilks obtained his PhD in Chemistry Education at University of Oldenburg in 1997. After working in school and at the University of Dortmund, in 2004 he became a professor for chemistry education at the Institute for Science Education at the University of Bremen, Germany.

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Endangered Elements & The International Year of the Periodic Table

Margaret Franklin
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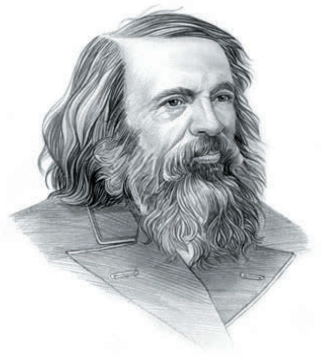
Biologists, and indeed the general public, are well aware of the problem of endangered species. We know that a number of biological species are threatened with extinction. But many people may not be aware that a significant number of chemical elements are now endangered, due to shortage of supply and rising demand.

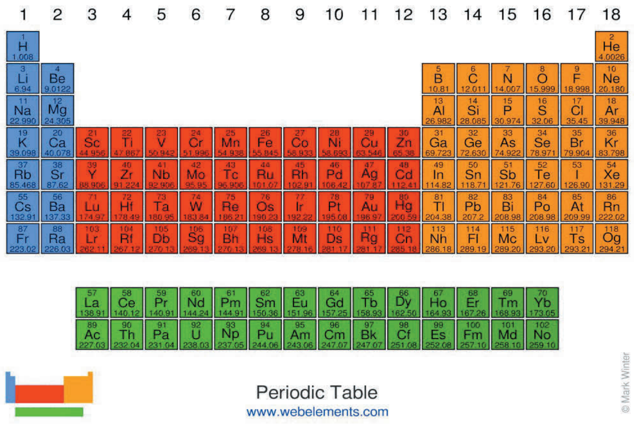


The Periodic Table of the Elements

This year is the 150th anniversary of the publication, in 1869, of Mendeleev's famous classification of the chemical elements, known as the Periodic Table. To mark this historic event, 2019 has been designated by UNESCO as The International Year of the Periodic Table (IYPT2019). The opening ceremony took place at UNESCO in Paris on 29th January and chemical societies all over the world are holding events throughout the year to celebrate the Periodic Table. In Mendeleev's time, not all of the naturally-occurring elements had been discovered. However, he left gaps in his table and was able to predict some of the properties of the then unknown elements, which included gallium and tellurium. The subsequent discovery of those elements served to validate Mendeleev's classification. All the remaining gaps in the Periodic Table have now been filled.

In more recent years, a number of transuranic elements, (i.e. elements with atomic numbers greater than that of uranium, no. 92) which do not occur naturally, have been synthesized in large atom-smashing machines. These elements are highly unstable and because of this, they undergo rapid radioactive decay. This is the reason why they are not found in rocks and minerals in the Earth's crust. Uranium itself is also radioactive, but it has a very long half-life and because of this, it still occurs in significant quantities in ores such as pitchblende and in trace amounts in a variety of rocks, such as granite.

The Periodic Table is now complete, up to element number 118. This last element was first synthesised in the year 2002 in Dubna, near Moscow. It has been named oganesson (symbol Og) after the Russian scientist Yuri Oganessian, who was one of the principal nuclear physicists involved in the discovery of some of these new elements. So, the wheel has come full circle, as the Periodic Table started in Russia and has now been completed in Russia. [This is not the absolute end and scientists are actively searching for elements beyond #118. Ed.]



The Completed Periodic Table of the Chemical Elements

Endangered Elements

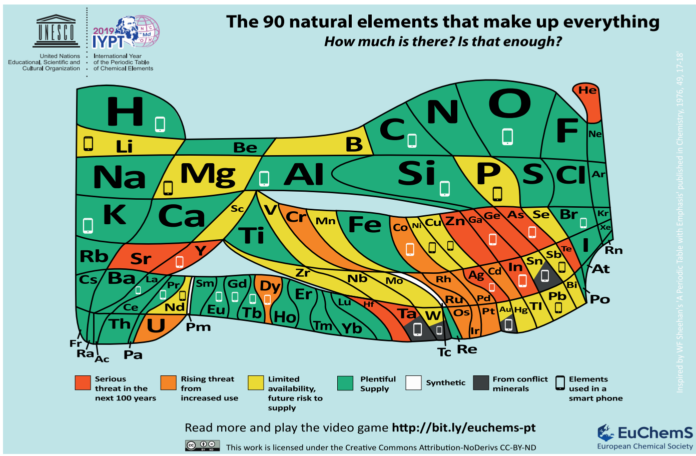
As part of its programme for IYPT2019, the European Chemical Society (EuChemS) has decided to highlight the problem of 'endangered elements' or element scarcity. It has identified about a dozen elements, which, owing to high demand and scarcity of supply, may become critical.

While not yet on the critical list, lithium may soon be in short supply. It is extensively used in rechargeable batteries, in cars and other devices. At present, global supply is about 40,000 tons per year. The largest suppliers are Australia, Chile and China, but Bolivia has the greatest reserves. If all the motor vehicles in use today were to be replaced by electric cars with lithium batteries, then 700,000 tons of lithium would be required per year! Yet, at present, less than 1% of lithium in use is recycled today. In the light of the Irish Government's recently published Climate Action plan, one has to ask if it is realistic to expect a complete change over to electric vehicles?

Another element, which is greatly in demand in recent years, is indium. It is used in screens on mobile phones and other electronic devices, because of its transparency and stability in air and water. The major producers are China, South Korea and Japan. However, this element is not mined directly, but is a by-product of zinc production and so its reserves are unknown.

Some of the so-called 'rare earth' elements are also in short supply. These are the fourteen elements, with atomic numbers from 57 to 71, which occur in the Periodic Table after Lanthanum and are known to chemists as the 'lanthanides'. They are not particularly rare, but they usually occur together and having similar chemical properties, are difficult to separate. While they are widely distributed, they are not very economic to recover, as they are not sufficiently concentrated in any one place. But they have very useful magnetic, phosphorescent, catalytic and optical properties. These elements are widely used in smart phones & other devices. There are some 40 elements present in an iPhone, of which 8 are rare earths. This is why, when upgrading a mobile phone, we should recycle the old one, so that the valuable elements can be recovered.

EuChemS has produced a version of the Periodic Table, which highlights, in a strikingly visual way, the relative abundance of the elements. It highlights the highly endangered elements in red, borderline elements in orange or yellow, while the abundant elements are shown in green.



You can download a copy of this table from the EuChemS website here: https://www.euchems.eu/euchems-periodic-table/

To find out more about the International Year of the Periodic Table and the events taking place to mark it, visit the official website: https://www.iypt2019.org/

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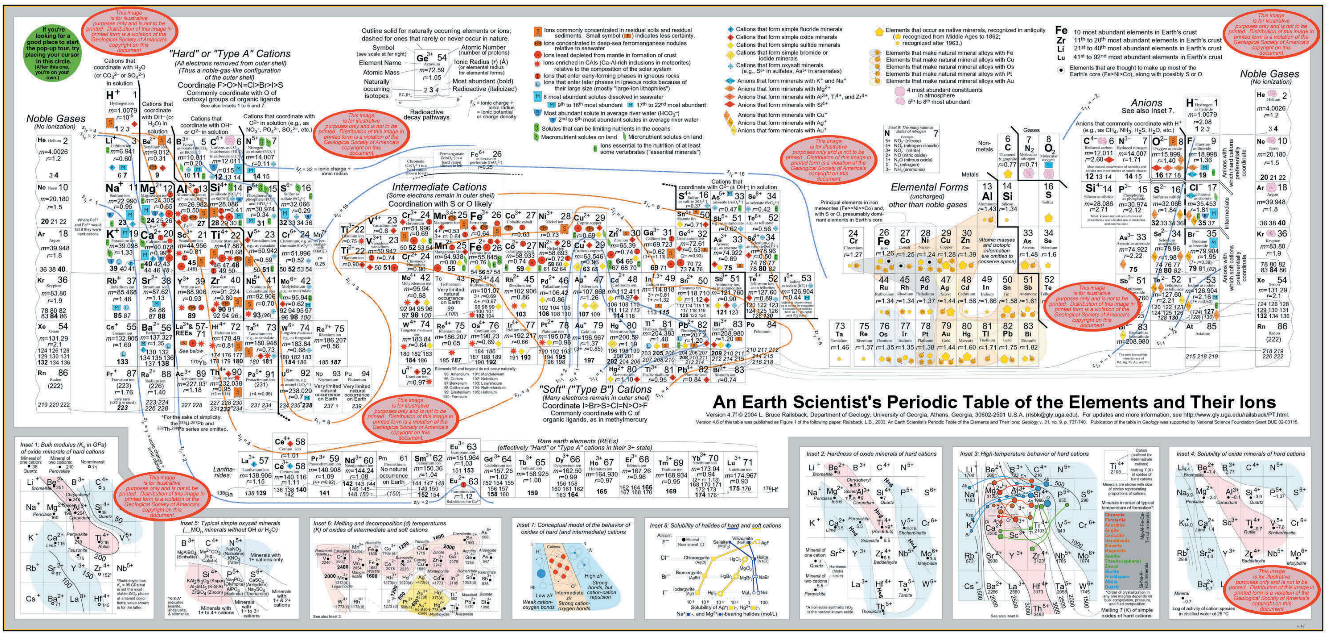
An earth scientist’s periodic table of the elements and their ions

http://www.gly.uga.edu/railsback/11111misc/PT46a12.pdf



This complicated diagram needs printing out on A3 paper (or large) in order to study it fully. It summarises a lot of data about the elements and their ions in relation to geology and earth science. It was created by Bruce Railsback and you can see a slide show explaining it at http://www.gly.uga.edu/railsback/PTTalk/PTTalk002.html.

All the natural elements occur in nature and thus are the province of the geologist and geochemist. But not all elements are found in the body or in biological systems. The biologist’s Periodic Table would thus be shorter, as shown in the version below (N.B. this is not fully up-to-date).

Elemental Haikus

Mary Soon Lee has published a website with a three line haiku for each elements of the Periodic Table. To be published in a book in October 2019. Here is an example:

Hydrogen, H
Your single proton
fundamental, essential.
Water. Life. Star fuel.

You can access them free of charge at:

https://science.howstuffworks.com/elemental-haiku-poetic-take-on-periodic-table.htm

(ULs Peter Davern has published a book of limericks based on the elements of the Periodic Table. It was available from Amazon but it is in the process of being revised and republished. Watch this space!)

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Russian studio reinvents the Periodic Table

A Russian art studio has reinvented the Periodic Table and data on the elements so that anyone can customise their own PT.
If you've ever dreamed of creating your own periodic table - and who knows, maybe discovering relationships between the elements that the scientific establishment had somehow overlooked until now - you can find Art.Lebedev's new version here.

Check out the video at:
https://vimeo.com/294347953
https://www.creativebloq.com/news/russian-studio-reinvents-the-periodic-tablehttps://periodic.artlebedev.ru/?gshl=ZsoThttps://periodic.artlebedev.ru/?gshl=ZsoThttps://periodic.artlebedev.ru/?gshl=ZsoThttps://periodic.artlebedev.ru/?gshl=ZsoThttps://periodic.artlebedev.ru/?gshl=ZsoThttps://periodic.artlebedev.ru/?gshl=ZsoT

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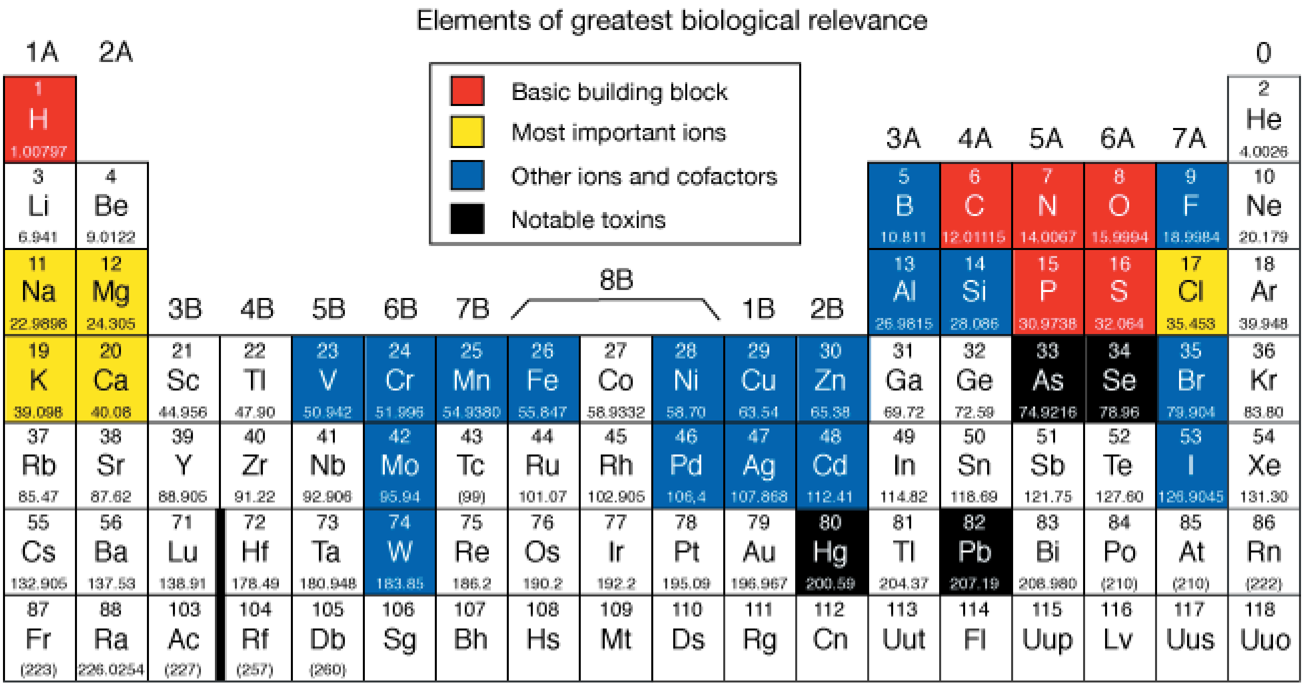
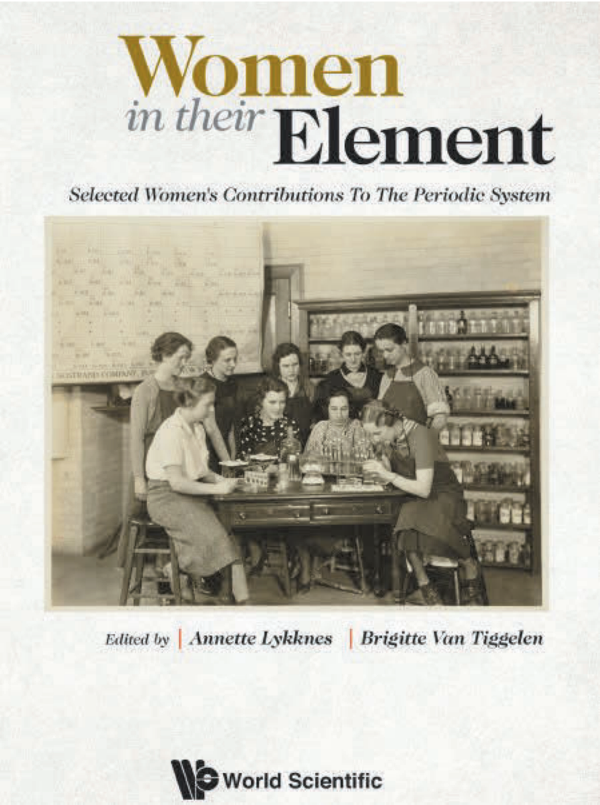


Source: http://xaktly.com/Chemistry_PeriodicTable.html

“The [periodic] table is one of the most beautiful and profound discoveries of the nineteenth century, but, until quantum mechanics was invented by physicists in the twentieth century, one could look upon it only as a mysterious cipher, a kind of crib sheet that served as an empirical reminder that elements come in families whose members show similar proclivities.”

Philip Ball, *The Ingredients: A Guided Tour of the Elements* (2002)



Women in Their Element

Selected Women's Contributions To The Periodic System

https://doi.org/10.1142/11442 | August 2019
Pages: 532

Edited By: Annette Lykknes (*Norwegian University of Science and Technology, Norway*)
and Brigitte Van Tiggelen (*Science History Institute, USA*)
(hb £75, pb £40)

This year we celebrate the 150th anniversary of Mendeleev's first publication of the Periodic Table of Elements. This book offers an original viewpoint on the history of the Periodic Table: a collective volume with short illustrated papers on women and their contribution to the building and the understanding of the Periodic Table and of the elements themselves.

Few existing texts deal with women's contributions to the Periodic Table. A book on women's work will help make historical women chemists more visible, as well as shed light on the multifaceted character of the work on the chemical elements and their periodic relationships. Stories of female input, the editors believe, will contribute to the understanding of the nature of science, of collaboration as opposed to the traditional depiction of the lone genius.

While the discovery of elements will be a natural part of this collective work, the editors aim to go beyond discovery histories. Stories of women contributors to the chemistry of the elements will also include understanding the concept of element, identifying properties, developing analytical methods, mapping the radioactive series, finding applications of elements, and the participation of women as audiences when new elements were presented at lectures.

As for the selection of women, the chapters include pre-periodic table contributions as well as recent discoveries, unknown stories as well as more famous ones. The main emphasis will be on work conducted in the late 19th century and early 20th century. Furthermore, the book includes elements from different groups in the periodic table, so as to represent a variety of chemical contexts.

Ideas for the temification of your science lessons

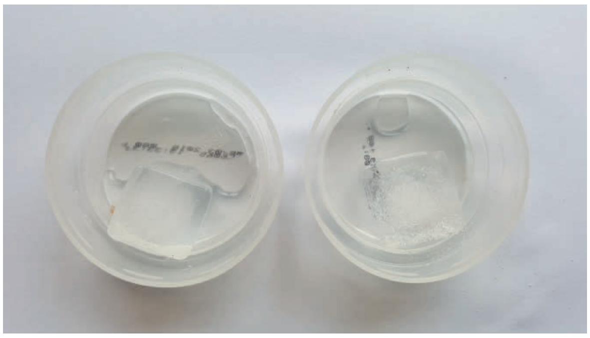
The melting ice cubes

Engagement – the mystery

When an ice cube is left in a warm room it melts. Nothing surprising about that, you may say. If we measured the temperature of the ice and water as it melts we would find something strange – the temperature stays constant until all the ice has melted. Why does that happen? But if we put some salt on the ice cube, it melts faster than the ice cube on its own, even in the same environment. The salt speeds up the melting of ice and you already know this is used in the winter to clear roads of ice. The two mysteries are: why does salt make ice melt faster and why does the temperature stay constant?

Start – salt on RH ice cube

After 20 minutes – more water in RH and ice cube eaten away



After 1 hour – much more melting when salt is present

Explore

If we observe carefully we can see that the salt eats away at the top of the ice cube as well as making it melt faster. If we measure the temperature of the ice cube and water (the control) it stays at 0ºC. If we measure the ice cube, salt and water the temperature drops below 0ºC. (Measure and record the minimum temperature). Is it just salt that makes ice cubes melt faster? Find out what local authorities use in winter to keep roads ice-free. Make up mixtures of ice and water and ice and salt water and measure their temperature. Why are they different? Why do they stay the same until all the ice has melted?

Explain

Why does salt (and other soluble substances) cause ice to melt quicker and also result in a drop in temperature? For ice to melt it must take in heat, which breaks the bonds in ice and forms liquid water. Normally this heat comes from the surroundings. The amount of heat coming in equals the amount used up in melting the ice, and so the temperature stays constant. When all the ice has melted, the temperature starts to rise as there are no more bonds to break and the heat coming in is used to raise the temperature.

What does the salt do? Notice that the salt seems to eat away the ice so that the salt dissolves. The salt dissolves in the water from the melted ice. Energy is being used to break bonds in ice, so that it melts, and also to dissolve the salt, whose ions are hydrated by water molecules. We could think of the salt grabbing water molecules from the ice to form salt solution, thus melting the ice. This energy is taken from the environment (ice and water) and so the temperature drops below 0ºC.

A more sophisticated answer for more advanced classes is in terms of the phase diagram for ice and water (see below).

Extend

Try making ice-salt water mixtures with different salt concentrations. Does the salt concentration affect the temperature of the mixture?

Try some other solids e.g. sugar, urea, sodium carbonate, limestone, sand. Which of them makes the ice melt faster and do they make the temperature fall? If so, do they all drop to the same extent? How do you make a fair test of this?

Can you classify solids which cause the ice to melt faster?

Does an ice cube melt faster in salt water than in fresh water? Set up an experiment to test this and measure the temperature. Soluble substances seem to behave the same as salt, and urea is also used in the winter to treat icy roads. Insoluble substances like limestone and sand don't have any effect.
Get the students to make up a freezing mixture to get the lowest possible temperature using ice, salt and water. This is often used to make ice-cream at home.

Evaluate

The design and conduct of the experiments to investigate the effect of different substances on the melting of ice and its effect on the temperature. The quality of the explanations in terms of ideas that the students already know. Identify that this effect depends on solubility, concentration and the number of particles in solution.

[So $Ca_3(PO_4)_2$, calcium phosphate, should have 2.5 times the effect of sodium chloride (5 particles versus 2); calcium chloride should be 1.5 times the effect of sodium chloride (3 particles versus 2), whereas sugar or urea would have half the effect (1 particle instead of 2).]

What limits the lowest temperature of a freezing mixture?

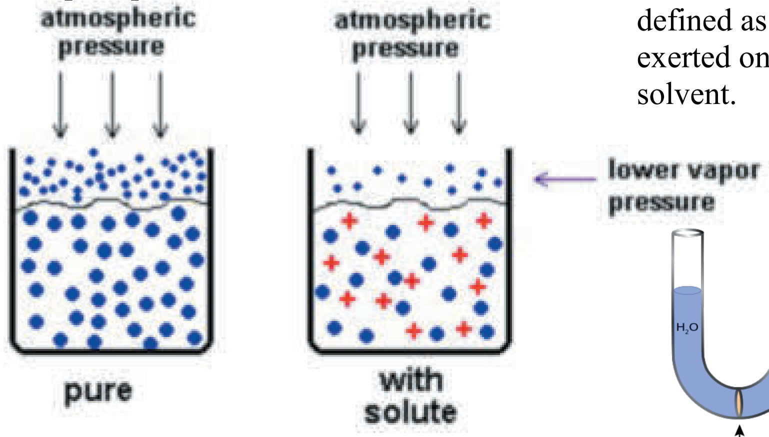
(A. The maximum solubility of the solute. For sodium chloride the limit is about -21ºC.)

What could you use instead of salt to produce lower temperatures? How could you do a fair test on different salts to see which was most effective?

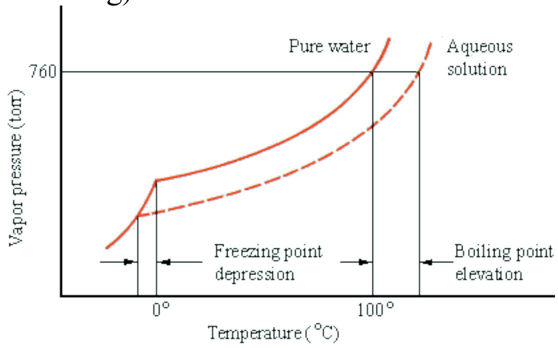
(Hint: Look for a salt which is more soluble than sodium chloride e.g. $CaCl_2$ or $MgCl_2$. A fair test would mean using not the same mass but the same concentration of solute i.e. same no. of moles/L.)

Further resources for the teacher:

The depression of freezing point by soluble substances is an example of a colligative property – others are elevation of boiling point and reduction of vapour pressure. Salts have a bigger effect than non-ionic soluble solids (sugar, urea) because the effect depends on the concentration of particles in solution. So salt (NaCl, which produces two moles of ions for every mole dissolved) produces twice as much an effect as sugar. The effect on freezing point and boiling point is usually explained in relation to a vapour pressure diagram for the ice-water-vapour equilibrium. The solute must be nonvolatile so that only the solvent is found in the vapour phase.

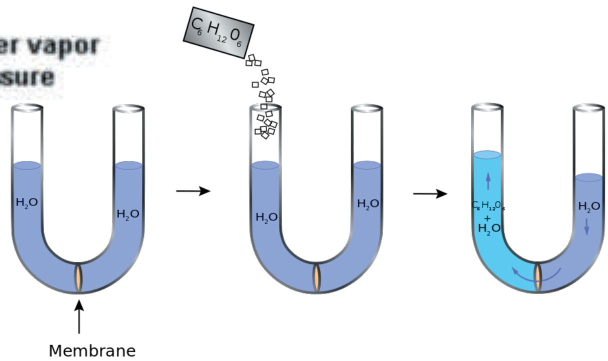


When a solute is present the chance of solvent molecules escaping is reduced and thus the vapour pressure is reduced. The greater the concentration of particles in solution, the lower the vapour pressure. Lowering the vapour pressure over the solution reduces the temperature at which ice and solution are in equilibrium (freezing point) and raises the temperature at which the solution and vapour are in equilibrium (boiling point), since it takes a higher temperature for the vapour pressure to equal atmospheric pressure (definition of boiling).



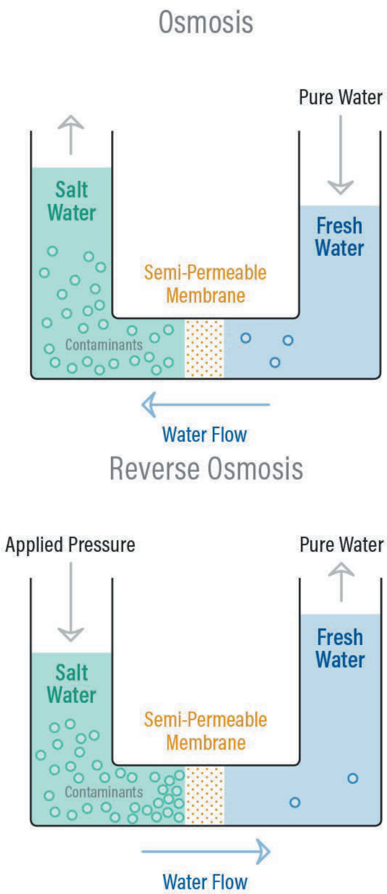
Osmotic pressure

The fourth colligative property is osmotic pressure. When a solution and pure solvent are in contact via a semi-permeable membrane (one that allows solvent but not solute to flow), solvent molecules move from high pressure (pure solvent) to low pressure (solution) to try and equalise the pressure. This is more commonly met in biology than in Chemistry, as cell membranes are semi-permeable membranes. The osmotic pressure is defined as the pressure that needs to be exerted on the solution to stop the flow of solvent.



https://en.wikipedia.org/wiki/Osmotic_pressure#/media/File:Osmosis_diagram.svg

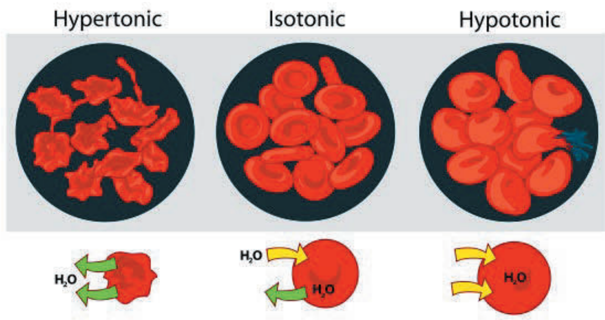
To start with the two liquid levels on either side of the membrane are the same. When glucose is added to one side forming a solution, the vapour pressure drops, and water moves across the membrane, raising the water level in the solution side. A 0.1M NaCl solution produces an osmotic pressure of ~ 5 atm. If we apply a pressure **greater** than the osmotic pressure, solvent is forced out of the solution and into the solvent. This is the basis of **reverse osmosis** used for producing pure water from sea water. The osmotic pressure of sea water at 25°C is ~30 atm. So we need a pressure greater than this to desalinate water using reverse osmosis. To produce pressure requires energy and so reverse osmosis is energy intensive.



For a good explanation of its commercial use see: https://puretecwater.com/reverse-osmosis/what-is-reverse-osmosis

Isotonic solutions

You will have come across the term ‘isotonic’ on sports drinks. Isotonic means equal (so) tone or tension (tonic) and refers to two solutions of equal osmotic pressure. When we drink such a solution, it neither takes water from or forces water into a cell. This is shown in the illustration below. On the other hand, a hypotonic solution inside the cell will take water in to equalise the pressure; a hypertonic solution will lose water to the outside. Both extremes can result in cell damage.



(https://en.wikipedia.org/wiki/Osmotic_pressure#/media/File:Osmotic_pressure_on_blood_cells_diagram.svg)

Osmosis can be thought of as a special case of diffusion but one where it only the solvent can move. If we use a membrane like cling film which is impermeable to water, non-polar solutes like iodine can diffuse through the membrane from high to low concentration trying to equalise the concentrations on either side.

□

Science Communication Races Ahead

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In September of 2017, a cohort of European students descended upon the University of Limerick (UL) for a science communication and public engagement module entitled RAw Communications and Engagement (RACE). What ensured was a week-long course with theoretical and practical components that illuminated an educational world that many students had not experienced before.
RACE is a European Institute of Innovation and Technology (EIT) funded project spearheaded by Dr Sarah Hayes of the SSPC, a SFI funded research centre. The project involved key participation from four third level institutions (University of Eastern Finland, Technical University of Madrid, Uppsala University, and UL) and two industry partners (Rusal Aughnish Alumina Ltd, Boliden Tara Mines Ltd). Driven by the idea that academia must move beyond traditional outputs, the module harnessed the expertise of all partners to develop educational content that would develop interpersonal, engagement and communication skills among participants. Over the last number of years, this has been highlighted as a skill deficit among scientists (Hulme & DeWilde, 2015; Hanson & Overton, 2010) one that needs to be addressed to build important bridges between science and society (Selin et al., 2017). Simply put, society funds scientific endeavours. In the past, this has often been a one way conversation, however, a two way dialogue is now being pushed by funding bodies and policy documents (European Commission 2008, Bauer & Seurdem, 2016).

This arguments above are the rationale behind the RACE module. Project leaders collaboratively designed a weeklong face-to-face and subsequent self-directed and group learning course that assimilates lectures, workshops and practical sessions in the areas of audience engagement, event planning, effective design and establishing relevance. This was grounded in a cycle of learning, implementing and reflecting. In addition, fundamental to the course are the concepts of modelling effective communication, the flipped classroom, active learning, demonstrations, experiments, peer feedback and assessment.

Over the course of the week students from Finland (4), Sweden (10) and Ireland (10) with specialisms in raw materials, batteries, crystal structures and fundamental chemistry made their first foray into a brand new discipline. Dr Sarah Hayes led the week with assistance from Dr Paul McCrory, a specialist in science communication. Participants were also treated to multiple guest speakers who demonstrated a range of methods by which scientists can interact with a variety of audiences from writing to school workshops to working with policy makers. Furthermore, participants developed and tested their own educational demonstrations while learning to present scientific detail in a way that was easy to understand. At the end of the module, every student was asked to conduct their own education or public engagement activity as part of their assessment.
The assessment represented a core part of the RACE programme. These activities were highly varied across multiple contexts with students working in a solitary manner or in teams. In Sweden, one of the highlights was an event called *Science & Beer* where RACE

participants gave entertaining talks in a pub environment (Figure 1).

Figure 1: Flyer for 'Science and Beer', a new type of public engagement event held in Sweden

Other unusual place for science to pop up was a large shopping centre in Finland. RACE participants brought posters, laboratory equipment and freebies as they interacted with evening shoppers and informed them about pharmaceuticals. In Spain, a hands on approach to science was taken on the streets of Madrid. The event allowed the public to get a glimpse into the world of mining and raw materials by panning for gold (Figure 2).

Irish events included school workshops and an

Figure 2: Members of the public panning for gold on the streets of Madrid

interactive science stand at a local Limerick market. In addition, a Thesis in Three event was held in which RACE participants presented their research in three minutes to a lay audience (Figure 3).

Figure 3: Thesis in Three event held in the University of Limerick

The implementation of public engagement activities proved to be extremely useful for participants. This was discovered through a research protocol instigated by the RACE project team that examined participants' views in relation to the course. Many noted how interacting with audiences in a real world environment brought their learning throughout the RACE programme to life. Moreover, the course gave participants an insight into the amount of practice and time that is invested into public engagement activities. Feedback also suggested that learning was highly valuable as many of the skills taught and modelled throughout the week are transferable to lecturing, presenting and writing. With this research informed evidence base, the course has been improved for the 2019 intake as the RACE team endeavours to keep the module at the cutting edge of communication and engagement. A shortened version of the course has also been established for companies that would like to promote effective communication in house or strengthen their Corporate Social Responsibility (CSR) programmes. More information on the RACE programme can be found at https://eitrawmaterials-race.com/

Acknowledgments

This project is funded by the EIT Raw Materials KIC. Project 15028, No. FPA 2016/EIT/EIT Raw Materials. This publication has also received support through the SSPC, which is funded by Science Foundation Ireland (SFI) and co-funded under the European Regional Development Fund under Grant 12/RC/2275, as well as the Centre for Discipline-Based Education Research in Mathematics, Engineering, Science and Technology at Uppsala University. This project would also like to thank the significant contribution of Prof. Daniel Brandell, Uppsala University and Dr Paul McCrory of Learn Differently Ltd in the implementation of the project.

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The Antimicrobial Resistance Epidemic

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Introduction

The issue of antimicrobial resistance is one that affects each and every one of us on a day to day basis. This 'crisis' presents a threat to the effective treatment and prevention of a wide, and ever increasing range, of bacterial, fungal, and viral infections. The World Health Organisation (WHO) has confirmed that the issue of resistance to common bacteria has reached alarming levels in many parts of the world. Findings suggest that surveillance of antimicrobial resistance is neither coordinated, or harmonised, resulting in many gaps within information on bacteria of major importance to public health. But what or whom exactly is to blame for this apparent epidemic? And what are we to do to help change this current state of public health? Well to address this, one must understand what the meaning of antimicrobial resistance is, how it comes about, and what potential alternatives are being explored.

How does this happen?

Overtime, microorganisms change upon exposure to antimicrobial agents such as anti-biotic/ fungal/ viral/ malarial agents, subsequently developing resistance to the antimicrobial activity of these agents. The microorganism is appropriately termed an antimicrobial resistance microorganism. The phenomenon of resistance to antimicrobial therapeutics is well understood by scientists, and is genetically intrinsic to bacteria.[1] However, in recent years, misuse and inappropriate application of antimicrobials such as antibiotics, has fuelled am impeding major threat that the so called 'antibiotic era'. One must appreciate however, that antibiotics have played a major role in increasing human life expectancy, and have greatly influenced human health and wellbeing through the selective action exerted on pathogenic bacteria/fungi, reducing the issue of 'infectious disease' which was the leading cause of death worldwide in the 1900's.

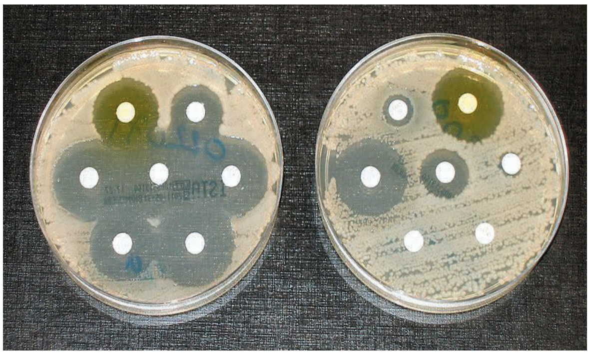

Figure 1: Petri dishes demonstrating the effect of various antibiotics on bacterial growth. https://web.archive.org/web/20110626190940/http://www.microbelibrary.org/component/resource/laboratory-test/3189-kirby-bauer-disk-diffusion-susceptibility-test-protocol

What's the big deal?

Drug resistant bacteria, however, have been the cause of an increasing number of deaths in recent years, with approximately 25,000 deaths in Europe, per annum, presenting itself as perhaps the single biggest threat to public health today. With bacterial resistance increasing exponentially over the last few years, such trends are set to continue. [2] The Centre for Disease Control and Prevention (CDC) have characterised the top 17 drug resistant threats based on their level of severity ranging from urgent to concerning. With serious threats including drug resistant Acinetobacter, multidrug resistant Streptococcus

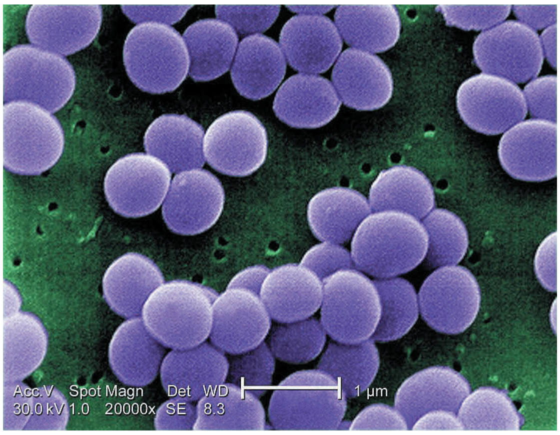

Figure 2: Image of *Staphylococcus aureus* under a Scanning Electron Micrograph (SEM)
https://phil.cdc.gov/default.aspx

pneumoniae, methicillin resistant Staphylococcus aureus, and drug resistant tuberculosis, to name but a few.

How can we overcome this crisis?

In an attempt to overcome the impact that current ineffectual therapeutics have triggered, scientists are researching potential alternatives to current treatments, with one potential alternative being peptide antimicrobial therapeutics. These cationic antimicrobial peptides have the potential to provide a viable alternative to current ineffectual antibiotics. They work by interacting with bacterial cell membranes [3], often via G protein coupled receptors or ion channels, triggering intracellular effects.[4] Their mode of action involves delocalisation of peripheral membrane proteins, which play an essential role in respiration and cell-wall biosynthesis. This delocalisation results in a limit to cellular energy, and undermines cell-wall integrity.[5] Their action ultimately leads to membrane lysis and eventual cell death. These therapeutics, however, are susceptible to hydrolysis and degradation in vivo, therefore the focus of our research in the University of Limerick is to develop polymeric matrices for bio availing and encapsulation of these drugs, for in vivo delivery

Synthetic drug delivery matrices

My research involves the synthesis of matrices designed to encapsulate these cationic antimicrobials, offering an effective and efficient mode of bio availing and delivering these sensitive drugs to the site of infection. One form of synthetic matrix are mesoporous silicates. These silica particles possess dimensions relative to many biologics, and with ordered pore structures, have been explored as a potential matric for the adsorption of peptide antimicrobials, to overcome associated problems with peptide stability.[6] Another matrix of interest is polymeric hydrogels which are 3D structures capable of possessing high volumes of water within their internal polymer network. Many hydrogel networks are synthesised via the crosslinking of two polymers, with encapsulation of drug particle during the crosslinking process. The synthesis of an injectable in situ forming hydrogel offers a potential alternative method of administration to a site of infection. While research is ongoing in this area, preliminary studies have shown the fantastic potential that these delivery matrices offer, with promising future societal impact.

What else can we do?

It's important that people understand the impact that antimicrobial resistance has, and how to look after oneself when they are sick. Educating children and adults alike that antibiotics shouldn't be used to treat viral infections, and to always finish a prescribed dose of antibiotics, even if you feel better, is a step that can be promoted through continued public engagement and education.

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Biography

James Flynn received his B.Sc. in Industrial Biochemistry from the Department of Chemical Sciences in the University of Limerick (2017). Upon completion of his degree he commenced a PhD under the supervision of Dr. Sarah Hudson (Chemical Sciences, U.L.) in August 2017. James' research focuses on the development of platforms for the delivery of antimicrobial peptides to bacterial sites of infection.

Acknowledgements

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The Future of Solar Energy

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In recent years, the solar industry has dramatically expanded as governmental supports become mainstream across the world and solar cell efficiencies continue to improve. Currently, silicon based solar cells dominate the market. However, new research into compounds, namely perovskites, have the potential to disrupt and dominate the market.

Perovskites represent a range of compounds with the same crystal structure as calcium titanium oxide (CaTiO3). The name is derived from the original mineral (Figure 1) that was discovered by Russian mineralogist Perovski in 1839. The research protocol investigating perovskites has traditionally focussed on their use as light emitters and the generation of laser light, however, in 2012, a Japanese team of scientists decided to assess the mineral's potential to adsorb light. They shone light onto the material and found that the perovskite transformed the light energy into electrical energy, just like solar materials. Due to their chemical adaptability, perovskites are now the forerunner for cheaper, more efficient and environmentally green solar cells. Although the potential is just beginning to be understood, it has caught researchers' attention as companies rush to develop and commercialize it. In 2013, researchers forecast perovskite solar panels would cost just 10 to 20 cents per watt (c/w), which is a substantial saving when compared to 75c per watt for silicon based installation. Furthermore, from a manufacturing perspective, silicon wafers require massive amounts of energy to produce, are expensive, heavy and bulky. They are made from in massive furnaces at temperatures above 1000 °C. However, a layer of perovskite less than 1mm in thickness can be made at temperatures lower than 150°C from a solution of ink. Given this, they have the ability be printed using inkjet printers onto materials such as clear plastics, just like rolls of newspaper.

Figure 1: Perovskite mineral displaying cubic crystal structures. https://www.minfind.com/mineral-419560.html

Figure 2: Perovskite solar panel
https://www.chemistryworld.com/news/first-building-integrated-deployment-shows-perovskite-solars-growing-maturity/3009953.article

Sheets of perovskite solar panels (Figure 2) will be lightweight, flexible, and easy to integrate onto any curved surface. Consider the curved surface of your car roof and bonnet absorbing energy to replenish the battery in your electric vehicle at any time that light is shining on it. Or the fitting over street lights which charge a battery during the day and power the light during night time. Due to its distinct advantages over silicon based solar installations, it may seem like perovskite will take over the market. However, scientists from Switzerland do not believe that perovskite and silicon need to be enemies. Perovskite does not absorb all light but allow some to pass through. Therefore, a perovskite panel can be coated on top of silicon panels meaning two solar panels can be installed in the place of one, transforming much more energy to electricity. We may see these monolithic, or tandem, solar panels soon.

Figure 3: Panda shaped solar installation in Datong, China
https://www.photonics.com/Articles/Solar_Farms_in_China_Masquerade_as_Pandas/a62839

Other applications of the technology are being tested by the National Renewable Energy Laboratory (NERL) who have built a prototype smart window that uses perovskite to absorb light on bright days. When enough light shines on the glass, a reversible chemical reaction occurs which turns the glass from clear to opaque. This could serve the dual purpose of keeping buildings cool by shading them, without the need for blinds, all while reducing the electricity costs of the structure. Heating/cooling and subsequent ventilation of a commercial building can cost up to 80% of their energy bills. Hence, this technology could tackle those bills head on. The majority (50-80%) of windows currently installed use some sort of low heat emission coating inside the glass.

Perovskite is also an ideal material for this purpose.

With new illuminating developments in the pipeline, the world is certainly opening its doors to solar energy. In 2016, the worldwide capacity for capturing of solar power doubled with China leading the way. One new solar farm occupies 250 acres and shows a solar farm designed in the shape of a panda (Figure 3), while Disneyland Florida is powered by a Mickey Mouse themed installation with 500,000 panels (Figure 4). These types of installations reflect the growing public support for solar energy as a passive and relatively non-intrusive form of green energy. Perovskites may be able to build on this momentum and improve and already bright outlook for solar.

Figure 4: Mickey Mouse shaped solar panel installation in Florida
https://www.nytimes.com/2018/10/09/business/energy-environment/the-magic-kingdom-is-going-green.html

Biography

Fiona McGrath received a B.Sc. in Energy from the Department of Physics in the University of Limerick (2016). Upon completing her degree, Fiona interned as a research assistant in Nanotechnology group at the Bernal institute for 6 months. She was awarded an IRC Enterprise Partnership Scholarship with Intel Ireland enabling the beginning of her PhD journey under the supervision of Prof Kevin Ryan in January 2017.
Her current research focus is the colloidal synthesis, characterisation and assembly of perovskite nanomaterials for next generation optoelectronic devices.

Acknowledgements
This work has been funded by the Irish Research Council and Intel Ireland.

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The miracle of carbon

“Carbon, in fact, is a singular element: it is the only element that can bind itself in long stable chains without a great expense of energy, and for life on earth (the only one we know so far) precisely long chains are required. Therefore carbon is the key element of living substance: but its promotion, its entry into the living world, is not easy and must follow an obligatory, intricate path, which has been clarified (and not yet definitively) only in recent years. If the elaboration of carbon were not a common daily occurrence, on the scale of billions of tons a week, wherever the green of a leaf appears, it would by full right deserve to be called a miracle.”

Primo Levi, *The Periodic Table* (1975) "Carbon"

Chemists you should know: #6

The Henry Family - 1734 to 1892

Adrian Ryder (E-mail tutorajr@gmail.com)

Three generations of Henrys are dealt with in this article – the grandfather Thomas was the prime mover and originator of the family fortune gained from his chemical business. His son William was to further the business and develop the findings of Thomas to become one of the best-known chemists of the time, considerably adding to the family fortunes at the same time. Both Thomas and William were elected Fellows of the Royal Society of London, an accolade not received by William's son William Charles, who was endowed with a fortune sufficient to enable him to dabble in the scientific world without really making any real contribution, but which allowed him to enjoy the comfortable leisurely life of a country gentleman.

No.1 Thomas Henry, 15 February 1734 to 18 June 1816 (Grandfather)

Thomas Henry

The first of the trio of Henry's, whose lives and work were intertwined, descended from several generations coming from Co. Antrim, through Wales and following Thomas's father's marriage to a clergyman's daughter, to Wrexham in North Wales, where he opened a girls' boarding school. Here Thomas was born, educated and trained as a surgeon-apothecary before the family moved to Knutsford (14 miles South-West of Manchester). From here he moved to Oxford as principal assistant to a Mr Malbron, then the leading apothecary, where he associated with members of the University and was able to attend anatomy lectures with John Hunter (1728-1793) as demonstrator. But not satisfied with the archaic science outlook found in Oxford in 1759, Thomas moved back to Knutsford to practice as an apothecary there. On June 16th 1760 he married Mary Kinsey and in 1764 they moved to King Street, Manchester, where he set up shop as a Surgeon-Apothecary. Thomas kept the practice open for more than forty years, catering for the more opulent citizens of the town and surrounding area. Further in 1779 he was appointed a visiting apothecary to the Infirmary and took an active part in its concerns to just before his death. The couple had at least five children that I could locate. These are Phoebe (born 3/Jun/1763), Thomas (1767 – 1798), who helped his father in presenting his lectures but moved to London to study medicine. Here instead he and others set up a vitriol (sulfuric acid) business, which ceased in 1793. With his friends, Thomas junior had become involved in the anti-Jacobin riots of that year and he and his friends absconded to America, but returned in 1796, only to find his place in the family business taken by William (1774-1836). Peter (1769 – 1808), decided to set himself up in business away from the family establishment and died aged 39 in 1808. Elizabeth (born 14/Mar/1771) and William (12/Dec/1774 – 2/Sep/1836) (about whom more below). All I could find about the two girls is their birth/christening date.

Thomas senior was more a practical scientist than a theoretical one. He invented a process for preparing magnesia alba (a suspension of basic magnesium carbonate), and having taken a patent for it began to produce it in 1772 as a cure for acute indigestion, acid stomach, heartburn, dyspepsia and other disorders. So popular was Thomas's product that he gained the nickname 'Magnesia' Henry!

The bottle shown inscribed Henry's Calcined Magnesia was four inches high and available at three shillings, nearly three weeks wages for a labourer. The product was to make the Henry's very rich and the product continued under the Henry name right up to about 1937.

A slightly later product from Thomas Senior was aromatic vinegar, a range of mixtures of vinegar and essential oils, intended to remedy respiration problems and a safeguard against infection; however, it really only sweetened the prevalent bad smells found in houses of the time. You can prepare this at home using two or three tablespoons of vinegar with five or six drops of an essential oil, such tea tree, lemon, citronella, basil, clove etc. in an open container, instead of buying an air-freshener.

An advert for Henry's Calcined Magnesia (1900)

The two preparations were exported far and wide and later the *Kilkenny Independent* newspaper of Wednesday, January 24, 1827 had an advertisement for both, each at a cost of three shillings.

Thomas was a founding member in 1781, and afterwards in 1807, President of the Manchester Literary and Philosophical Society. As a result of papers read to this Society by Thomas Henry and the Rev. Thomas Barnes, the Manchester 'College of Arts and Sciences' was founded in 6th June 1783, the first institution of its kind in England. Here Thomas lectured on Chemistry with reference to Arts and Manufactures. He also gave public lectures to large audiences on Chemistry which included 'a course on the Arts of Bleaching, Dyeing and Calico-Printing', which he continued even after the demise of the College in 1788. From the mid 1790's Thomas began to hand over the control of the businesses to William, who became a full partner in 1797. Thomas passed away on the 18th of June 1816 knowing that the business was thriving and in good hands.

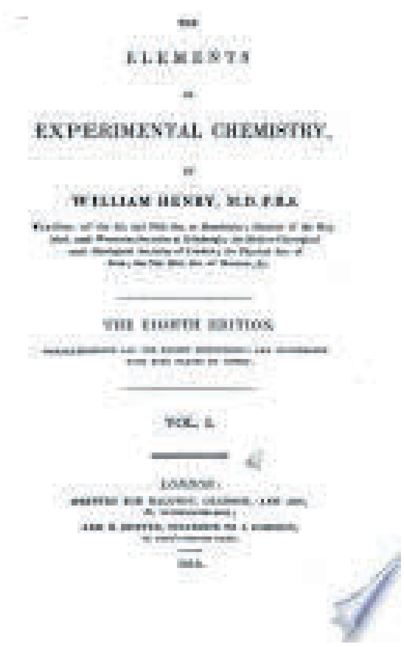
No.2 William Henry, 12 December 1774 to 2 September 1836 (Son)

William Henry

As a young boy William suffered severe injuries when a beam fell on his right side. The acute neurological pain he suffered was to remain with him throughout his life and when it flared up it incapacitated him, so much so that he would have to sit in the street for some time if caught outdoors at the time. Unable to take part in physical boyhood activity, he turned to intellectual work and found scientific investigation to his taste. At the last, the pain was such that he was unable to sleep for weeks and in 1836 he shot himself in his private chapel in Pendlebury to his misery.

In 1795 William went to Edinburgh to study medicine but after only a year there was recalled home by his father, who needed him in the work of the family industry. From 1797 he ran the Magnesia factory as a partner with his father. The factory continued to operate under the name T. & W. Henry up to 1937. While continuing the practical side, William became more involved in the theoretical side of chemistry than his father had been. William continued his experimental work while at work and in 1803, and was inspired by the carbonation of water which, following initial work by his father, Thomas from 1781 and the production of the first mineral waters in 1802 by the family firm, which are still today a major 'soft drinks' industry worldwide today. He proposed, in one of his nine papers published in the *Philosophical Transactions* of the Royal Society in late 1802, what is now known as Henry's Law. This states that *'for dilute solutions the quantity of a gas absorbed by a liquid is proportional to the pressure of the gas above the liquid providing no chemical reaction takes place.'* His work was done at a temperature of 55 degrees Fahrenheit and he went further to show that at higher temperatures less gas was absorbed.

Prior to this in 1799 he published a text-book, *'The Elements of Experimental Chemistry'*, which was very well received and during the following thirty years went through some eleven editions. Prior to this William had made studies into the composition of Muriatic Acid (hydrochloric acid) and ammonia. He had shown that the acid contained the elements hydrogen and chlorine but assumed that being an acid that oxygen was, as generally believed, also present. However, later on in 1812, Humphry Davy proved the acid contained only hydrogen and chlorine. William was quick to write in support of Davy and presented further experimental details.



ELEMENTS

EXPERIMENTAL CHEMISTRY.

WILLIAM HENRY, M.D. F.R.S.

THE EIGHTH EDITION.

VOL. I.

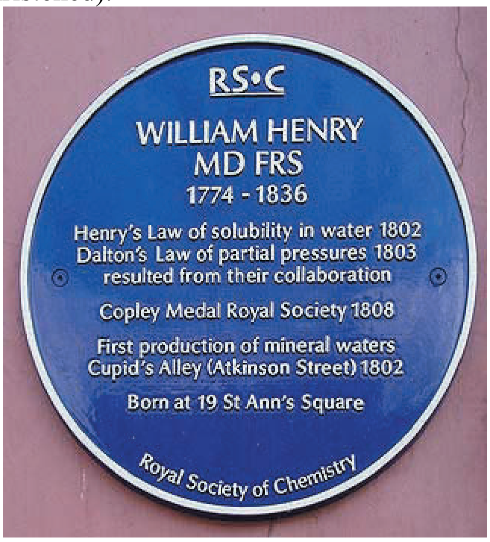
LONDON:

Title page of vol. 1 of William Henry's textbook

In 1805 business had settled down and leaving it in the hands of a manager, William was able to return to his medical studies in Edinburgh, where he took the MD degree in 1807. His work in chemistry led to the award of the

Association for the Advancement of Science and was also Vice-Chairman of both the Literary & Philosophical Society and the Natural History Society of Manchester.

William married Mary Bayley, daughter of Thomas Bayley and Mary Kennedy, on the 27th June 1803. The couple had nine children of whom only six lived to maturity. The children were William Charles (31 Mar 1804); Mary (25th Aug 1805, Christened); Thomas (07 Feb 1807); Lucy (1 Sep 1808); Lucy Anne (20 Mar 1810); Frances (19 Aug 1811); Amelia (5 Mar 1813); Thomas (15 Apr 1816, Christened); Charlotte (18 Jan 1818, Christened).



Plaque erected in St Ann's Square, Manchester by the Royal Society of Chemistry

From 1805 to 1820 William undertook a series of experiments on the destructive distillation of coal for use in gas lighting, the only experiments on this topic are prior to the 1850's.

William was also one of the founders of the Mechanic's Institute, which met in a public house, the Bridgewater Arms, on April 7th 1824, to set up a body that on 29th July 1955 received a Royal Charter to become the University of Manchester Institute of Science and Technology (UMIST), now part of the University of Manchester.

Like his father, William continued to practice as a physician and in 1829 we find him listed as a physician in Princess Street, Hulme, an inner city area and electoral ward immediately south of Manchester city centre.

Following Thomas's death in 1816, William had taken Samuel Thompstone (1805-1847) as a partner, but in the early 1830s William dissolved the partnership amicably, keeping the Magnesia processing side and leaving the mineral water side to Samuel. In 1842 Samuel is listed as a pawnbroker in Glebe Street, near the business set up by the Henrys, a dramatic change in profession.

After his son William Charles married in 1834, William Senior and the rest of the family moved to Pendlebury, four miles out from Manchester, where he died two years later, his wife Mary passing away the following year.

No.3 William Charles Henry, 31 March 1808 to 7 January 1892 (Grandson)

William Charles Henry

William's son, William Charles, generally called Charles, was born on the 31st of March 1808. Like his father and grandfather he also studied medicine, graduating from Edinburgh with a M.D. in 1827 and was a physician to the Manchester Infirmary from 1827 to 1835 and also on the Board of Health, and is listed as a physician in 23 Bond Street in 1829. He married Margaret Allan in 1834 and the couple produced ten children, 6 girls and four boys, the first two born in Manchester and the rest at Haffield, Herts. None of the children were to make any great mark in the world. Margaret (18 Oct 1834, Manchester); William (22 Nov 1836, Manchester); Mary (13 Dec 1837);

Harriet (10 Dec 1838); Charles (8 Apr 1840); Thomas Allan (1 Oct 1841); Francis (8 Dec 1842); Caroline (18 Apr 1846); Lucy (4 Sep 1847); Emily (19 May 1851).

Following the death of his father, William, in 1836, William Charles moved to Haffield, Ledbury, Herts. and with the family business now his, led the life of a country gentleman. His interest in scientific studies was nothing like that of his father and grandfather, with his publications being mainly biographical, apart from two prepared for his M.D. degree. He lectured at Pine St. School of Medicine on physiology in 1839 and did some of the earliest work on the physiology of the nervous system as well. His scientific experience in the family business meant that he could keep an eye on the purity of the magnesia being produced. In 1851 he donated a collection of scientific books to the Owens College (later the University of Manchester) library. He was, a few years before his death, to become a fellow of the Institute of Chemistry of Great Britain and Ireland and was a Justice of the Peace for his neighbourhood. He died on the 7th Jan 1892 two years after his wife Margaret d. 26th April 1890.

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Carbon is special

"There are several points we need to tie up before leaving this aspect of alliances in the kingdom. One concerns the overarching power of carbon to participate in molecule formation, a power that results in such complexity of structure and collaboration that the alliances it forms become alive and can reflect upon themselves. The essential reason for this latent power of a single region is, as noted, carbon's intrinsic mediocrity, its lack of self-assertion. Sitting as it does in the middle of the northern coast, it is neither an aggressive shedder of electrons, as are elements to the left, nor is it an avid receiver, like the atoms to its right. Carbon is mild in its demands on the alliances it makes. Moreover, it is even content with its own company, and can make extensive liaisons with itself, forming chains, rings, and trees of atoms. Were it readier to give up its electrons, it would do so at the demand of another atom, and then find that it had not retained sufficient electrons to bind other atoms in a precise disposition. If it were more avid for electrons, it would soon satisfy its tendency to bond and would lack the opportunity for subtle conspiracy with others. By being in the middle, undemanding and not particularly generous, it can spin lasting alliances rather than hasty conspiracies."

P. W. Atkins, *The Periodic Kingdom: A Journey into the Land of the Chemical Elements* (1995)

SuBATOMIC

Supporting Better Activities To Overcome Misconceptions In Chemistry

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The SuBATOMIC website was creating as part of research project involving student science teachers. The goal of this research was to address common alternative conceptions, also known as misconceptions, in chemistry. As part of this, we created the SuBATOMIC website – **www.subatomic.ie** – which provides student science teachers with activities, practical advice, and resources for use in their lessons. These activities and resources are directed towards overcoming the chemistry misconceptions that are likely to be found in the classroom, and they are now publicly available at **www.subatomic.ie**.

Teaching Chemistry

The primary purpose of the website is to provide useful information and resources for teaching the chemistry concepts in the Junior Certificate science syllabus. Teaching Junior Certificate science might seem easy on the surface, but when you are new to teaching, not familiar with students' level of prior knowledge, and quite possibly terrified of students asking questions that you don't know the answer to, it can be quite a challenge.
For the topic areas of materials, chemical bonding, water and solutions, and the classifications of substances, the SuBATOMIC website provides:

- A list of common misconceptions that teachers are likely to come across in the classroom
- An overview of the important concepts related to the topic, so that student teachers can revise their own understanding and increase their confidence prior to teaching the topic
- Practical activities for each topic that are designed to reveal students' common misconceptions and address them
- Ready-made resources, such as concept cartoons and questions that can reveal students' understanding

An example of one of these diagnostic questions is provided at the end of this short article.

Teaching Tips

Student science teachers face a greater challenge than more experienced teachers when it comes to preparing for lessons. There is a lot of consider for someone who is a novice:

- How does this lesson connect to the wider syllabus?
- How do I write an effective lesson plan?
- What is the prior knowledge level of the students and what ideas am I likely to come across?
- How will I handle questions when I have doubts about my own deeper understanding of this topic?
- What activities can really support my learning objective?

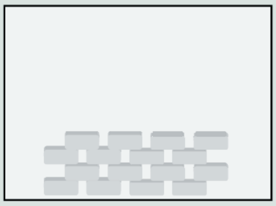
Of course, all of these considerations are secondary to the bigger concern for student teachers everywhere – how can I avoid discipline issues, and if they arise, what am I going to do about that?
Initially, we had not intended to include general information about teaching on the website. However, the student science teachers we worked with were very unclear about the basics of

lesson planning and asked us to provide a practical resource for lesson planning novices. Many experienced teachers have moved beyond creating formal lesson plans, but student teachers need these plans to organise their lessons, as well as ensure that their teaching methods are visible to examiners and tutors.

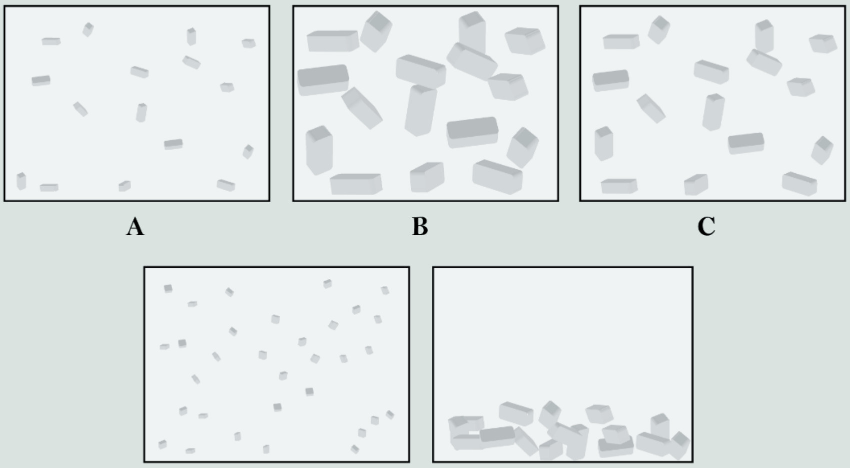
To support lesson planning and the more practical aspects of teaching, the SuBATOMIC website provides a 'Teaching Tips' section. Here, you can find practical and concrete information about writing lesson plans, using YouTube clips in PowerPoint presentations, and using mobile phones in the classroom. The student science teachers we worked with were very intimidated by lesson planning, and the practical lesson planning resource was probably the resource they valued the most.

Lesson planning is stressful when you are new to it, and when combined with fears about the content to be taught, and the questions that students might ask, teaching a lesson can be a real hurdle. If you need some support, practical advice, or teaching ideas, please visit www.subatomic.ie.

A solid is inside the container below (the box). The particles of this solid are shown.



Which of the pictures (labelled A-E below) best represents the particles after the solid has changed state to become a gas? (**Select one answer below**)



A B C

D E

Select the reason for your answer

1) The particles break up and contract when the substance changes from solid to gas.
2) The structure of the particles is not altered when the substance changes from solid to gas.
3) The particles contract as the substance changes from solid to gas.
4) The particles break down into smaller parts when changing from solid to gas.
5) The particles expand as the substance changes from solid to gas.

The Colourful World of Gemstones, Part 1

Adrian J. Ryder (E-mail tutorajr@gmail.com)

What is a gemstone? In general a gemstone is a mineral with a specific chemical formula, which can be found as a crystal and has inherent beauty, durability and rarity. It becomes a jewel when faceted or cut into a cabochon. (A cabochon (from Middle French caboche "head") is a gemstone which has been shaped and polished as opposed to faceted. The resulting form is usually a convex (rounded) obverse with a flat reverse.)

Photo 1.1 (Author): Month Stone Jewels; Top left to Bottom right; January to December; Garnet, Amethyst, Aquamarine, Diamond, Emerald, Moon-stone, Ruby, Peridot (Pendant), Sapphire, Opal, Citrine, Topaz. The Moon-stone and Opal are shaped as cabochons, the others are faceted.

One can divide the gemstones into two groups based on the origin of their colour. One, called **ideo-chromatic**, derives its colour from the atoms in its basic formula. The other, called, **allo-chromatic**, derives its colour from atoms, not in the basic formula but which have replaced some, usually a very small percentage, of the basic formula atoms.
Examples of ideo-chromatic gemstones are, Peridot, Malachite and the various Garnets.
Examples of allo-chromatic gemstones are the Beryl, Quartz, Spinel, Topaz, Tourmaline and Corundum (Ruby, Sapphire), groups.
The colour displayed by a gemstone is the reflected white light spectrum less wavelengths absorbed by the excitement of electrons to higher energy levels of atoms or ions in the solid. Atoms of the first transition series of the elements are the principal cause of colour in the gemstones. (Scandium, Titanium, Vanadium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper. Zinc with this d shell full is the exception.) The light energy absorbed is, of course, released later but at wavelengths not seen in the visible spectrum and so a particular colour-void is created in the gemstone leading to the colour seen. Thus in a blue Sapphire, the wavelengths toward the red end of the spectrum are being absorbed, while the blue wavelengths are being reflected, while in the green Peridot both the blue and red wavelengths are being absorbed, while the green and yellow are being reflected.

Photo 1.2 (Author): Tray of precious stones, Top to Bottom: Diamonds, Garnets, Rubies and Sapphires. (each container has a 1 inch diameter)

The number of gemstones is so large - one set of physical information deals with some 441 entries - that I have selected nine of the best known groups to look at in this short series of essays. These are the Beryls, Diamond, Garnets, Peridot, Quartz, Ruby and Sapphire, Spinel, Topaz and the Tourmalines.
To begin I am departing from the alphabetical order above and taking Peridot as the first topic as there are no varieties of this gem only a colour deepening which is clearly visible in the following photograph.

Peridot

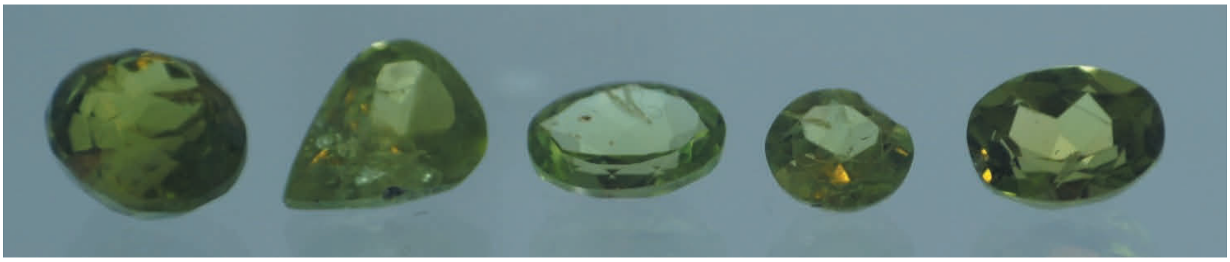
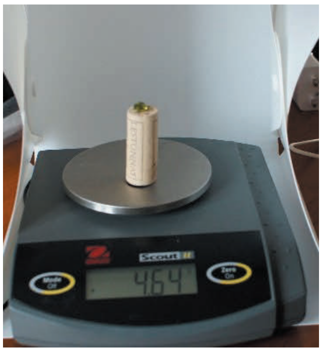


Photo 1.3 (Author): 5 faceted Peridot. From L to R, 3.3 carat, 1.9 carat, 1.25 carat, .85 carat, 1.65 carat (colour change Peridot).

The general chemical formula for the very recognizable ideo-chromatic green Peridot gemstone is $(Mg,Fe^{2+})_2SiO_4$. Peridot is the mid-member of the Forsterite-Peridot-Fayalite series, from Mg_2SiO_4 to Fe_2SiO_4, which has a range of colour, darkening from colourless, through shades of green, to brown-red depending on the amount of the ferrous (Fe^{2+}) ion present. Only those in the mid-range, the Peridot, are used as gemstones.
The specific gravity (s.g.) also increases across the series depending on the proportion of the ferrous (Fe^{2+}) ion in the compound. The Forsterite s.g. is 3.28 Peridot runs from 3.28 to 4.39 and Fayalite has a s.g. of 4.39. (The s.g. is dimensionless as it is the density relative to the density of pure water.)
The olive green of Peridot is one of the few colours in the gemstone world that gives an immediate identification of the gem.

Peridot reacts to a magnet, which can be used to further identify the gem The top photo shows the 3.3 carat Peridot on top of a wine-cork placed on the balance showing a reading of 4.64 g. (The cork is placed so that the magnet has no appreciable effect on the pan of the balance.) The bottom photo shows the effect of bringing some coin magnets close to the stone showing a drop to 4.43 g. The loss of the 0.21 grams, from a gem weighing 0.66 g, is due to the pull of the magnets on the Peridot gem. The attraction is such that the magnets could drag the gemstone along a table with ease.



Photos 1.4 & 1.5 (Author) 3.3ct Peridot on Cork on an electronic balance

Photo 1.6 (Author) 13 carat Forsterite-Peridot Laughing Buddha carved gem.

The magnets had no visible effect on the laughing Buddha in the above picture, as the iron content of the green coloured section is too little to show a reaction.Armstrong1984 The magnetic effect can be amusing by floating a Peridot on, say, a piece of bubble-wrap in a dish of water, and using a coin-magnet stick to draw the floating stone around the dish.
(A coin-magnet stick is made by linking 4 or 5 coin magnets together and using an ordinary nail which is attracted to one end of the magnets as a handle.)

Beryl

Focus is now brought to bear on the second of the gemstone types to be considered, the Beryl group.

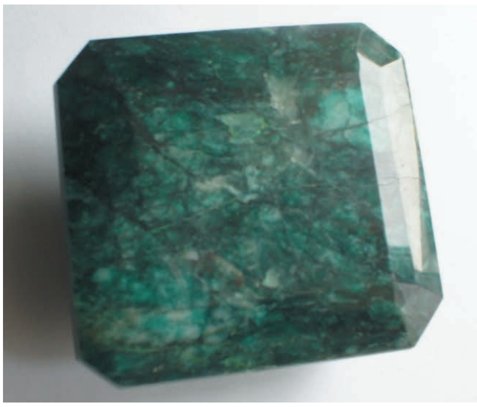


Photo:1.7 & 1.8 (Author): A huge Emerald of 4395 carat left and a 980 carat, yellow Beryl right.

The general formula for the allo-chromatic Beryl gemstones is $Al_2Be_3Si_6O_{18}$. Here the stones unadulterated by atoms of other elements give a colourless gemstone called Goshenite. It should be noted that all the allo-chromatic varieties of gemstone will have a colourless member along with their coloured cousins. Apart from Goshenite, the two principal coloured Beryls are the green Emerald and the Blue Aquamarine. The main varieties of Beryl are now described.

Photo 1.9 (Evan Ryder): Selection of Beryls; Centre Stone: Bixbite 23.2 carat, Clockwise from top: Aquamarine 1 carat; Goshenite 2.75 carat, Goshenite 5.65 carat: Morganite 0.65 carat: Lab Morganite 7.25 carat:: Blue Beryl 5.5 carat: Emerald 6.15 carat

Emeralds are coloured by chromium atoms replacing some of the aluminium atoms giving the rich deep green colour. Other green Beryls are found, one is coloured by vanadium atoms and another by ferric (Fe^{3+}) atoms, which gives a light yellow green colour. These latter two are properly called green Beryl and Heliodor respectively. Emeralds themselves may have their colour shading affected by small amounts of vanadium and/or iron being present as well as the chromium. Emeralds exhibit a magnetic effect due to chromium based on the depth of colour. Very light-coloured emeralds may show none. Aquamarine, the delicate blue Beryl, is coloured by iron atoms replacing the aluminium atoms. A mere 1% replacement by the iron gives the lighter shades of blue, while the darker shades may have up to 3% of iron replacement. A green form of Aquamarine is also found, and heat changes the colour to blue. A darker blue, massive Beryl, again coloured by iron, is also known. In general, the darker the blue the greater the magnetic effect.

A raspberry coloured Beryl, called Bixbite, owes its colour to the presence of manganese atoms. A pink coloured Beryl, called Morganite, again coloured by manganese but also containing cesium and lithium atoms, makes for a very pretty gemstone. Neither lithium nor cesium in themselves causes coloration in gemstones in which they are found, but may moderate the effect of other elements. No magnetic effect was found for this stone.

A lemon yellow to golden yellow coloured Beryl, simply known as Golden Beryl, is coloured by iron atoms. This stone's colour is removed by heating to a mere 250° C. (A hot oven's temperature.)
The specific gravities of the Beryls run from 2.66 to 2.87, with the deeper/darker colours giving the greater values. Thus the clear mineral Goshenite will have the lowest value.

Diamond

Photo 1.10: (Evan Ryder): Flashes of reflected colour from a 1 carat colourless Diamond

Diamond is the crystalline form of the element carbon, in a sense crystalline coal, so do not drop it in the fire.

Diamonds are found in many colours as well as the well-known colourless form found in engagement rings. Yellow Diamonds are graded along with the colourless ones on a scale from D to Z, absolutely colourless through shades of yellow. Rarer colours known from nature are red, blue, orange, purple, green and yellow and are often termed fancy coloured. Brown and black Diamonds also occur.

Photo 1.11 (Author): Some Coloured Natural Diamonds, 0.2 to 0.3 carat.

Diamonds hold pride of place in the gemstone world, with the market value of the Diamond production being over 90% of the entire gemstone trade. About 20% of the Diamond production is designated gem quality. Another 20% is declared near-gem quality and the rest is used in industry. One can buy a diamond nail-file at very little more than the plain metal ones.

(In the last 50 years science differentiates between type 1a, 1b, 11a and 11b and 111

Diamonds, none of which is of importance in the trade but does assist the cutter of these gemstones. Type 1a Diamonds contain platelets of Nitrogen to a significant degree. The type 1b contain molecules of Nitrogen finely dispersed throughout the stone. These are seldom found in nature but virtually all synthetic Diamonds belong to this category. The 11a Diamond type have no significant nitrogen in them. They are rare in nature but have a greater brilliance and heat conductivity than the other types. Type 11b Diamonds harbour traces of Boron as impurities leading to a blue colour generally and are semi-conductors allowing electrical current to pass through. The type 111 diamonds, with a hexagonal crystal structure instead of the basic cubic system of the ordinary Diamond, have been found in meteorites and have also been lab-produced.)

Diamonds in which small amounts of boron combine with carbon atoms have red, yellow and green light absorbed, giving the stone a blue colour.

Some diamonds, in the course of their ascent from the depths of the earth, have distortion caused to the crystal structure by the changes in pressure and temperature. The wavelengths up to and including green are being absorbed giving resultant pink, red and brown stones. Nitrogen atoms within the diamonds affected absorb more blue light to give resultant yellow and orange stones.

Diamonds affected by natural radiation have their outer layers altered, resulting in a green colour, which changes to yellow on heating. Purple and violet Diamonds are thought to be due to crystal distortion by hydrogen. Poorly coloured Diamonds can be improved (colour-wise) by the application of high pressure and high temperature (HPTP), which can change light brown Diamonds to the most sought D colourless variety.

Is my "Diamond" genuine? With the great difference in the price of a clear diamond compared to a colourless variety of a similar sized stone of different chemical formula, it is not a wonder that a simulant (other stone) can be substituted for the unwary buyer. The following shows a quick test without the use of expensive equipment and the theory behind the test.

Specific gravity is the ratio of the mass of an object divided by the mass of the same volume of pure water. From this it follows that if we have two gemstones of the same size their specific gravities are in direct proportion to their masses, $SG1/SG2 = M1/M2$ or $SG1 =(M1/M2) \times SG2$

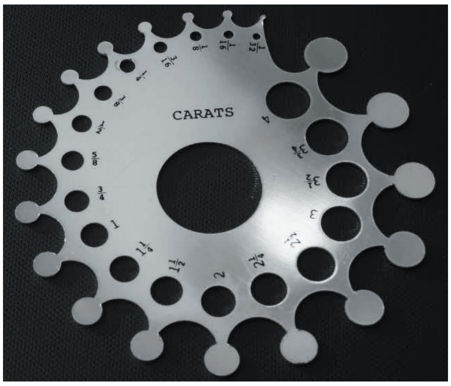


Photo 1.12 (Author): A typical Diamond Gauge

The Diamond gauge in the photo consists of a series of circular holes corresponding to carat weights of a circular standard cut Diamond. The outer circles are the same diameter as the corresponding holes. (Other gauges are available for different varieties of cut. One puts the stone table facet down on a surface and finds which hole just allows the stone through it. The carat size is etched on the gauge.

Photo 1.13 (Evan Ryder) Selection of possible Diamonds.

5 clear colourless round gemstones were taken, shown in photo 1.13 above, and weighed. They were then matched to a hole on the gauge. The results were

Stone	**Mass/Carats**	**Diamond carat size (from Gauge)**
1	2.376	2.5
2	0.936	1.0
3	0.830	0.75
4	4.605	3.5
5	1.605	1.125

(1 carat is 200 mg for precious stones)

Applying the formula SG1 = (M1/M2) x SG2 to each, where SG2 is the specific gravity of Diamond 3.515 (Average) and M1 and M2 are in carats, we get:

SG Stone 1 3.34
SG Stone 2 3.49
SG Stone 3 3.89
SG Stone 4 4.62
SG Stone 5 5.01

The five stones tested, in order, were Orthoclase, Diamond, Sapphire, Topaz and Cubic Zirconia. Their book values for specific gravity are, 2.62 to 2.67, 3.50 to 3.53, 3.95 to 4.03, 3.49 to 3.57 and 5.50 to 6.00 respectively. Thus stone 2 is the Diamond. The values found for Orthoclase and Topaz caused the author to look for factors causing the large difference between the experimental data and the book data. Taking direct measurements of the depth to the diameter of the stones it was found that the % ratio was abnormally high, the stones having a greater carat size than is warranted by the diameter measurement. Colourless stones were used above but the same method could be used for coloured stones.

Conclusion:

Use of the gauge can quickly differentiate between a Diamond and non-Diamond. A ratio other than more or less 1 for the mass in carats divided by the Gauge Diamond size in carats, indicates clearly that the stone is not a diamond.

Some References:

https://www.gemsociety.org/article/gemstone-coloring/

Gemstones of the World, Walter Schumann, 4th ed., Sterling, New York/London

https://www.gia.edu/seeing-green

Gemstones, properties, Identification and Use, by Arthur Thomas, 2008, New Holland Publishers (UK) Ltd. London

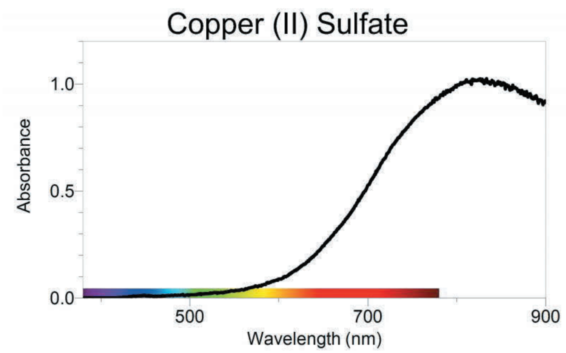
https://www.gemsociety.org/article/select-gems-ordered-density/

Gemstones, Michael O' Donoghue, 1988, Chapman and Hall, London & New York.

Biography

Editor's note

The origin of colour in gemstones is similar to that in coloured solutions, e.g. in copper(II) or iron(II) salts or in solid salts. The colour is due to absorption of light in the metal ions, exciting d electrons to a higher energy level. Part of the visible spectrum (certain wavelengths) are removed and we see what is left. Thus absorbing the red end of the spectrum means we see blue, and absorbing the blue end means we see red. This absorption of light by coloured ions or compounds is the basis of colorimetry, as the amount of absorption is proportional to concentration. This is nicely shown in the spectrum below from Vernier. The peak shows the wavelengths being absorbed superimposed on the visible spectrum. We see what is left after the wavelengths have been removed. Copper(II) sulfate is blue because the red end of the spectrum has been absorbed.



https://www.vernier.com/news/2016/03/23/how-does-a-colorimeter-compare-to-a-spectrophotometer/

See also 'What causes the colour of gemstones?' at https://www.compoundchem.com/2014/06/29/what-causes-the-colour-of-gemstones/

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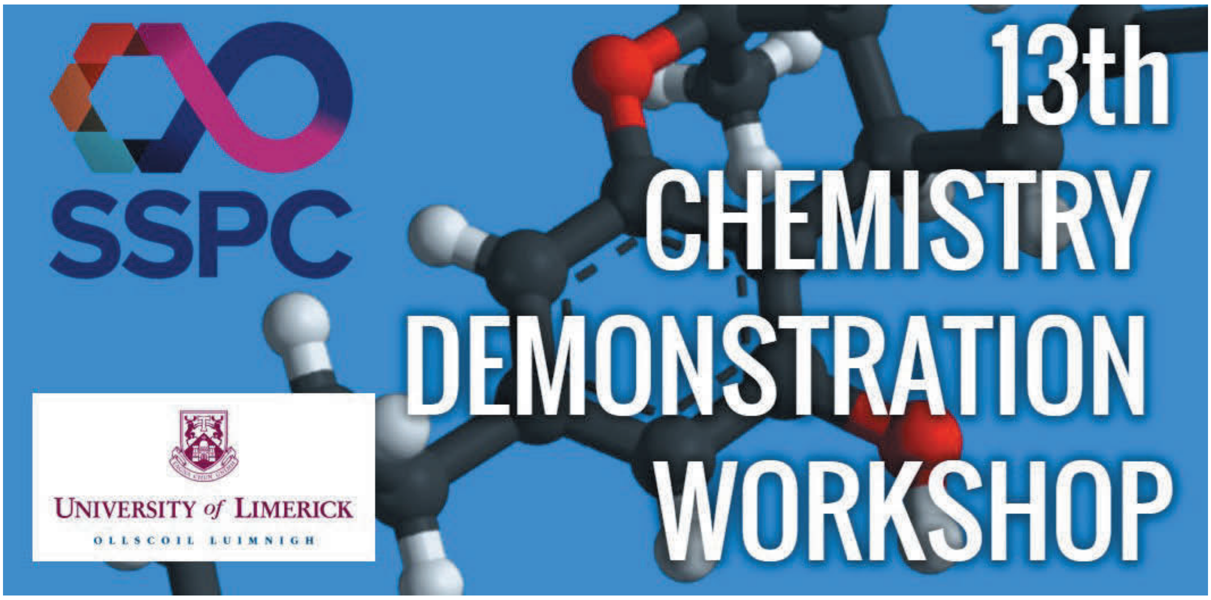


13th Chemistry Demonstration Workshop

25-27 June 2019

Dept. of Chemical Sciences and SSPC, University of Limerick
Peter E. Childs, Martin McHugh & Sarah Hayes
Info: martin.mchugh@ul.ie

Overview

2019 saw the return of the highly successful Chemistry Demonstration Workshop. The course, created for science teachers and science education students, ran from the 25th to the 27th of June. This is the 13th consecutive year in which the event has been held in the University of Limerick and it continues to grow from strength to strength. The residential workshop hosted 15 teachers over three days. The participants, currently teaching in Cork, Clare, Dublin, Galway and Limerick, along with four science education students from the National University of Ireland, Galway, University College Dublin, University College Cork and the University of Limerick, worked with experienced science educators in a collaborative manner to sharpen their demonstration skills. Figure 1 below shows the teachers listening intently to one of the 40 or more demonstrations modelled throughout the course.

Figure 1: Dr Peter Childs demonstrating an experiment to the 2019 teacher cohort

The objective of the course is to offer teachers an exemplary professional development opportunity in the area of chemistry and science demonstrations. The course is hands-on and active as teachers get the chance to try a range of experiments in an encouraging and supportive environment. Key aspects of the course include safety in chemical demonstrations, relevance to the curriculum and inquiry-based approaches to enthuse and engage students. Competence and confidence are fundamental to the course as these are integral to any science demonstration performed in front of a live audience. Teachers gain these skills by observing experiments modelled effectively by science educators and then by trying it for themselves. Our maxim is: 'If you haven't done it yourself, you haven't done it.' Favourites this year included the 'Screaming Jelly Baby' (Figure 2), Liquid Nitrogen Ice-cream (Figure 3) and the 'Methane Mamba', where teachers get to set their own hands on fire.

Figure 2: Teachers observing the 'Screaming Jelly Baby' experiment inside a fume cupboard.

Building on Success

This year retained the successful 3 day format after first being introduced in 2018. However, more time was built into the timetable to allow teachers to get hands-on experience. The main new addition this year was a session on the elements in our everyday lives delivered by Dr Peter Davern. This was to mark 2019 as the International Year of the Periodic Table and 150 years since the discovery of the Periodic System. The annual staples of the course also returned with Dr Sarah Brady conducting a session on physics demonstrations, supported by the Institute of Physics (IOP), Ireland. Also a sample Science Demonstration Show was conducted by Dr Sarah Hayes. Teachers were engrossed by the insider tips and tricks furnished to them by a Chemistry Demonstration Workshop veteran. In addition, this year saw the return of the Chem Demo quiz which was held at the Pavilion Bar and Lounge. An important aspect of the course is the community of practice it has built over the years with teachers and social aspects give participants time to connect. This culminates in the teachers working in teams of 2 or 3 to perform their own science shows at the end of the course. This year, themes for the shows included Fawlty Towers and Toy Story.

Figure 3: Mary Tighe of O'Carolan College, Co. Meath and Thomas Fagan from the National University of Ireland, Galway making liquid nitrogen ice-cream.

Feedback from teachers

The Chemistry Demonstration Workshop always works collaboratively with teachers and their feedback is vital to the longevity of the course. Overall, the course exceeded the teachers' expectations. Some snippets of feedback are below.

"As the only chemistry teacher in my school, I would be anxious about trying experiments, therefore, it was a wonderful opportunity."

"Honestly the best/most informative piece of education I have ever completed."

This puts the workshop in an excellent position as it moves into 2020 and its 14th year. We would like to give a special thanks to Peter Davern, Sarah Brady, Brian O'Shaughnessy, Sinead Walsh, Maria Munroe and Leo Kirby. We would also like to thank Science Foundation Ireland, the School of Science and Engineering, the University of Limerick and the IOP.

We hope to run it again next year around the same time. Contact martin.mchugh@ul.ie if you are interested in coming next year. The workshop is subsidised and includes all meals and two night's B&B on campus. It is an experience not to be missed.

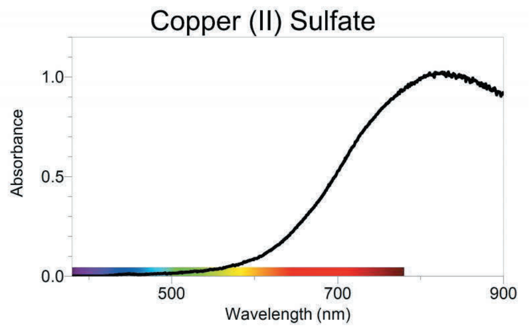
□

Complexation and colour

Set up four small beakers (or test-tubes), each containing 10 mL dilute (2M) copper(II) sulfate solution. Label them A to D. Keep one (A) as a reference. To beaker B add conc. HCl (CAUTION!) until there is no further change. Observe that the colour changes from blue to bright green. To beaker C add conc. NH_3 solution (CAUTION!) dropwise until there is no more change. Observe that first a pale blue precipitate forms, which redissolves to form a deep-blue solution. To beaker D add 2M NaOH solution. A pale blue precipitate forms which does not redissolve on adding excess NaOH solution. To beaker C and D add 2M H_2SO_4 solution dropwise; observe that the colour changes are reversed and you end up with a blue solution. Add water to beaker A to bring it up to the same volume as C and D, to make the colour comparison fair. (The colour density depends on concentration.)

What is going on here and what do the colour changes indicate? Remember that colour changes usually indicate a chemical reaction has taken place and a new substance has been formed.

The colour of aqueous copper (II) sulfate solution is due to the hydrated copper(II) ion. The interaction of the water molecules bonded to the copper ion with its d orbitals, produces a splitting of energy levels corresponding to wavelengths in the visible region (see diagram below) The red end of the visible spectrum is absorbed and the complex appears blue in solution, and also in $CuSO_4.5H_2O$ crystals, which also contain the hydrated ion.



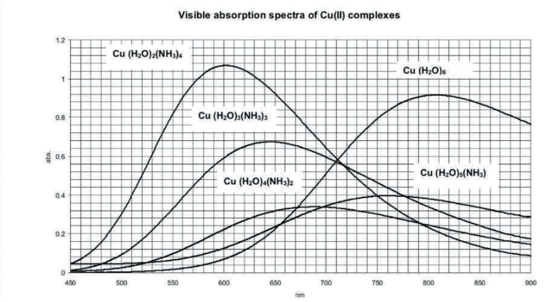
When $CuSO_4.5H_2O$ crystals are heated they lose water and turn white. The copper (II) ion is no longer coordinated to water molecules, the d orbitals are not split and do not absorb visible light. Adding water to the crystal restores the blue colour and this is used a s simple test for water. (The old cobalt (II) chloride paper test for water also used a change in complexation from pink (Cl^- ligand) to blue (water ligand)). The colour is due to the formation of a complex ion with water molecules (acting as ligands) and the consequent splitting of the d orbitals. If we change the way the orbitals are split, then we change the colour as different wavelengths are absorbed.

When conc. HCl is added to a solution of copper (II) sulfate the chloride ions replace the water molecules around the copper (II) ions, a new chloro complex is formed and the colour changes to green.

What would you expect to happen a) if sodium chloride solution was used instead of hydrochloric acid? And b) if excess water was added to the green solution?
The change in colour is due to excess chloride ions not acidity so sodium chloride solution would also turn the blue solution green. There is a competition between water and chloride ions for the copper (II) ions and so when excess water is added the solution turns blue again, but is less intense as it is diluted.
When sodium hydroxide solution is added to copper (II) sulfate solution, a precipitate of copper(II hydroxide is formed.

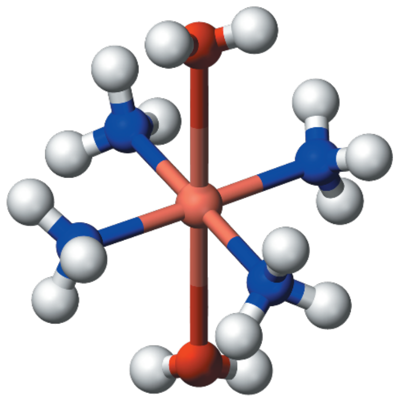
$$\mathbf{CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)}$$

When ammonia solution is added to copper (II) sulfate solution the first thing that happens is that copper (II) hydroxide is formed, as above, due to hydroxyl ions in the ammonia solution. However, when excess ammonia solution is added the precipitate redissolves and a deep blue solution is formed. The water molecules are replaced one by one by ammonia molecules and this alters the energy levels and shifts the absorption (see spectrum below).



Ammonia is also a ligand and is stronger than water so that it coordinates the copper (II) ions and brings them into solution as an ammine complex, which is a deep royal blue colour. Adding sulfuric acid neutralises the ammonia forming ammonium ions, reversing the colour changes and redissolving the precipitate to reform copper (II) sulfate solution.

It is the convention to write the formula of a complex ion in square brackets to show that it is a single molecular entity, e.g. $[Cu(H_2O)_6)]^{2+}$. A complex may be positively charged, negatively charged or neutral.



The cuprammonium ion, $[Cu(NH_3)_4(H_2O))_2]^{2+}$(aq)
https://upload.wikimedia.org/wikipedia/commons/a/a0/Tetraamminediaquacopper%28II%29-3D-balls.png

Colours of some copper (II) compounds

$[Cu(H_2O)_6)]^{2+}$ (aq)	blue solution
$[CuCl_4]^{2-}$ (aq)	yellow green solution
$[Cu(H_2O)_6)](OH)_2$ (s)	pale blue ppt
$[Cu(NH_3)_4(H_2O))_2]^{2+}$ (aq)	deep blue solution
$CuCO_3$ (s)	blue-green ppt

The cuprammonium solution is also known as Schweitzer's reagent and it is used as a solvent for cotton (cellulose) in the making of rayon. Cotton is dissolved in the cuprammonium solution and then reprecipitated by adding an acid in a form which allows it to be spun into fibres. For an experiment showing this see: https://www.instructables.com/id/How-to-Dissolve-Cotton/ or https://www.youtube.com/watch?v=yHXBOznRMDk

Transition metal colours

Coloured complexes are a feature of transition metal chemistry because they contain d orbitals in their outer shell, and these orbitals are split by interaction with the complexing ligands, tuning the energy levels so that they absorb different wavelengths and have different colours depending on the metal ion, its oxidation state (compare iron (II) and iron III) in solution), and the ligand. This gives us access to some colourful and interesting chemistry. The colour of transition metal ions is also found in solids, especially hydrated salts, and when found as impurities in minerals (see the article above on gemstones) and in glass. These coloured complexes are often very strongly coloured so that they absorb light strongly and this used as the basis of colorimetry and many colorimetric methods are available for the analysis of various metal ions.

Try this series of reactions. Make a solution of 0.1M iron(II) sulfate, which is yellow in solution. To this solution add 0.1M potassium or ammonium thiocyanate solution (KCNS) and separately 0.1M potassium hexacyanoferrate(II) (ferrocyanide, $K_4Fe(CN)_6$). This gives an intense blood-red colour with thiocyanate and a dark blue (Prussia blue) colour with ferrocyanide. Salicylate ion gives a purple/violet colour with iron (III) and this can be used for the colorimetric analysis of aspirin (see http://www.jenway.com/adminimages/A09_009A_Determination_of_Aspirin_73_series.pdf)
The colours of iron (II) complexes can used in a variation of the water to wine demonstration using an iron (II) solution. The same iron (III) solution can used to reveal hidden messages on paper or cloth painted with potassium thiocyanate (red) or ferrocyanide solution (blue).

WELCOME POSTER DEMO

Solution A: 0.1 mol L^{-1} ammonium thiocyanate, NH_4SCN (0.8 g/l00 mL)
Solution B: 0.1 mol L^{-1} potassium hexacyanoferrate It (potassium ferrocyanide), $K_4Fe(CN)_6.3H_2O$ (4.2 g/ 100 mL) - must be freshly made!
Solution C: 0.1 mol L-1 iron III chloride, $FeCl_3$ (16.2 g/100 mL)

What to do: Paint your poster with solution A (turns red) and solution B (turns blue) using small paint brushes or cotton buds. Allow to dry (hair dryer for quick result) and apply a fine spray of solution C when required. Best results are obtained if solution B is not applied too soon before the show as its colour darkens with time.

$$Fe^{3+} + SCN^{-} \rightarrow FeSCN^{2+} \text{ (red)}$$

$$Fe^{3+} + Fe(CN)_6 \rightarrow Fe(Fe(CN)_6) \text{ (Prussian blue)}$$

This link has a nice experiment with different iron (III) colours - https://sciencenotes.org/olympic-rings-chemistry-demonstration/

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Diary

2019

ChemEd-Ireland
19 October
DIT, Kevin Street
Claire.O'Donnell@dit.ie

Science Week
10 – 17 November
http://www.sfi.ie/engagement/science-week/

2020

ASE Annual Conference
8-11 Jan.
University of Reading
https://www.ase.org.uk/events/ase-annual-conference-2020

ISTA Annual Conference
7-9 February
Clayton Hotel, Leopardstown, Dublin, D18 NR24
www.istaconference.com

8th NPSE 2020
19-20 March
Florence, Italy
https://conference.pixel-online.net/NPSE/index.php

15th ECRICE
6-8 July
Weizmann Institute, Israel
ron.blonder@weizmann.ac.il

26th IUPAC ICCE
13-17 July
Lagoon Beach Hotel
1 Lagoon Gate Drive, Milnerton
Cape Town, South Africa
https://iupac.org/event/chemistry-education-icce-2020/

26th BCCE 2020
18-23 July
Oregon State University, Corvallis, Oregon, USA
https://bcce2020.org/

ChemEd-Ireland 2020
17th October
UCC, Cork
d.kennedy@ucc.ie

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

Chemlingo: Test-tubing – chemistry *in vitro*

Peter E. Childs

The test-tube is the iconic tool of chemical education and depends on the unique properties of glass – hard, transparent, heat and chemical resistant. Chemistry would have been impossible without glass vessels and it is still an essential part of chemical education at all levels. We might say that chemistry was born *in vitro* or *in silico* – the terms biologists use when describing doing their investigations outside living systems e.g. in a petri dish. Maybe today we should also talk of *in plastico*! *In vitro* or *in silico* are alternative ways of describing 'in glass'. Chemistry has been referred to disparagingly as 'test-tubing' when it involved doing experiments without thinking about them – hands-on without minds-on. But where would we be without our test-tubes? Seeing, handling and smelling chemicals are essential for getting a real 'feel' for chemistry. Long may chemical education be done *in vitro*!

Experiments involving living tissues or subjects are known as *in vivo*, in life. *In ovo* means in the egg and describes the use of eggs as an incubation medium for growing live viruses for producing vaccines. *In vacuo* means something done under vacuum and *in situ* means in the same place, e.g. doing chemistry measurements in the environment rather than in a laboratory.

These terms are of course in Latin and as a foreign language should be given italics. Latin was once the language of science and religion and so we use many Latin abbreviations in everyday language, often without knowing where they come from, e.g. (itself an example): *Q.E.D, N.B., et. al, viz., ibid., op. cit., etc. etc.* Once these were well known when the educated person knew Latin and Greek, and these two languages were used to coin new scientific words and we use their prefixes and suffixes all the time in scientific words, like poly- or -gen. Today's student finds it difficult to decode these words as they lack the background in classical languages, and so try to learn them as complete and unique words. You can help your students understand and remember scientific terms if you break them down into their component parts and show how complex words can be built up. It helps to recognise, for example, that words ending in -ose are sugars e.g. sucrose, lactose or that poly- in front of a word means many e.g. polymer, polychromatic. Learning some basic prefixes and suffixes will help your students decode scientific language.

(N.B. if you look up Chemlingo online you can find many past articles on the Education in Chemistry website. See for example, links in https://stemspelling.wordpress.com/teacher-background-reading/)

Interesting links:

Irish sugar industry

In issue #113 I looked briefly at the history of the Irish sugar industry and the prospects for reviving it. Caitriona Devery from UCD has just produced a much more detailed look at this topic in *Feast Journal* and you can read it at the link below. Closing down the Irish sugar industry was a big mistake and apart from losing jobs in farming and processing, it also made Ireland dependent on outside supplies for sugar. Reviving the sugar industry should be considered as a real possibility on a number of grounds, not least of which is the environmental aspect in reduced shipping costs.

Bittersweet Beet: A History of Irish Sugar
Caitriona Devery
http://feastjournal.co.uk/article/bittersweet-beet-a-history-of-irish-sugar/

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Information Page

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TY Science Modules

We have discontinued selling these modules as postage got too expensive. Some of them are available online, free of charge, at our website:

www.cheminaction.com

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In the next issue:

40th birthday issue!

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