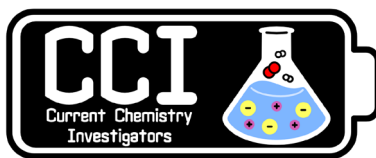
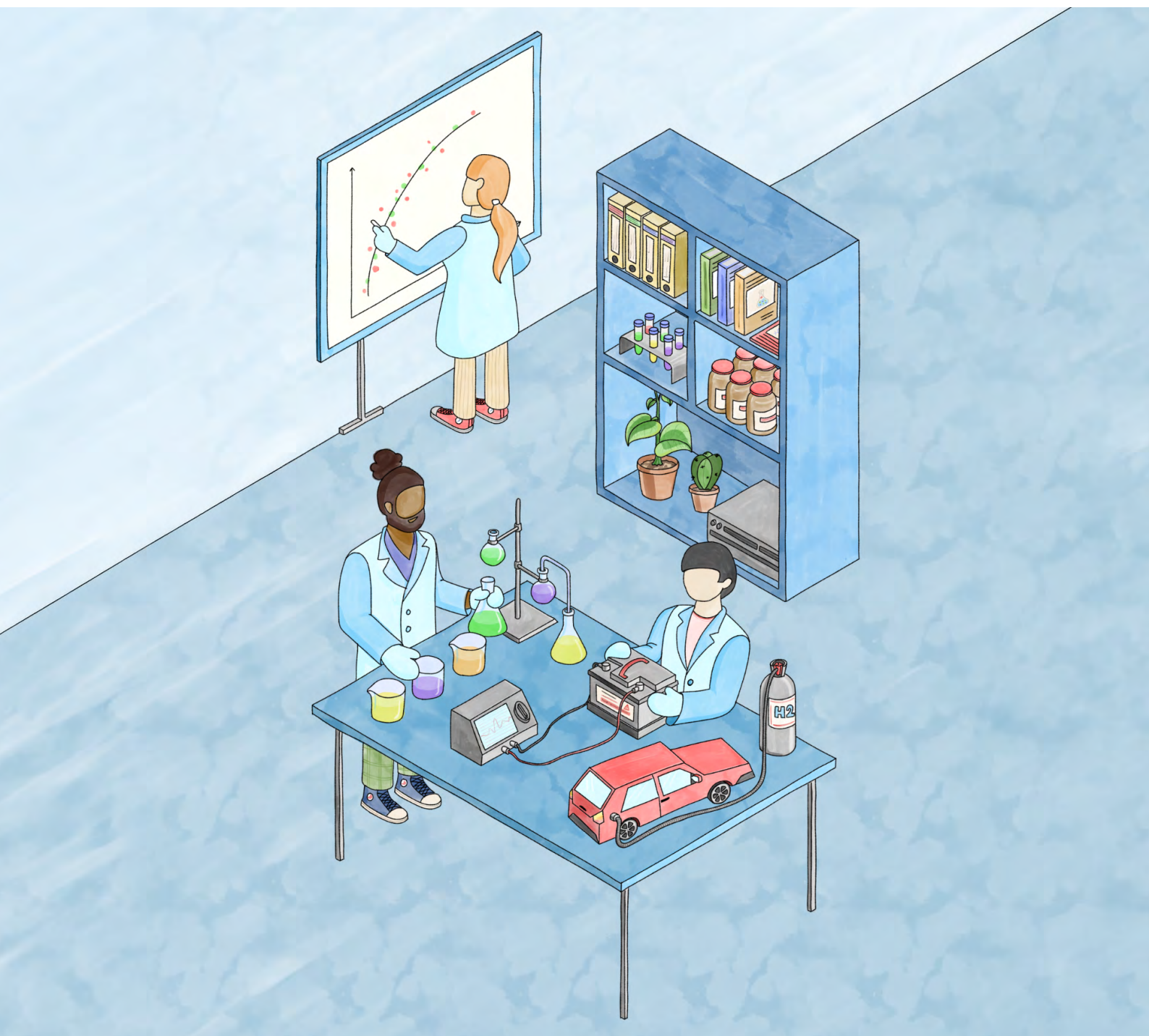




Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin



CCI Impact Report and Resources



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Part 1: Introduction



Dr John O'Donoghue,
Founder and Project Manager, Trinity College Dublin

Welcome to our CCI Impact Report and Resources Book. The core aim of this project has always been the desire to connect science teachers with early career researchers as equal partners for meaningful informal education, public engagement and societal impact with students and the public. It has been an absolute pleasure to work with my colleagues in Trinity College Dublin (TCD), the Atlantic Technological University (ATU) Sligo, Tyndall National Institute, University College Cork (UCC) and Lifetime Lab, as well as over two hundred science teachers and event organisers. I am truly grateful to everybody we've worked with. Finally, at the heart of CCI are the PhD researchers and Postdoctoral Fellows who served as our facilitators (Ambassadors). Their enthusiasm, friendly demeanour, professionalism and teamwork always shone through.

I wholeheartedly believe that our co-creation approach has been the key to our success, creating a shared understanding of green energy education and engagement that has transcended societal boundaries. Together, we provided thousands of young people with tangible career role models, hands-on activities and societal context for difficult scientific concepts. In return, teachers, students and the public provided our early career researchers with invaluable teaching, public speaking, communication, teamwork and leadership experience. This impact report is an overview of the enormous volume of data we collected over a 5-year period, across school workshops, professional development, training and public engagement. We '*Sparked Conversations*' with tens of thousands of people and I wholeheartedly believe the impact of CCI will be felt for many years to come.



Dr Fiona McArdle,
Co-Founder, Atlantic Technological University, Sligo

Supporting schools in the Northwest of Ireland has always been a focus for us, so we were delighted to partner with our Trinity colleagues in 2021 to launch this programme. CCI has been invaluable to our region due to the rural nature of our schools, who have little or no public transport options. In addition to visiting schools, we have also invited teachers and students into the ATU campus in Sligo, combining a CCI workshop with an opportunity to see real-world science equipment. We also spearheaded several public engagement activities to break down barriers related to green energy, from music and arts festivals to family fun days. We have hugely enjoyed developing these accessible activities and experiences for everyone, regardless of language, education level, prior STEM awareness or age. Our team of early career researchers also developed communication skills, leadership skills as well as logistic and management skills. They also became proficient in succession planning and upskilling their peers to ensure CCI continued smoothly over a 5 year period. The impact that CCI will have on their future careers is difficult to measure, but will no doubt be substantial.

1.1 Team Members:



Photocall in Dublin Castle, May 2022. L-R John O'Donoghue - Founder and Project Manager, Áine Coogan - Postgrad Facilitator, Norma Foley - Minister for Education, Ruth Freeman - Director - Research for Society - Research Ireland, Simon Harris - Minister for Further and Higher Education and Natalia Garcia Domenech - CCI Project Coordinator.

CCI Project Leadership Team:

Dr John O'Donoghue, TCD (2021-2026)

Dr Niamh McGoldrick, TCD (2021-2026)

Dr Natalia Garcia Domenech, CCI Coordinator (2021-2025)

Dr Fiona McArdle, ATU Sligo (2022-2026)

Mary Connolly, ATU Sligo (2022-2026)

Dr Yvonne Lang, ATU Sligo (2022-2024)

Mervyn Horgan, Lifetime Lab (2023-2026)

Dr Lynette Keeney, Tyndall National Institute (2023-2026)

Dr Will Daly, UCC (2023-2026)

Dr Dave Otway, UCC (2023-2026)

Dr Nishanth Thomas, CCI Coordinator (2025-2026)

CCI Researcher Facilitators (Ambassadors):

Áine Coogan, TCD	Matthew Rowe, TCD	Pooja Verma, ATU
Munirah Ghariani, TCD	Cian Clarke, TCD	Sara Finnerty, ATU
Laura Ramirez, TCD	Urte Vityte, TCD	Jessica Mallet Doran, ATU
Nadia Prochukhan, TCD	Jack Moore, TCD	Keith Sirengo, ATU
Susie Calvert, TCD	Mert Can Özarpaci, TCD	Anagha Ramesh, ATU
Aoife Kavanagh, TCD	Hariharan Melarcode, TCD	Fiona Kinsella, UCC
Iñigo Iribarren, TCD	Teodora Faraone, TCD	Rebecca O’Keeffe, UCC
Diara Bura, TCD	Orlagh Beggs, TCD	Sam Koledoye, UCC
Oscar Kelly, TCD	Ben McLoughlin, TCD	Ruth O’Connell, UCC
Joshua Pepper, TCD	Rebeka Jurickova, TCD	Forest Yap, UCC
Liam Cribbin, TCD	Claire Bradley, TCD	Jack Daly, UCC
Yekatherina Tske, TCD	Grace Odunlade, TCD	Tara McInerney, UCC
Karlijn Hertsig, TCD	Aoife Morris, TCD	Neil Curtis, UCC and Tyndall
Niamh O’Shea, TCD	Jessica Howard, TCD	Amy Twomey, UCC
Ellen Fay, TCD	Lucia Barielli, TCD	Veronica McTigue Fennell, UCC
Conor Williams, TCD	Andrea Scutti, TCD	Alison Walsh, UCC
Luisa Lavelle, TCD	Sarah Shanfrezan, TCD	Ben O’Donoghue, UCC
Ailish Newton, TCD	Maria Rönby, TCD	Si Lok Ko, UCC
Joshua Thorogood, TCD	Keerthi Nair, ATU and Tyndall	Oscar Dunne, UCC
Sophie Maguire, TCD	Debismita Dutta, Tyndall	Stephen Sweetnam, UCC
Amani Al Riyami, TCD	Ehren Dixon, Tyndall	Chloe Kearney, UCC
Bláithín Rawson, TCD	Muskan Jain, Tyndall	Isabel Janssen Cahill, UCC
Aoife Donohoe, TCD	Rajan Bharti, Tyndall	Conor Goggin, UCC
Fayanne Nolin, TCD	Yesim Demiroglu, Tyndall	Michaela Wentz, UCC
Chloé Flandrin, TCD	Martina Piletti, Tyndall	Estela Bocarando Salcido, TCD
Fatima Sarwar, TCD	Sreedhanya Pallilavalappil, ATU	Kareem Ouhalla Knipschild, TCD
Conor Brennan, TCD	Parnia Forouzandeh, ATU	Ryan Waldren, ATU
Joe Martyn, TCD	Lokash Yadav, ATU	Adam McDonnell, ATU
Eleanor Cripwell, TCD	Keith Sirengo, ATU	Kris O’Dowd, ATU
Julie Mason, TCD	Shaista Jabeen, ATU	Kathleen Kennedy, Tyndall
Lucy McCormack, TCD	Irthasa Aazem VS, ATU	Emily Duggan, Tyndall
Lua Henderson, TCD	Tanya Mehra, ATU	

1.2 Acknowledgements:

We wish to thank Research Ireland (formerly Science Foundation Ireland (SFI)) for their unwavering support through the Science Week Programme (21/SW/9112) and Discover Programme (21/DP/9763 and 23/DP/11826), without which CCI would not have been possible. We also wish to thank the Royal Society of Chemistry (RSC) for their support and an Undergraduate Research Bursary (U23-0349066363) which allowed Dearbhla Tully to conduct a summer project to investigate and evaluate our public engagement activity. Thanks also to Tim Reynolds and the entire RSC Belgium Local Section for providing the funding and support to carry out some international workshops.

The success of CCI has only been possible due to the support of many colleagues across all the partner institutions from TCD, ATU Sligo, UCC, Tyndall and Lifetime Lab. This includes everyone from the estates and facilities teams to procurement, technical officers, finance teams, faculty teams and more. Thank you to everyone who supported the CCI programme across all our partner institutions, no matter how small a contribution you made. Hosting the CCI programme increased administrative work for many of our colleagues. As such, we wish to specially thank Peter ÓBriain for his exceptional support in terms of purchasing, general finances and technical support, as well as Sinead Boyce, Noelle Scully, Ben Power, Manual Reuther, Anne-Marie Farrell and all our TCD colleagues for their support throughout. Special thanks also to Mike Lyons and Graeme Watson for believing in the project leadership team to host the project.

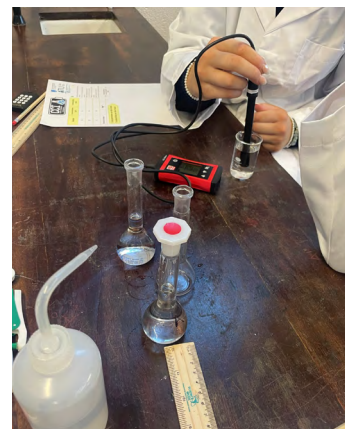
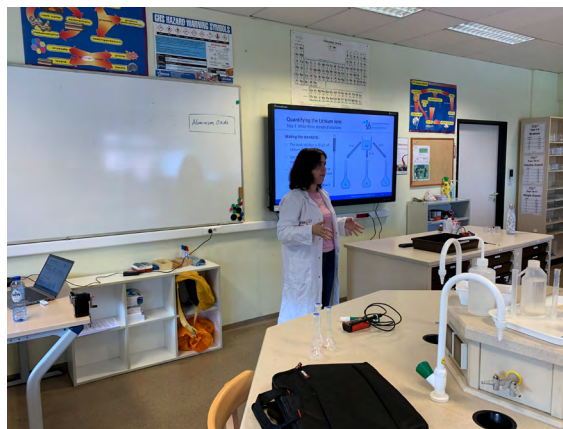
Additionally, we wish to thank Michelle Browne, Head of the Electrocatalysis: Synthesis to Devices Group at Helmholtz-Zentrum Berlin for being our electrochemistry expert and consultant, especially at the beginning of the CCI programme. Thanks also to Muriel Grenon at the University of Galway, Yvonne Lang at ATU Sligo and Elspeth Sinclair at UCD for all their advice, guidance and support over many years. Thanks to Phil Smyth for introducing us to the ESB ecars team, providing our PhD facilitators with unique opportunities and for supporting our activities on several occasions. Thanks also to Fergus McAuliffe from the Trinity Research Office for providing training to our facilitators at the 2025/26 CCI Symposium.

Since 2021, over 100 PhD and Post-doc facilitators have been involved in the CCI programme. We especially want to thank Iñigo Iribarren for all the illustrations, Niamh O'Shea for the Irish translations, Bláithín Rawson for managing our social media and Áine Coogan for assisting with the Teacher CPD programme and for providing extensive leadership. Many of our facilitators also took on extra roles at various stages as they stayed involved with CCI over several years, thank you to Keerthi Nair, Keith Sirengo, Irthasa Aazem VS, Tanya Mehra, Ellen Fay, Susie Calvert, and Sam Koledoye among many others. We also wish to thank Conor Williams for his data analysis on the student evaluation data as part of his MSc thesis in statistics. Thanks also to our two CCI Coordinators, Natalia Garcia Domenech and Nishanth Thomas, who led the delivery and data monitoring, as well as providing training and support to the facilitators.

We also want to express a huge thanks to the Irish Science Teachers Association (ISTA) who have supported the CCI programme at a national and branch level throughout, through their promotion, facilitating CPD and for having us at their conferences. Thanks also to Peter Childs at the University of Limerick for his support of the programme through the Chemistry in Action Magazine and ChemEd-Ireland conferences. Finally, last, but very much not least, thank you to the hundreds of teachers all over Ireland who invited us into their classroom, supporting our programme from the very beginning. Without the support, encouragement, open-minds and enthusiasm of so many science teachers, the CCI programme would never have got off the ground.

1.3 Secondary School Data Summary:

261 student workshops run with 5,000 students from 111 secondary schools.	65% of teachers found the student workshop to be better than other workshops they have received.
The CCI Workshop resulted in a 57% shift in the perception of electrolytes towards batteries and/or conductivity.	Teachers highlighted “lab practical skills”, “real-life situations”, “teamwork” and “speaking to researchers” as the best parts of the workshop.
81% of students felt the CCI workshop was useful for their studies.	17 CPD activities run with 581 science teachers in 8 locations around Ireland.
66% of students from Public Schools, 23% DEIS and 9% Private, closely matching national breakdown.	All teacher survey respondents agreed that the CPD will have a positive impact on their teaching.
Female students were significantly more likely to be greatly encouraged to pursue a STEM career due to the CCI workshop.	Teachers have noted an increased student interest in studying science “More students in our school took Chemistry at senior cycle which is very positive.”
Over the past decade, consistent interest in studying chemistry in Ireland has bucked international trends.	PhD facilitators have stated that the CCI programme was “very rewarding”, and has revived their own enthusiasm for doing science.



1.4 Public and Primary Data Summary:

Over 50 Researchers from 4 different institutions have served as facilitators for public and primary engagement.	50,000 is the total number of people we have engaged with between 2021 and 2026.
80% of our researcher facilitators felt it was better than other activities they took part in, the remaining 20% said it was equal.	Our overall Customer Satisfaction Score (CSAT) is 93%, calculated from 8,099 people who provided direct feedback. The American Customer Satisfaction Index (ACSI) considers over 90% to be exceptional.
The micro-workshop format prevented talking down to participants and facilitated wheelchair users.	All respondents to a detailed participant survey stated they would tell their friends and family about the activity.
Real-time participant data collection helped us identify quiet periods for facilitator breaks and for those in the ASD community.	We provided hands on activities at 22 festivals and public events, as well as 6 primary schools and community groups e.g. Girl Guides
Visual and audio-based outputs from the experiment were used to facilitate participants with sensory impairments.	We created new partnerships with Research Centres and ESB ecars to provide training to future proof our activity





Part 2: Deep Dive

The CCI programme built on the experience of the leadership team with previous large scale multi-institutional informal education and public engagement programmes. Throughout the COVID-19 pandemic, members of the CCI leadership team maintained close relationships with science teachers and schools through initiatives such as Stories from the Lab, Transition Year (TY) programmes, Access Programmes, Science Week and Career events among others.

The inspiration for CCI came from the 2019 Nobel Prize in Chemistry, which was awarded for the “*development of lithium-ion batteries*”. Lithium-ion batteries have revolutionised modern society and now dominate our lives. However, they are also associated with several misconceptions related to fires, degradation and reliability.¹ In 2021, at the beginning of the CCI programme, Ireland had one of the lowest market shares for Electric Vehicle’s in the European Union (EU). Although it has improved, in 2025 it was still far behind the UK, Portugal, Belgium and many others.² Sustainable Development Goal (SDG) 7 advocates for access to clean and affordable energy, which is key to agriculture, business, communications, education, healthcare and transportation.³ A generational change is needed in how we create, store and use energy to meet our carbon commitments no later than 2030.⁴ In addition to energy, similar scientific concepts are also used for rapid analytical techniques such as blood glucose sensors, alcohol breath analysers, gel electrophoresis and many more.

Chemistry and Physics are often referred to as “difficult subjects”, with many people associating Chemistry with formal education settings such as schools. Additionally, societal applications for chemistry are almost entirely linked to medicinal and human health.^{5,6} However, the world is becoming ever more reliant on battery technology, clean transport and rapid analytical techniques. We need to facilitate public discussion, encourage development and expand expertise in these areas. This area of scientific research and learning is referred to as “*electrochemistry*”, a multidisciplinary topic spanning the chemical and physical sciences. However, most of the concepts are found within the chemistry discipline, therefore it was decided to focus our efforts on LC chemistry teachers and students, with physics students welcome to join also. The aim of CCI was to facilitate deep discussion about these concepts, with a focus on batteries and other clean energy technologies (e.g. hydrogen) while incorporating analytical techniques. These important societal concepts facilitated community engagement, reduced misconceptions and showcased the work of Irish researchers by “*sparking conversations*”.

7 AFFORDABLE AND CLEAN ENERGY



2.1 The CCI Co-Creation Process:

At the beginning of CCI, electrochemistry was mostly confined to the optional section of the Leaving Cert (LC) Chemistry course. Unlike many other education systems, it was avoided by teachers and students due to its optional nature. As a result, it was one of the least attempted and worst answered questions in exams.⁷ For the 2021 Chemistry Olympiad Ireland Round 1 exam, despite the high calibre of entrants, only 37% answered the electrochemistry questions correctly. The theoretical foundation for CCI is based on a theory of change i.e. societal context through tangible career role-models will increase interest, discussion and understanding in this vital area. The target audience was secondary schools and community/public festivals. However, other groups such as primary schools and community groups (e.g. Girl Guides) were also involved at various stages. A broad suite of resources were also designed to outlast the programme, with posters now hanging in hundreds of schools, colleges, universities and public spaces all over Ireland.



PhD and Post-Doc Research Facilitators in ATU testing the CCI workshop in April 2022

All activities and resources were designed for the Irish Education system from the ground up. Formative work began in 2019 with a survey of 158 teachers as well as a focus group with 21 teachers to establish the needs for a green energy intervention programme in Ireland. Research into case studies from South Africa, Turkey, the US and the UK identified successful examples of electrochemistry based interventions.⁸⁻¹¹

Lab testing of the first hands-on activities (Battery Maker) took place during the summer of 2021, leading to the first pilot workshops with students in November 2021 through the “Power Our Future” Science Week project. In February 2022, over a dozen science teachers tested and provided feedback on the “Battery Maker” activity. Feedback from students indicated that they wanted an opportunity to use “real” scientific equipment. Additionally, teachers wanted opportunities for their students to develop lab skills i.e. using glassware to make-up standards, serial dilutions and graphs. This led to the development of an electro-analytical style workshop which was piloted with our PhD and Post-Doc Facilitators in Trinity and ATU Sligo and then with 3 schools in May 2022. We are truly grateful to every teacher, researcher and student who helped us develop and improve the CCI school workshop throughout the life of the programme. We have no doubt that this extensive co-creation and feedback process directly led to the success of the programme overall.

The final CCI workshop was based around a “*Scientist in a Classroom*” model, in which the expertise and enthusiasm of practicing scientists is used to aid learning, in what is sometimes referred to as the “third space”, i.e. a mix between formal and informal learning. Workshops based on this model have frequently been reported to be successful, despite their one-off nature.¹² They provide school students with tangible scientific career role models and professional expertise through two-way communication.¹³⁻¹⁶ Additionally, it has been previously reported that some widening participation interventions are only effective when conducted in a school setting. School-based interventions can help build relationships with students who may be experiencing educational and/or socioeconomic disadvantage and may not be able to visit university campuses or other venues.¹⁷ In terms of content, the CCI workshop involved a problem based learning (PBL) exercise based around a battery malfunction due to an error in the manufacturing process. Students were challenged to work out what happened and who was responsible.

2.2 Student Data:

Anonymous feedback was collected directly from student participants using multiple choice ‘Digital Clickers’ (Audience Response System - ARS) immediately before, during and after the CCI workshop. Prior to the arrival of the facilitators to a school, a Participant Information Leaflet and Consent form was sent to the teacher. About a month after the completion of a workshop, the teacher was also provided with a feedback survey. The CCI student data set represents an incredible 75% of total student responses, totalling 4,238 from 261 workshops, collected between September 2022 and February 2026. It does not include the data collected during the pilot workshops since the content and wording of the questions were not finalised. From the data, 65% of the students attended public schools, 26% were categorised as DEIS at the time of the intervention and 9% attended fee-paying (private) schools. This closely resembles the national breakdown for Secondary schools in Ireland at the time of the intervention as 61% public, 31% DEIS and 7% fee-paying.¹⁸



Secondary School students testing the final version of the CCI Workshop in May 2022

CCI Secondary School data by Academic Year

Academic year	Number of Schools Visited	On Campus Workshops	Total Number of Workshops	Valid Student Responses
2022/23	43	4	74	1,169
2023/24	32	8	61	1,007
2024/25	38	8	68	1,160
2025/26	35	2	58	902
CCI Total	148	22	261	4,238

In terms of gender, 50% identified as female, 42% male and the remainder identifying as non-binary, other or preferred not to say. This closely resembles the national gender breakdown for LC Chemistry at the time of the intervention (58% Female and 40% Male). In terms of regional distribution, based on the NUTS (Nomenclature of Territorial Units for Statistics) system, responses were collected from every IE sub-division region. Owing to the location of the host institutions, the largest regional datasets are from Dublin City (1,064), the Eastern region (756), the Northwest region (677) and the Southwest region (635). All other regions in Ireland represent between 200 and 300 responses. Over 4 academic years, the CCI teams visited 111 unique schools in Ireland, 2 schools in Belgium and hosted 22 workshops on campus in ATU, UCC, Tyndall and TCD.

To make each school trip as cost-effective as possible, most schools received 2 workshops on the same day for different classes, with some receiving 3 workshops due to large numbers. Some schools were visited twice over the course of the CCI Programme where the previous students completed their studies, but we only met each student once overall. Breaking down the total dataset by year group, it consists of 1,662 TY students, 1,240 Fifth Year LC students, and 776 Sixth Year LC students. In the first year of the CCI programme some Fifth- and Sixth-year students were mixed into the same class and individual year group data was not obtained, as a result there are 2,189 LC students in the data i.e more than the fifth- and sixth-year numbers

combined. Most of the data represents in-school workshops where students did not need to travel or apply to take part i.e. Research Facilitators travelled to the school and included all students from a group.

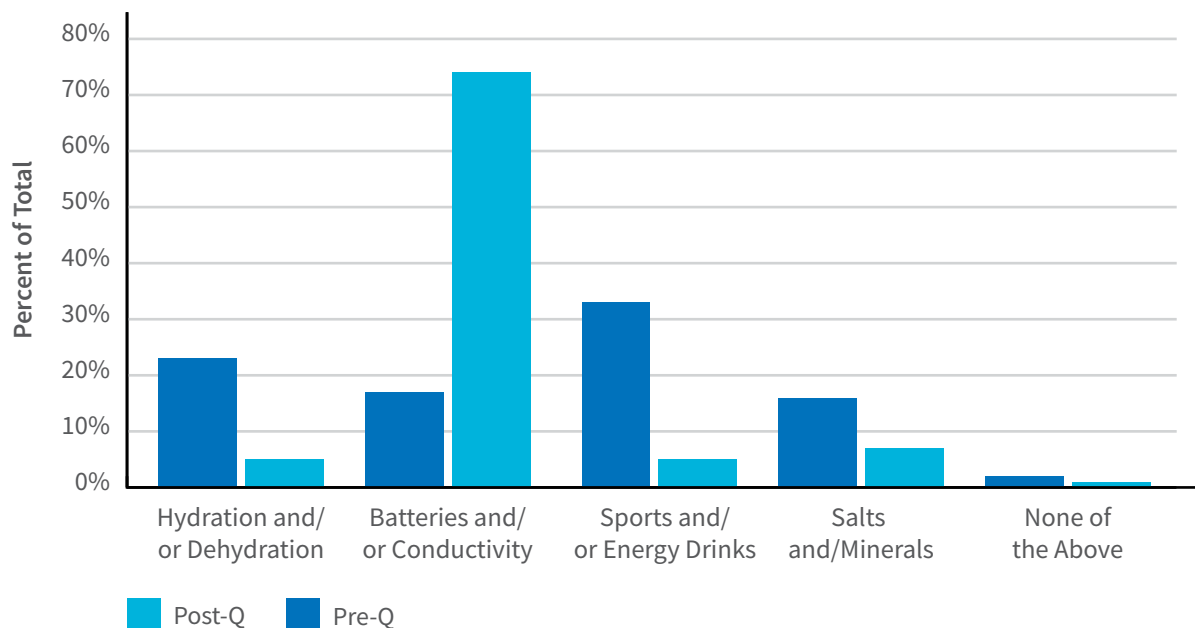
Location by Nomenclature of territorial units for statistics (NUTS3)	Valid Student Responses
IE061 Dublin City	1064
IE062 Kildare, Meath, Wicklow and Louth	756
IE041 Cavan, Donegal, Leitrim, Monaghan and Sligo	677
IE053 Kerry and Cork	635
IE042 Mayo, Roscommon and Galway	316
IE063 Laois, Longford, Offaly, Westmeath	270
IE051 Clare, Tipperary and Limerick	253
IE052 Carlow, Kilkenny, Wexford and Waterford	205
BE100 Brussels and BE310 Walloon Brabant	62
CCI Total	4,238

However, for on-campus CCI workshops, nearly all the participants consisted of TY students from a variety of different schools. In a small number of cases (less than 1%), these students represent a duplication since they previously completed a CCI workshop via their school. In most cases, the on-campus CCI workshop represented only one part of a larger TY programme coordinated by a third-party organisation such as a Research Centre. To take part in these programmes, students needed to apply either through their school or individually to the organisers, with a success rate that was sometimes as low as 10% due to high demand and limited capacity. The CCI team did not have control over the application process, but the organisers were encouraged to increase the number of places for DEIS schools. The data collected from students involved in these On-Campus TY programmes (296 students) was found to be substantially different compared to those collected for in-school workshops. Henceforth, these students will be referred to as “TY Programme” students to differentiate them from “In-School TY” students.

2.3 Engagement and Outcomes:

The narrative of the workshop required students to solve who was responsible for the battery malfunction from a choice of three suspects linked to the scientific properties of Iron, Copper and Aluminium. 76% of student participants chose the correct suspect based on the science and narrative provided, demonstrating a high level of engagement in the workshop content. Only 3% chose “I Don’t Know”, with the remainder choosing another suspect. Also, a post-workshop question asked the students if they felt the CCI workshop was “useful for their studies”, to which 81% responded that it was *Somewhat* or *Very Useful*, with the rest mostly undecided. In the second year of the CCI programme (2023/24), a Pre- and Post- workshop multi-choice clicker question was introduced to examine the impact of the workshop on student perceptions towards the electrochemistry term “*electrolytes*” in a societal context. It asked students “*What do you think of when you hear the word electrolytes?*”. The choices provided were decided through pilot testing with the facilitators, teachers and students, resulting in only 1% of pre-workshop answers and 2% of post-workshop responses for “*None of the above*”. Comparing the Pre- and Post- workshop responses from students demonstrates a substantial shift towards the “*Batteries and/or Conductivity*” option, away from a broad range of options chosen in the pre-workshop question.

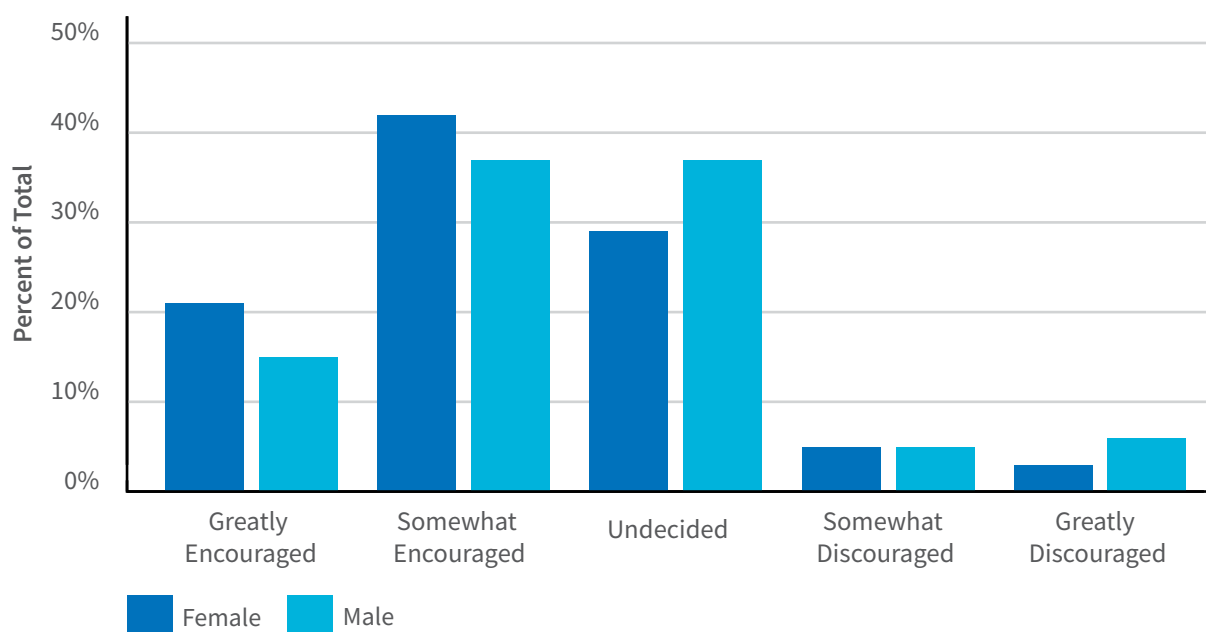
What do you think of when you hear the word “electrolytes”?



Comparison of Pre- and Post-workshop perception question

There were insignificant differences across year groups, however male students were significantly more likely to choose “*Sports and/or Energy Drinks*” for the Pre-workshop question (42% male vs 33% female). Male students also demonstrated a 54% shift (13% to 67%) from Pre- to Post- whereas female students demonstrated a 60% shift (23% to 83%) for the “*Batteries and/or Conductivity*” option.

Has this experience influenced your interest in doing a STEM career? (In-School)



Comparison of STEM Career Influence by Gender

Similar gender differences were also found for the responses to the post-workshop question “*Has this experience influenced your interest in doing a STEM career?*”. Here, female students were significantly more likely (63%) to respond *Somewhat Encouraged* or *Greatly Encouraged* compared to their male peers (53%). Conversely, male students were more likely to remain undecided. Overall, about 10% felt *discouraged* by the workshop, mostly consisting of In-School TY students. It was expected that this figure would be higher since all TY’s were welcome to take part in the CCI workshop, regardless of whether they were interested in STEM or not.

As expected, TY programme students were significantly more likely to feel *encouraged* by the workshop (72%), with 25% undecided and only 3% feeling *discouraged*. Finally, in terms of how useful students found the CCI workshop for their studies, the overwhelming majority scored it Good or Excellent (80%), with most of the remainder rating it as fair (15%) and less than 5% scoring it Poor or Very Poor. There were no discernible differences between year groups. However, female students were significantly more likely to rate it as *Excellent* (44%) compared to their male peers (34%).

Teacher feedback about the CCI student workshop was also hugely positive with 65 (about 50%) responding to the post-workshop feedback survey. 65% of teacher respondents said the CCI workshop was better than other STEM workshops they received from Higher Education institutions, with 15% saying it was equal. The remaining 17% stated they did not have a workshop before, while only 3% said it was worse. All the teacher respondents stated that the CCI Workshop had a positive impact on the lab skills of the students. 95% of respondents also agreed that it had a positive impact on student problem solving skills, with only 5% stating that it had no discernible impact on these skills.



Open text responses also revealed that the CCI workshop encouraged teamwork, reinforced prior learning, provided societal context, improved communication, helped with future career planning and provided insights into university life. Since it takes a further 2 years for TY students to finish secondary school in Ireland and make final career decisions, it can take several years to directly measure longitudinal behavioural change. However, follow up discussions with teachers who received student workshops in the first year of the CCI programme (2022/23) has revealed significant long-term impact after receiving the workshop;

“

“More students in our school took Chemistry at senior cycle which is very positive”

– Teacher A

“

“My students have now left school, there was an increase in the numbers choosing science related courses for that year group”

– Teacher B

“

“More engaged, more interest in the uptake of senior cycle science”

– Teacher C

“

“Some of the students have taken a significant interest in chemistry and forensic science”,

– Teacher D

“

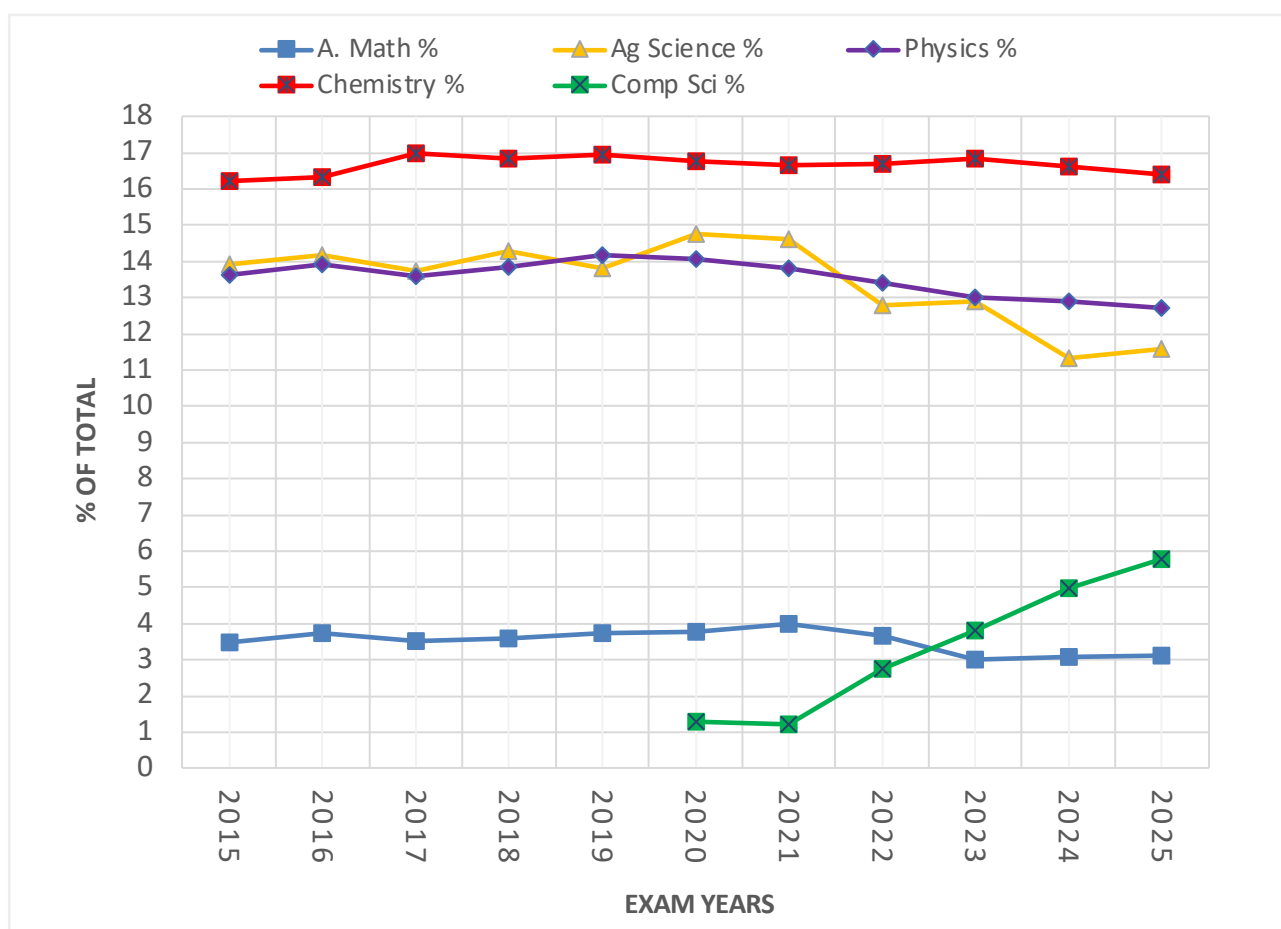
“My students were very impressed and inspired by the PhD students, and many have since gone on to study chemistry or chemistry-related sciences at third level. They often recall the careers Q&A session as the moment when they seriously began to consider studying chemistry and science further. They also took encouragement from the idea that meaningful learning often happens during productive struggles. As a result, they’ve become more willing to persevere through challenges rather than give up.”

– Teacher E

2.4 Indirect Impact:

In addition to direct feedback and teacher case studies, national student education statistics also reveal some change which could be attributed to the CCI programme due to the nationwide scale and multi-year timescale of the programme. Ireland has one of the highest numbers of secondary schools per capita in the world (double compared to Scotland which has a similar population), ensuring smaller schools but making it difficult to offer a wide range of LC subject choices. LC Chemistry requires lab space, equipment and consumables, making it less likely to be offered in DEIS schools. Over the past decade, the number of schools offering LC Chemistry has grown from 568 in 2015 (75%), to 650 schools (85%) in 2023. This is second only to Biology (756), slightly ahead of Physics (573) and AgScience (467). Over the past 5 years, the demand for chemistry based Higher Education courses has dropped across the US and Europe.¹⁹ In the UK, Chemistry undergraduate numbers have dropped 26% since 2020, but the demand for chemistry in Ireland remains steady.

Biology is the most popular LC science subject, and along with chemistry are the only two science subjects with a female majority (both 60%). LC Computer Science was introduced on a pilot basis in 2018 and 2019 (exam years 2020 and 2021) and rolled out to all schools from 2020 onwards (exam year 2022). The rapid growth in the popularity of LC Computer Science has affected the numbers choosing other LC Science subjects. Since 2020, LC Computer Science has increased by 3,515 students, LC Biology has increased by 1,081 students and LC Chemistry has increased by 336 students. However, in contrast, LC Physics has decreased by 350 students, LC Ag Science has decreased by 1,443 students and LC Applied Maths has decreased by 286 students. It is proposed here that the CCI programme and our focus on LC Chemistry helped to maintain the numbers choosing chemistry in the face of huge popularity for LC Computer Science.



Uptake of LC Science subjects by exam year (LC Biology removed for clarity - 59%)

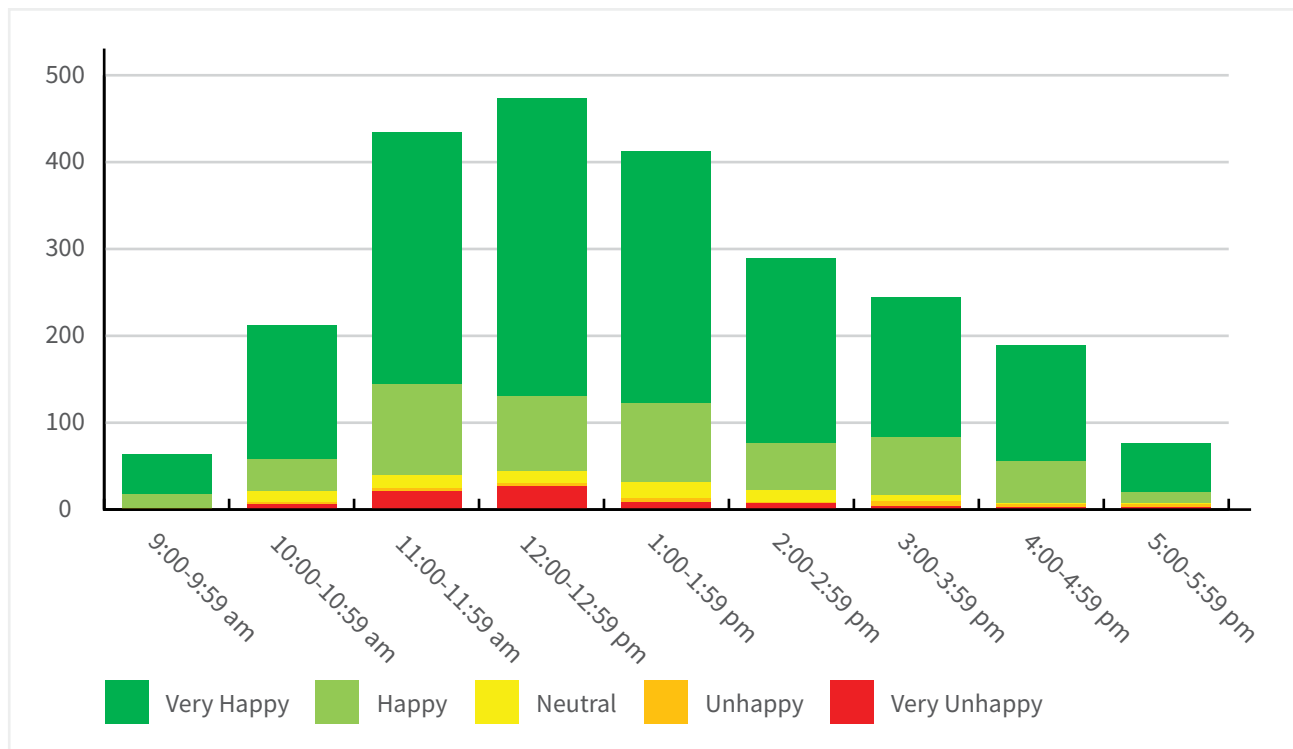
It is well established that undergraduate HE STEM students typically develop teamwork and communication skills by working in groups to solve problems and conduct lab experiments. While this kind of active learning positively impacts the achievement and retention of students, it is also a significant source of anxiety. Female students in particular report higher levels of group work anxiety and lower STEM identity compared to their male counterparts.²⁰ The CCI workshop can help to reduce this anxiety through group-based experimental activities and prioritizing female career role models for female only schools.

In terms of Higher Education courses, the demand and gender makeup of the ATU Sligo chemistry related courses has remained mostly unchanged when compared with two years prior to the CCI programme (2021/22 and 2022/2023). However, the number of female applicants for the TCD Chemical Sciences (TR061) course has swung from 55% to 66% female for 2024/25. This is higher than LC Chemistry for the same year (60% female) and higher than the UK HE average (50%). This may demonstrate the impact of providing tangible female STEM career role models and the significant scale of the CCI programme in the Dublin City (IE061) and Eastern region (IE062). The CCI programme emphasised accessibility and inclusion, prioritising DEIS schools where possible. The number of SUSI grant holders in the TCD Chemical Sciences course has increased from 22% in 2022/23 to 30% for 2025/26, of which 69% are female compared to 58% reported nationally [HEA Statistics, 2023]. There is also a slight increase in SUSI grant holders for the ATU Sligo chemistry related courses, although the number of those entering from DEIS schools has remained mostly the same.

2.5 Public and Primary:

The CCI public, primary and community engagement programme centred around our hugely popular Battery Maker activity (Lesson 2 - Do You Want to Build a Battery? Page 26), which facilitated two-way discussion between participants and facilitators. Participants were guided to build a historic Voltaic Pile from aluminium foil, Play-Doh® and copper coated coins. This simple, safe, low-cost sustainable battery can power a Light Emitting Diode (LED) or an alarm clock for visually impaired participants. The activity also incorporates a variety of skills development such as numeracy, dexterity, inquiry, teamwork and more.

At least 50,000 people have engaged with the activity across 22 public/community events as well as 6 primary schools or community groups mostly consisting of 3rd and 4th class, with some 5th and 6th. The Battery Maker activity is highly flexible and adaptable to an incredible number of formats and venues. A “micro-workshop” format with everyone seated was preferred by 90% of facilitators. It provided more time for two-way conversation, prevented talking down to participants and facilitated wheelchair users. A “Front-of-House” leader controlled the crowds, assigned participants to tables and managed breaks. Keywords provided by facilitators in relation to “impact” are highlighted include; social, excitement, accessible, fun, curiosity, diversity, connect, trust and equal among others. Formative research found that some interventions can result in unexpected outcomes and negative responses.^{21,22} As a result, a HappyorNot ‘Smiley Face Stand’ using ‘emojis’ was deployed to gather large-scale participant feedback (n = 8099) at busy public events. Customer Satisfaction Score (CSAT) is widely used by retailers, over 90% is considered exceptional or exemplary.²³ For mixed themed public events, 97% was achieved, while 92% was achieved at science focussed events. Comparing indoor vs outdoor events, outdoor scored higher with 95% vs 90% for indoor. In case of the Ballina Salmon Festival, Boyle Arts Festival, Beyond the Pale and Night&Day, the CCI Battery Maker activity was one of the only science activities on offer to participants. Regardless of the event, the CSAT score proved it was always exemplary.



Real-time large scale audience feedback monitoring

In addition to feedback, the “Smiley Stand” also provided us with real-time audience response monitoring, which helped us tailor the language, layout and emphasis for different events and audiences. Negative feedback was minimal overall and usually associated with busy periods e.g. lunchtime. This has led to format changes such as spreading out facilitator break-times, more tables and better crowd control. The real-time data also allowed us to identify quiet periods for those in the ASD community. Analysis of the feedback also indicated that a participant to facilitator ratio of 10:1 per hour should not be exceeded. Where the ratio reached 15 or 20 participants per facilitator, a significant increase in negative and neutral responses was observed across all event types. A ratio of 10:1 per hour translates to about 5-6 minutes per participant. This can be controlled by the “Front of house” leader. A detailed public participant survey (n = 56) also found that all answered “yes” to the statement “I will tell my friends and family about these experiments”. Detailed feedback from the primary workshops found that 57% “loved it”, with 34% indicating that they “liked it”, while the rest indicated that “it was ok” and nobody hating it.



The Battery Maker activity has also been run with public participants and schools through franchising and partners. In May 2024, the CCI team provided a Battery Maker kit and training for 10 staff from ESB ecars to use at the Big Bang Fair in Birmingham. Hundreds of school groups engaged with the ESB ecars exhibition stand at the Big Bang fair in 2024 and 2025, building batteries and discussing green energy technology. Similarly, the activity has also been adapted by Irish based Research Centres, such as Amber, to use during Science Week. It is difficult to quantify the scale of partner engagement using our Battery Maker activity, but it is estimated to be around 10,000 people to date.

2.6 Policy and Professional Development:



42nd ChemEd IRELAND CONFERENCE

TIMETABLE

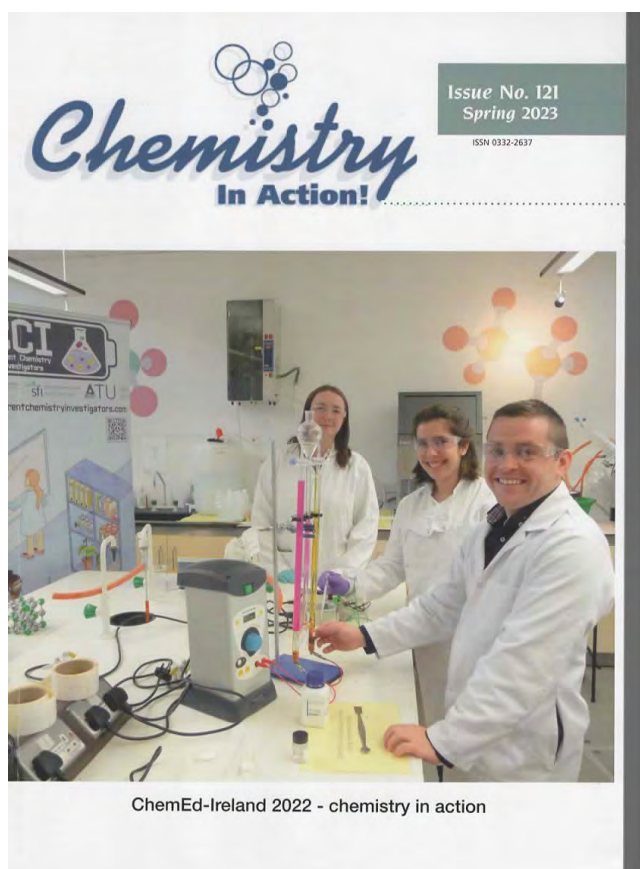
- 9:30 - 10:00 **Registration, Coffee and Posters**
- 10:00 - 10:10 **Welcome and Conference Opening**
Prof. Graeme Watson - Head of Chemistry, TCD
- 10:10 - 10:40 **Hydrogen, Solar Cells and our Future**
Dr Michelle Browne - Helmholtz-Zentrum, Berlin
- 10:40 - 10:55 **Current Chemistry Investigators**
Dr Natalia Garcia Domenech - Trinity College Dublin
- 10:55 - 11:00 **Oide: the new CPD service for teachers**
Seán Kelleher - Oide & Colaiste Choilm Swords
- 11:00 - 11:25 **Coffee and Posters**
- 11:25 - 11:35 **Chemistry Olympiad Ireland**
Dr Carl Poree and Dr Brian Murphy
- 11:35 - 12:05 **Demonstrations and how to survive them**
Chris Lloyd - Scottish Schools Education Research Centre (SSERC)
- 12:05 - 12:40 **Clean Energy Storage**
Prof Serena Cussen - University of Sheffield
- 12:40 - 13:10 **WORKSHOP**
- 13:10 - 14:05 **Lunch**
- 14:05 - 14:35 **WORKSHOP**
- 14:35 - 15:05 **Crystallography for the people**
Dr Claire Murray
- 15:05 - 15:25 **A new approach to school lab design**
Humphrey Jones - ISTA Vice-Chairperson and St. Columba's College
- 15:25 - 15:45 **Overview and pitfalls from the 2023 Leaving Cert Chemistry exams**
Gerry Hyde - State Examinations Commission (SEC)
- 15:45 **Close of Conference**

WORKSHOPS

- Activities in Junior Cycle - Michael Kavanagh
- Big Impact in Little Chemistry - Dr Johanne Brolly
- Green is Safe - Seán Kelleher & Team
- Current Chem Investigators - Dr Natalia Garcia Domenech

SPONSORS

ICRAG, ROYAL SOCIETY OF CHEMISTRY, Trinity College Dublin, CCI, Edco, ista, Oide, diamond



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ChemEd-Ireland 2022 - chemistry in action

CCI Teacher CPD Activities and Policy Work

One of the aims of CCI was to work with science teachers as equal partners. With the aim of ensuring CCI has a long and lasting impact, we provided complimentary Continuous Professional Development (CPD) opportunities for science teachers. For the 2022 ChemEd-Ireland conference, hosted at the Technological University of the Shannon (TUS) in Limerick, we supported a teacher (David O'Connell) to develop and deliver a new electrochemistry CPD workshop for teachers. The feedback was hugely positive, and it later featured on the front cover of the Spring 2023 edition of *Chemistry in Action* Magazine. Since then, the CCI leadership team has engaged with over 500 science teachers through 13 hands-on workshops, 4 demonstration activities and hosted the 2023 ChemEd-Ireland conference at Trinity College Dublin. The success of our teacher CPD programme was achieved through partnerships with the Royal Society of Chemistry (RSC), several Irish Science Teacher Association (ISTA) local branches and other stakeholders.

The first draft of the new LC Chemistry specification for schools was released for public consultation in December 2023, with the final specification released in 2024. The CCI project leadership team took part in the consultation process through online submissions and in-person events. In 2023, the CCI team hosted the annual ChemEd-Ireland conference with over 120 people at TCD with the theme of “green energy”. Speakers included international expertise in the areas of batteries and hydrogen technology, as well as representatives from the State Examinations Commission (SEC) alongside hands-on workshops for teachers. This policy campaign cumulated with the introduction of the 2025 LC Chemistry specification which features electrochemistry as a core topic for the first time. As well as engaging in policy work, the CCI leadership team also developed a new 2-hour CPD workshop to help teachers prepare for these changes. For the “Hands-On LC Electrochemistry” CPD workshops, 37 of the 38 survey respondents “Strongly Agreed” that the workshop will have a positive impact on their teaching (1 said Agreed).

Date	Type of Activity	Partner/Venue	Teachers
February 2022	Junior Cycle CBA - Battery Maker	Galway ISTA, Taylors Hill	20
April 2022	Junior Cycle CBA - Battery Maker	ISTA Conference, UCC	10
September 2022	Junior Cycle CBA - Battery Maker	MU Practical Chem	61
October 2022	ChemEd-Ireland Conference Micro-scale LC ElectroChem	Teacher, TUS Limerick	15
November 2022	Junior Cycle CBA - Battery Maker	Dublin ISTA, St. Columba's	16
November 2022	Junior Cycle CBA - Battery Maker	Google Foundry, Kinia	18
February 2023	Junior Cycle CBA - Battery Maker	Limerick ISTA, TUS Limerick	11
April 2023	Demo Stand, Hydrogen Fuel Cells	ISTA Conference, TUS	50
June 2023	Demonstration – Battery Maker	BASF Summer School, UCC	65
October 2023	ChemEd-Ireland Conference, CCI workshop and Keynotes	Trinity College Dublin	101
October 2024	Hands-On LC Electrochemistry	Galway ISTA, Taylors Hill	24
October 2024	Hands-On LC Electrochemistry	Dublin ISTA, St. Andrews	28
November 2024	Hands-On LC Electrochemistry	Waterford ISTA, DeLaSalle	11
April 2025	Demo LC Electrochemistry	ISTA Conference, MU	46
June 2025	Demo LC Electrochemistry	BASF Summer School, UCC	80
October 2025	Hands-On LC Electrochemistry	Sligo/Donegal ISTA, Boyle	16
November 2025	Hands-On LC Electrochemistry	Kerry ISTA, Killorglin	9
CCI Total CPD	17 Activities	8 Locations	581

Summary of CCI Secondary Teacher CPD activities

Additionally, three posters were also produced as long-term resources to assist teachers and students in the learning and appreciation of the science of green energy. The posters were developed through a co-creation process with two PhD facilitators (Iñigo Iribarren and Niamh O'Shea) i.e. the content was provided by the CCI Leadership team, with the design and Irish translations completed by our PhD facilitators. The posters were printed with the English language version on one side and the Irish language version on the other, offering a choice for schools. The first poster was produced in 2023, entitled “The Green Energy Map of Ireland”, showcasing the historic Irish connections to a variety of electrochemistry and green energy related concepts. The second poster promoted our “Battery Maker” activity in 2024, encouraging everyone to try the activity themselves in school and at home. Our final poster was specifically designed for the re-developed 2025 LC Chemistry specification, providing a visual representation for one of the new learning outcomes (primary vs secondary cells). Over a thousand posters were printed and delivered to schools all over Ireland, providing passive long-term impact for many years.

In addition to the provision of CPD and resources for teachers and schools, we also provided training and support to our PhD and Post-Doc research facilitators. The annual CCI symposium provided a valuable opportunity for the entire team to share best practise, network, and upskill through training. In addition to guest speakers from Lifetime Lab, the Trinity Research Office and the iCRAG research centre among others, PhD facilitators also shared their own experiences, stories and ideas. Data collected through our monitoring and evaluation was also scrutinised by everyone present, with changes to content also decided by consensus. The 2022, 2023 and 2024 meetings took place in TCD, which provided the shortest travel time for our Cork and Sligo colleagues. The 2025/26 symposium took place in the Education Centre at the iLOFAR radio telescope in Birr, Co. Offaly, which is also home to the historic Great Leviathan Telescope. The central location and unique setting provided the entire CCI team with new perspectives and ideas thanks to the TCD School of Physics.

Do you want to make a battery?

Prepare the battery

1. Cut out 6 disks of aluminium foil.
2. Create 6 small balls of play-dough.
3. Stack the coin, play-dough & aluminium in the correct order to create a battery.

Light it up!

1. Hold the long leg of the LED to the furthest coin electrode.
2. Hold the short leg of the LED to the furthest aluminium electrode.
3. What is the fewest number of cells needed?

How does it work?

The aluminium foil will oxidise into Al³⁺ ions. The electrolyte (play-dough) helps to move the charge. The coin acts as an inert conductor for the oxygen reduction reaction to complete the circuit. Play-dough is an excellent electrolyte because it contains a lot of salt and water, which helps move the charge.

The Chemistry

$4Al + 3O_2 + 6H_2O \rightarrow 4Al(OH)_3$

Cill Ceallraí Phríomhúil vs Tánaisteach

André príomh: Clóirín Measá Sinc (Zn) a ocsaídú chun eiri Zn²⁺ ag scaoileadh 2 leictreon (e⁻) mar leictreónach.

Príomhach dhúchú: Coibhídh leictreón (e⁻) ón andró go dtí an chaidéir trí chablaí chun obair a dhéanamh (i.e. solas).

Tánaisteach: Tá líon an dhúchúis, déantar an míod hidríd a ocsaídú, agus ag scaoileadh leictreón 1 (e⁻) mar leictreónach. Laghdáil ar le líon athchaithe.

Ceallraí príomh: Laghdáil de-ocsáid mangánais (MnO₂) ag fáil 2 leictreón (e⁻).

Tánaisteach: Tá líon an dhúchúis, laghdáil hidracsáid ocsáid níol (NiOOH) ag fáil 1 leictreón (e⁻). Ocsaídáil ar le líon athchaithe.

Príomhach dhúchú: Curann fionne cumhachta seachtach allach ar leictreón (e⁻) a scaoileadh ón gceallraí go dtí an andró trí chablaí.

Cill Tánaisteach (Alcailéach Indúscartha)

- Scaoileadh ion hidracsáid (OH⁻) an leictreón óm an chothromóid an luchtach.
- Tá na hionidí cumhachta de-oxaídáil: Scaoileadh an cailcail nuair a ocsaídáil an sinc ar fáil 2e⁻ → Zn²⁺
- Bailiúir níos mó 200 tonna de na gaeilí seo in Éirinn (sainleir).

Cill Tánaisteach (ni-athchaithe NIMH)

- Tá líon na hionidí a ocsaídáil i gceallraí hidríd níol. Aníall trí athchaithe le fionne cumhachta seachtach.
- Comhábhaí ion hidracsáid a leictreón an luchtach níol na leictreóní le líon dhúchúis agus athchaithe.
- Tá líon na hionidí níol hidríd a ocsaídáil agus a scaoileadh trí "fóid" inchailéil ar fáil thart ar 1000 téimhail.

LED: Tá n-imoibriú ocsáid, is é is ocsaídú na cailteas leictreón, is é an luchtú ag fáil leictreón

An Fuinneamh Glas Leársaí na hÉireann

Aeráilíoch agus líonach

Infó nuair ceallraí agus líonach

An dhúchúis níonach

Treosín ceallraí a ocsaíd

Fuinnemh in-athchaithe

Scaoileadh ceallraí

Fuinnemh níonach

Three CCI Posters were produced during the programme with PhD Facilitators and delivered to schools all over Ireland, available in Irish and English.

Feedback and interviews with our PhD facilitators indicate that the CCI programme has had a significant impact on them personally and professionally. They stated that it revived their own enthusiasm for doing science because “sometimes I think you kind of lose that”. One interviewee stated that it “reminds you why you like science”, which demonstrates the benefits of two-way communication. Another stated that “it gives me quite a lot of enthusiasm for science again”, because you can “forget the broader picture”. They also expressed a sense of pride that they could act as a role model to “inspire a younger generation to think that science might be possible for them” while another interviewee hoped “that science is more approachable after doing something like this”. They also hoped that people “come away realising science is actually for everyone”. Moreover, they expressed that these activities should help the participants realize “how everything is related to science, and you can do very cool things with very little materials and very basic stuff”. The opportunity to develop various skills were also highlighted. The broad spectrum of people that they encountered meant that they had to “adapt the activity to the different ages and the different groups”. This developed their communication skills as they answered hundreds of questions about energy science and their own research. It also helped them develop their leadership and organisational skills while running the activity with different types of people. In general, they expressed that it was a tiring experience, “but it’s very rewarding”.



CCI Symposium 2023 at Trinity College Dublin

The training and experience provided to the PhD and Post-Doc facilitators has also given them an evidence base to create their own initiatives linked to their research. This has resulted in the production and delivery of new engagement opportunities separate to CCI at events such as Science Week and the European Researchers Night. The methods employed by the CCI programme for training, monitoring and evaluation have also been shared for others to use, at the 2023 Research Ireland (SFI) partners meeting, at the 2023 and 2025 Variety in Chemical Education and Physics Higher Education (ViCEPHEC) Conference and at the 2024 and 2026 Science and Maths Education Conference (SMEC). The CCI project has also produced two peer-review publications in the Journal of Chemical Education in 2023 and 2024.



CCI Symposium 2025/26 in Birr, Co. Offaly

Part 3: Lessons and Resources

Over the course of the CCI project we have produced three core lessons that are available here for everyone to use as they wish. All these lessons are probably best suited for upper secondary school students (Transition Year (TY), 5th and 6th Year Leaving Cert in Ireland) since it best matches the Leaving Cert (LC) specifications (16-18 years old). However, lesson 2 could be used for any age group. Electrolytes and electrochemical cells bring together chemistry and electricity. In these lessons you will explore these concepts through three closely connected lessons supported by hands-on experiments.

- In **Lesson 1**, you will learn what electrolytes are and how they conduct electricity. By exploring how dissolved ions allow electric current to flow through solutions, you will develop the core concepts needed to understand electrochemical systems. This lesson is an adaption of the one we ran in secondary schools.
- **Lesson 2** builds on the foundation from Lesson 1 by demonstrating how chemical energy can be converted into electrical energy. You will explore this process by constructing simple batteries and observing how ion movement and electron transfer produce an electric current. This lesson is an adaption of our public engagement activity.
- **Lesson 3** focuses on the reverse process of what you observed in Lesson 2. Instead of converting chemical energy into electricity, you will use electrical energy to produce a fuel and then use that fuel to generate electricity again. Specifically, we focus on hydrogen as the fuel. This lesson is an adaption of our teacher professional development activity.

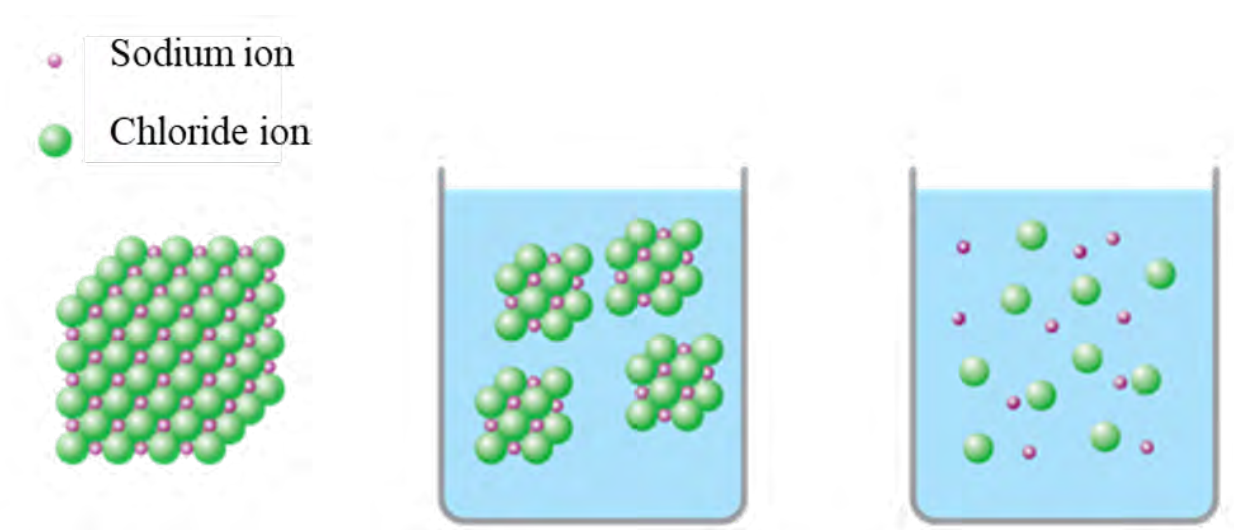
All activities are designed to encourage teamwork with students in teams of 2–3 each. The items mentioned in the materials section for lesson and in the Technical Notes are for each team. The preparation assumes a class of ~24 students, working in 8 teams of 3 students each.



3.1 Lesson 1 – Charged Up! The Conductivity of Electrolytes

Ions are atoms that have lost or gained one or more electrons, which causes them to become electrically charged. **Electrolytes** are ionic substances (liquid or moist solid) that contain free ions and can carry an electric charge. When salts are dissolved in water, the ions move and allow electric current to flow. Example: Table salt (NaCl) in water separates into sodium () and chloride () ions, enabling the solution to conduct electricity.

Conductivity is the measure of a solution's ability to carry an electric current *via* moving ions. A conductivity meter can measure the concentration of dissolved ions present in a solution. A concentrated salt solution (many ions) has higher conductivity than a dilute solution (fewer ions). Conductivity is typically measured in **siemens or millisiemens per centimeter** (S or mS/cm). In this experiment, you will test how salt concentration affects conductivity.

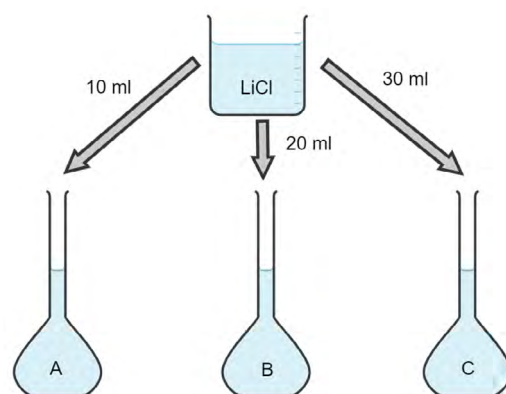
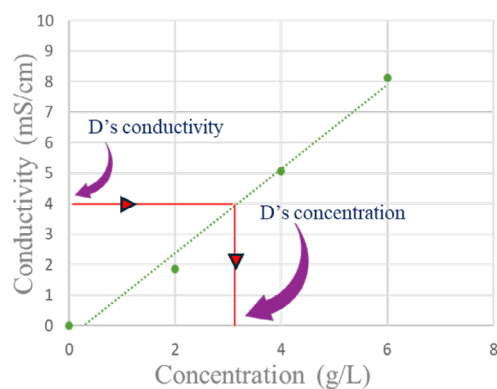


Materials:

- 100 mL of 10 g/L NaCl stock solution in a plastic container
- Four 50 mL volumetric flasks with stoppers (A–D)
- 100 mL beaker
- 250 mL wash bottle with tap water
- 10 mL graduated pipette and pipette filler
- Conductivity meter (Note: see the 'Technical Notes')
- Graph paper, pencil and ruler

Experimental Procedure:

1. Prepare A, B, and C from the NaCl stock by pipetting 10 mL for A (2 g/L), 20 mL for B (4 g/L) and 30 mL for C (6 g/L). Top up to 50 mL with water (Figure 2).
2. Stopper each flask and invert 5 times to mix it fully.
3. Measure the conductivity by pouring each solution separately into a beaker and fully immersing the conductivity meter probe.
4. Record the conductivity value in the table provided.
5. On your graph paper, plot conductivity against concentration for all three flasks. Mark these points and draw a best-fit line (your calibration curve).



Sample calibration curve of conductivity (y-axis) vs concentration (x-axis). Values are for demonstration purposes only.

Solution	Concentration (g/L)	Conductivity (mS/cm)
A	2	
B	4	
C	6	
D		

Use Graph to Solve Unknown:

- Make an unknown solution D by adding 25 mL of solution B and 25 mL of solution C to a new flask D. Mix gently and measure conductivity as before and record it in the table provided.
- Use your calibration curve to find D's concentration. Use D's conductivity to read across the best fit line. Record the concentration in the table.

Lesson 1 Questions:

Q1.1 Which of the following solutions are electrolytes. Tick all that apply.

- Solution in batteries ☐
- Oil ☐
- Salt water ☐
- Sugar in water ☐
- Sports drinks ☐

Q1.2 Based on your understanding of electrolytes, how will these salts break into ions?

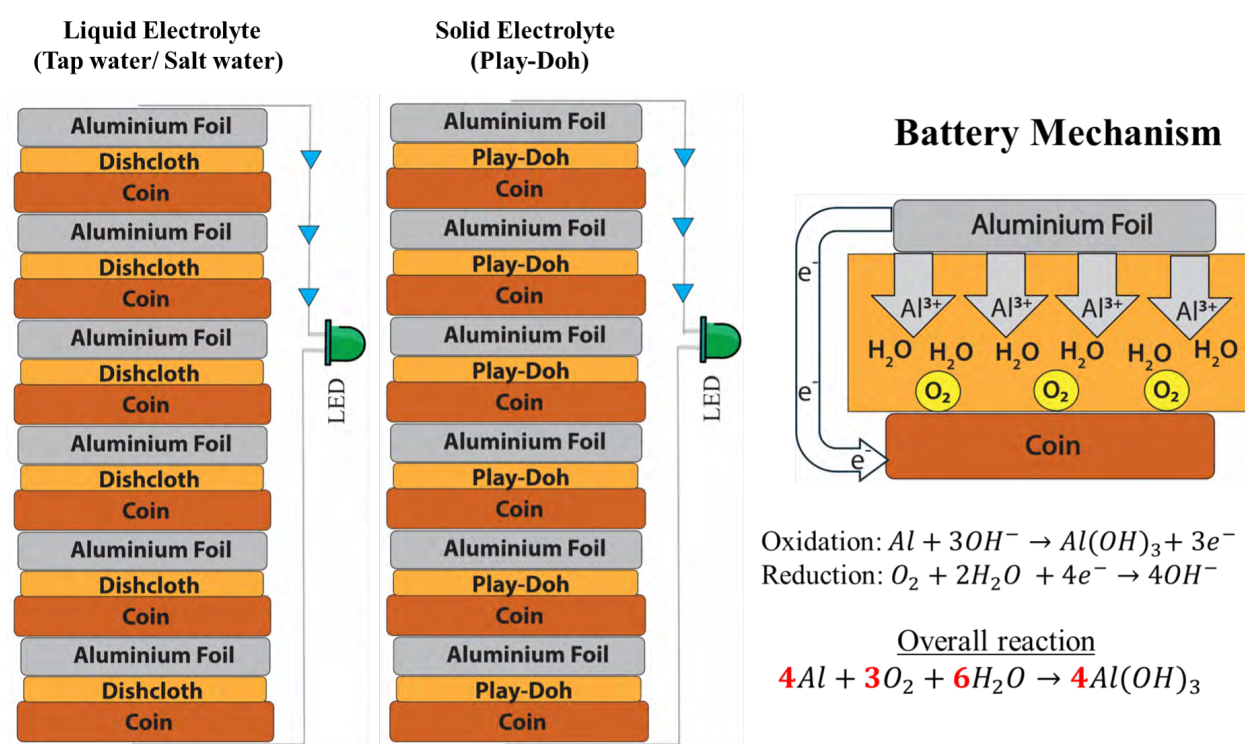
- KBr: _____
- CaCl₂: _____
- KCl: _____

Q1.3 For solutions containing the same ions, how would you explain the relationship between conductivity and concentration?

3.2 Lesson 2 – Do You Want to Build a Battery?

Batteries convert chemical energy into electrical energy through a process called **redox**, where **oxidation** (loss of electrons) and **reduction** (gain of electrons) occur simultaneously. You may memorise it as **OIL RIG** – **O**xidation **I**s **L**oss of electrons; **R**eduction **I**s **G**ain of electrons. These reactions occur between two different metal electrodes in the presence of an ion-conducting electrolyte. A redox reaction pushes electrons through an external circuit from the **anode** (negative) to the **cathode** (positive), while ions move through the electrolyte to balance the charge within the battery. In summary, an anode (–) is a negative electrode where oxidation occurs and cathode (+) is a positive electrode where reduction occurs.

In this activity, you will build two stacked coin batteries (voltaic pile) using three different **electrolytes** (two liquid and one semi-solid). The Aluminium foil will **oxidise** into **Al³⁺ ions**. The copper **coin** acts as a **conductor** for the O₂ reduction reaction to complete the circuit (Figure 4).



Liquid and solid electrolyte battery setups showing the redox reactions.

Materials:

- Scissors and marker
- Six 5c coins, Aluminium (Al) foil and dishcloth
- Tap water and salt water (~10 mL of each) in separate plastic glasses
- Play-Doh
- Multimeter and light-emitting diode (LED)

Experimental Procedure:

1. Using scissors, cut 6 Aluminium foil discs and 12 dishcloth discs (use coin as a template).
2. Dampen 6 cloth discs with tap water and 6 with salt water (moist, not dripping).
3. Make one cell by stacking a coin, then the cloth and the foil in the correct order.
4. Measure voltage with the multimeter (red lead to coin, black lead to the Al-foil) and record in Table 2. If the reading is negative, swap the leads.
5. Continue adding cells, measuring voltage after addition of each cell. Add up to 6 cells.
6. Connect the LED (long leg to coin, short to Al-foil), how many cells are needed to light the LED?
7. For the solid electrolyte battery, clean the coins and aluminium foil and replace the cloth with a small layer of play-doh (use compressed balls).

Number of cells	Battery 1 (Tap water) Voltage (V)	Battery 2 (Salt water) Voltage (V)	Battery 3 (Play-doh) Voltage (V)
1			
2			
3			
4			
5			
6			

Lesson 2 Questions:

Q2.1 Fill in the blanks: Electrons move from the _____ to the _____.

The battery works through a _____ reaction. Oxidation is _____ of electrons at the _____. Reduction is _____ of electrons at the _____.

Q2.2 Discuss why an electrolyte with more ions might perform better?

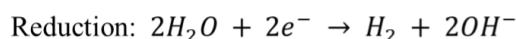
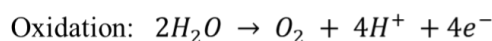
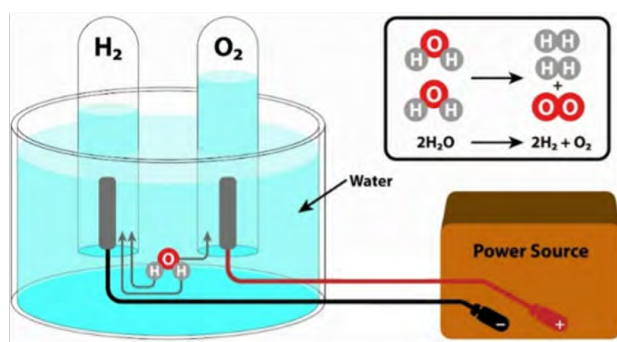
Q2.3 What are some advantages of using a solid electrolyte like Play-Doh instead of a liquid electrolyte? (*Hint: think of practical aspects*)

3.3 Lesson 3 – From Water to Wheels: Hydrogen in Action

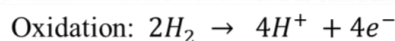
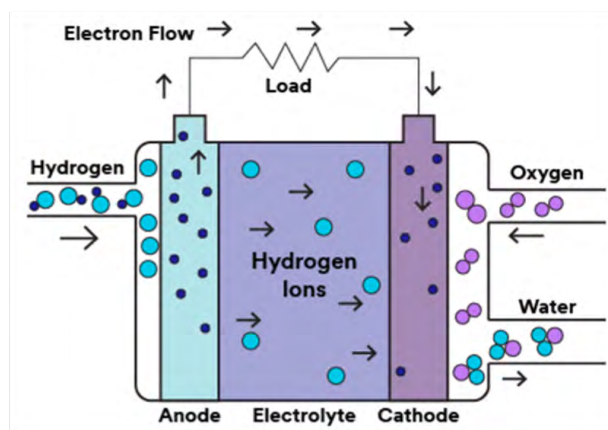
Hydrogen (H_2) is considered a clean fuel because it produces only **water** (H_2O) when it reacts with **oxygen** (O_2). However, H_2 gas does not occur freely in nature, so it must be produced. One method of doing this is electrolysis, which uses electricity to split water into H_2 gas at the cathode and O_2 gas at the anode. The H_2 gas produced can then be used in a **hydrogen fuel cell**, where H_2 and O_2 combine to produce water and generate electricity. The operation of a hydrogen fuel cell is therefore essentially the reverse of water electrolysis. Unlike a battery which has a fixed number of reactants, a hydrogen fuel cell will continuously generate electricity as long as it has fuel (H_2) and O_2 . In this activity, you will split water and collect the resulting gases (H_2 and O_2).

Safety: Wear goggles and gloves throughout. Keep flames away, as H_2 gas is highly flammable. Be careful of the sharp thumbtacks used in this activity.

Electrolysis (put e^- in)



Hydrogen Fuel cell (take e^- out)



Comparison of water electrolysis and hydrogen fuel cell reactions.^{24,25}

Materials:

- Two plastic cups
- Two metal pushpins/thumb tacks (please exercise caution)
- 2 glass test tubes (~10 cm height)
- 300 mL dilute sulfuric acid (0.1 M) in a plastic container
- 9V battery
- Double-sided tape
- Food colouring and a Pasteur pipette

Experimental Procedure:

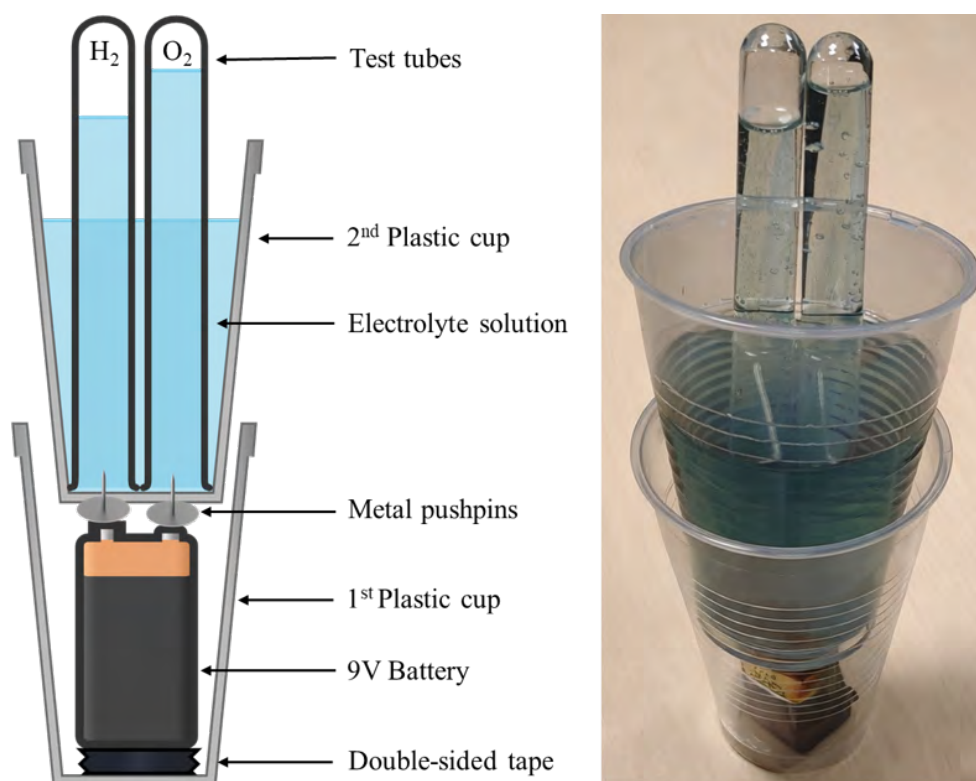


Figure 6. Experimental setup for electrolysis of water.

1. Attach the 9V battery to the centre of the 1st cup using a double-sided tape.
2. Push two metal pushpins through the bottom of the 2nd cup, 1–2 cm apart so they line up with the battery terminals.
3. Fill this 2nd cup to about 80% with 0.1M Sulphuric Acid and add two drops of food colouring using a Pasteur pipette to improve bubble visibility.
4. Place the 2nd cup inside the 1st one so that the pushpins touch the battery terminals. You should now see bubbles forming at both pushpins.
5. Fill both test tubes with 0.1M Sulphuric Acid to the brim. Close the opening of the test tube with your finger and gently invert it into the acid in the cup. **Caution:** Release once the opening is fully submerged to avoid trapping air.
6. Place one inverted test tube over each pushpin so the gases collect separately. Let the test tubes rest against the sides of the cup for support.
7. Collect gases for 5–10 minutes.
8. Once a visible amount of gas has formed, remove the 2nd cup from the 1st cup carefully.
9. Compare the gas volumes in the two test tubes.

Optional Add-On Activity:

Assemble the fuel cell car (Note: see the ‘Technical Notes’) by mounting the fuel cell on the chassis, attaching the H₂ and O₂ storage containers, and filling the fuel cell with distilled water. Connect a battery pack to electrolyse the water and generate H₂ and O₂ gas. Then disconnect the battery and let the car run on the fuel cell. The only exhaust produced is water, demonstrating the potential of H₂ as a clean fuel to power vehicles.

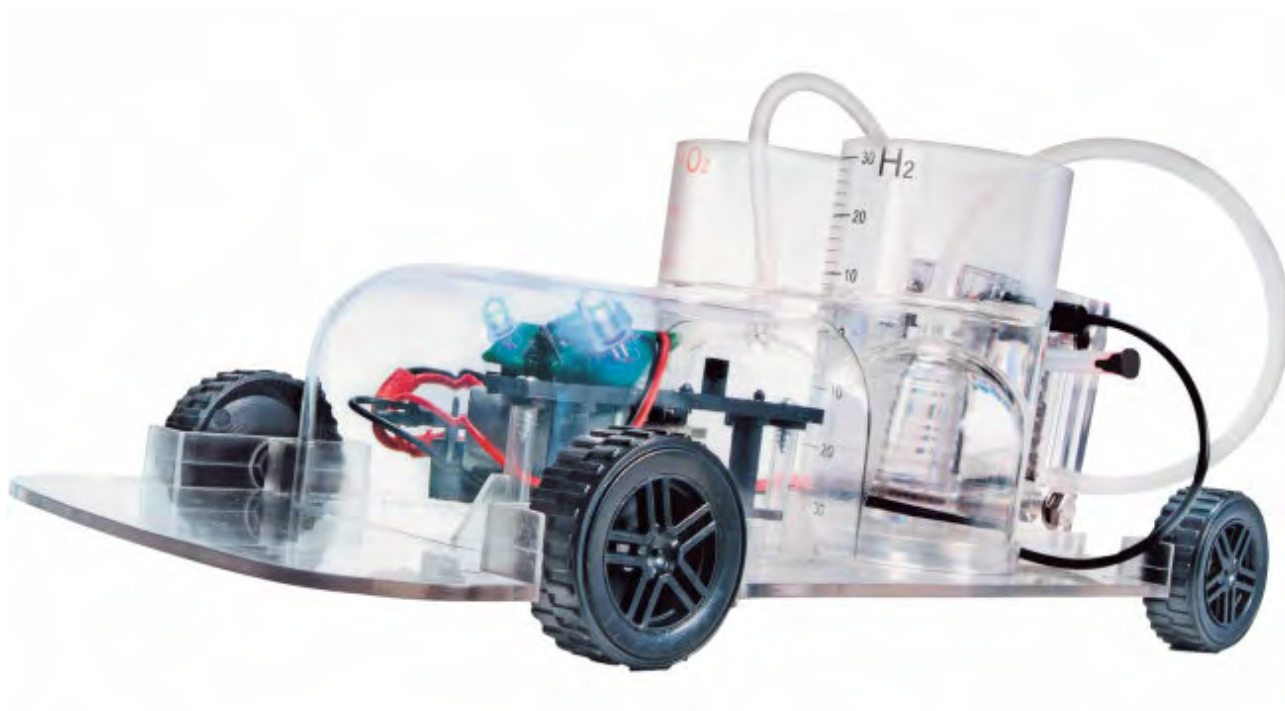


Figure 7. Hydrogen fuel cell car.²⁶

Lesson 3 Questions:

Q3.1 Name one similarity and one difference between water electrolysis and a hydrogen fuel cell.

Q3.2 What is the Hydrogen to Oxygen volume ratio (from electrolysis results)?

How does this ratio relate to the chemical formula of water?

Q3.3 What happened when the H₂ and O₂ in the fuel cell were used to power the car? What does this demonstrate about how a fuel cell works in comparison to electrolysis?

3.4 Technical Notes, Safety and Answers to Questions:

Salt water (NaCl) and Play-Doh are consumer grade. Wash your hands after handling. Dispose of the salt water and acid safely by diluting with running tap water. For **Lesson 3:** Wear goggles and gloves. Even dilute H_2SO_4 can irritate skin and eyes, so rinse spills immediately.

Lesson 1 - Charged Up! The Conductivity of Electrolytes

Preparation: Make a 10 g/L stock by dissolving 10 g of NaCl in 1 L of tap water.

Tips: Wait for conductivity meter reading to stabilise before recording the data.

Purchase and Cost: The conductivity meter (Model No: RS 1410-1002) is available from RS Radionics (<https://ie.rs-online.com/web/p/conductivity-meters/2050958>), for ~ €418.

Lesson 2 – Do You Want to Build a Battery?

Preparation: To make 100 mL of saturated NaCl solution, stir NaCl (~36g) into tap water until some remains undissolved. Provide ~2 cm³ size of Play-Doh per team to form six small balls (enough to cover coin faces). Al-foil and dishcloth cut to one third of an A4 sheet are sufficient for one team.

Tips: If the LED doesn't light, add more cells or check polarity. Avoid squeezing Play-Doh stacks too hard or using excess Play-Doh, as this may cause short circuits. Cut the dishcloth discs slightly smaller than the coin for better results. Use different coloured dishcloths to distinguish between electrolytes.

Lesson 3 - From Water to Wheels: Hydrogen in Action

Preparation: Make 3 L of 0.1 M sulfuric acid (H_2SO_4) by slowly adding ~16.3 mL concentrated acid to distilled water in a fume hood. Assemble and pre-test the fuel cell car using distilled water.

Tips: Use sturdy plastic cups that can be pierced with pushpins. Spacing between the pushpins should match the distance between battery terminals. Avoid reinserting pushpins, as this may cause leaks. Test tube should be filled with acid while immersing into solution. Trapped air inside the test tubes (if any) may lead to inaccurate gas volume readings. If the gas ratio is not 2:1, check for gas escaping from the test tubes.

Purchase and Cost: The following fuel cell car kits are available from the websites below:

(a) Horizon Fuel Cell Car Science Kit - FCJJ11 (<https://amzn.eu/d/0AUeLws> or <https://www.horizoneducational.com/fuel-cell-car-kit/p1232>) for ~ €110.

(b) Fischertechnik 559880 Profi H2 Fuel Cell Car-Kit (<https://amzn.eu/d/62y4PQF>) for ~ €109.

Answers to Questions:

Q1.1 Electrolytes: solution in batteries, salt water, and sports drinks. Oil and sugar in water are not electrolytes because they do not produce ions.

Q1.2 (a) $K^+ + Br^-$ (b) $Ca^{2+} 2Cl^-$ (c) $K^+ + Cl^-$

Q1A. $A < B < C$. Higher salt concentrations release more ions into the solution.

Q1B. The D is expected to be about 5 g/L. Differences can come from volume measurement errors, incomplete mixing, or reading errors from the graph.

Q2.1 Fill in the blanks in the following order: anode/negative electrode, cathode/positive electrode, redox, loss, anode, gain, cathode.

Q2A. Salt water produced a higher voltage per cell and lit the LED with fewer cells because its abundant ions improve conductivity, while tap water contains very few ions, resulting in higher resistance and lower voltage output.

Q2B. Play-Doh prevents spills and makes stacking cells easier. It also reduces electrode corrosion compared to liquid electrolytes.

Play-Doh conducts electricity because it retains salt within its matrix, providing mobile ions that carry charge efficiently.

In addition, the polymer amylose present in Play-Doh acts as an intrinsically conducting polymer due to its tightly packed conformation, within which ions can flow.

Q3.1 Similarity: both involve redox reactions and water.

Difference: electrolysis uses electricity to split water into H_2 and O_2 ; a fuel cell combines H_2 and O_2 to produce electricity and water.

Q3.2 H_2 and O_2 gases; H_2O is the main product of a hydrogen fuel cell.

Q3A. The $H_2:O_2$ is about 2:1. Water is H_2O , so there are two hydrogen atoms for every one oxygen atom.

Q3B. When H_2 and O_2 were fed into the fuel cell, it released electrical energy to power the car. This shows that the reaction in a fuel cell is the reverse of electrolysis.

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Appendix

Unfortunately, some student feedback data was lost due to technical errors caused by the Audience Response System (ARS). Some students also declined consent for their data to be included, amounting to about 25% in total. None-the-less, the data presented in this report represents 75% of the students we engaged with. The data is also entirely anonymous.



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