



Spectroscopy in a Suitcase: A Model for Implementing and Coordinating a National Chemistry Education and Public Engagement Programme in Ireland

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Abstract

The Irish senior secondary school (Leaving Cert) chemistry curriculum requires students to learn about spectroscopic techniques such as Infra-Red (IR) and Ultra-Violet (UV) spectroscopy. However, most teachers find this section one of the most difficult to teach since schools don't normally have access to the required equipment due to its prohibitively high cost. As a result, the instrumentation question on the annual Leaving Cert Chemistry exam was reported to be the least attempted question across the entire paper.[1] In addition to this, only about a third of Leaving Cert chemistry students who sit the exam continue on to pursue a chemistry related course at an Irish Higher Education Institution.[2] Unlike biology which enjoys widespread school coverage, not all Irish schools teach chemistry or physics to senior secondary level and the schools who do offer these subjects can regularly change depending on demand.[3] Collectively this situation presents a unique challenge for school-based interventions involving chemistry or physics in Ireland. The Spectroscopy in a Suitcase programme is run through six Higher Education Institutions chosen for their expertise in chemistry and geographic location to maintain a high standard and widespread national coverage respectively. Using portable spectrometers and context based learning (CBL) techniques, workshops are run by a team of trained higher level students usually in school labs during school time as a short-duration intervention activity. The benefits of the "scientist in the classroom" model to postgraduate students, secondary students, teachers and the partner Higher Education Institutions are numerous.[4] Recently, the programme has expanded to provide public engagement events and teacher enrichment workshops in addition to the already successful student workshops which have now been running for over four years in Ireland. Feedback and evaluations received to date have been overwhelmingly positive and the programme has provided workshops in half of all Irish secondary schools nationwide as well as running dozens of public engagement and teacher enrichment events.

Keywords: *Public Engagement, Science Communication, Spectroscopy, Chemistry Education, Outreach, Context-Based Learning*

1. Introduction

Spectroscopy in a Suitcase (SIAS) started as a pilot in 2007 across four regions in England as part of the Royal Society of Chemistry (RSC) "Chemistry for our Future" project.[5] Using a kit of professional spectroscopy equipment two models were initially developed; one where teachers were trained to use the equipment so they could borrow it for their classroom and the other based on the familiar Scientist in the Classroom model with postgraduate students trained to use the kit and deliver workshops in schools.[5] In 2014 the RSC Ireland team brought the Scientist in the Classroom model of SIAS to the Republic of Ireland after running successful pilot workshops in a number of Irish schools. Workshop content and the specific kit equipment (IR and UV Spectrometers) were adapted for the Leaving Cert Chemistry curriculum and three hosts were initially chosen from a number of applications in the two largest urban centres; Cork and Dublin.

The Irish programme was expanded further in 2015, 2016 and 2017 with support from three successful Science Foundation Ireland (SFI) grant applications. The SFI funding provided more kits, a greater range of school visits and new host institutions to expand the programme nationally. Together these expansions have now ensured that all Irish secondary schools are within reach of the programme.[6] To date about a hundred postgraduate students and a dozen undergraduate students have visited nearly half of all Irish secondary schools from six host institutions in the Republic of Ireland. Feedback from Irish teachers has been overwhelming positive and SIAS is now integral to the postgraduate training programme at most of the host institutions.



2. Chemistry in Irish Schools

The current Irish senior secondary school chemistry curriculum, as part of the Leaving Cert, was first introduced in 2000 and is currently being revised.[7] Assessment of the current Leaving Cert Chemistry course is by way of a terminal examination only. Mandatory practical experiments are undertaken by students throughout the two year course and these are currently assessed in written form as part of the terminal exam. Instrumentation is the term normally used for spectrometers or other analytical devices described on the course. The Higher-Level course (taken by 86% of chemistry students)[2] requires students to learn the principles of Mass Spectrometry, Atomic Absorption Spectroscopy, Chromatography (TLC, GC and HPLC), Infra-Red (IR) and Ultra-Violet (UV) Spectroscopy. However, from experience, to date the only instruments or relevant techniques on the syllabus that are available for students to use in Irish schools are colorimeters, pH meters and TLC. Students are required to know that IR is a 'fingerprinting' technique involving the absorption of infra-red radiation and UV is a quantitative technique involving the absorption of ultraviolet light. The current syllabus specifically states that students do not need to interpret spectra.[8] This is in stark contrast to the UK chemistry curriculum where students are required to interpret spectra[9] and therefore when SIAS was expanded to Ireland, the workshop material needed to be adapted to make it relevant.



Fig 1. Left the IR spectrometer with ATR attachment and right the UV-vis spectrometer, both of which are used for SIAS workshops in the Republic of Ireland.

Each SIAS kit comprises of an IR and UV Spectrometer as well as all the required glassware, worksheets and stock solutions to run the workshop. Students are split into equal groups to accurately measure out serial dilutions of a known stock solution usually with pipettes and volumetric flasks. During the workshop the identity of an unknown sample is identified with the IR spectrometer. A straight-line graph is also produced using absorbances obtained from the UV Spectrometer against the known concentrations. The concentration of the unknown sample is then identified using the calibration graph as per the Beer-Lambert law.

A story is weaved around these methods to give students context and real-world examples of what the instruments are used for. Determining an unknown concentration based on a calibration graph of known concentrations is already on the course as a mandatory experiment using colorimetry. Therefore, the students can identify the workshop as being relevant to their studies with respect to the course. Also, because SIAS workshops are linked to the syllabus, teachers have embraced the programme in Irish schools and are consistently willing to give up scheduled classes to allow ambassadors to run SIAS during school time.

3. Regionally Specific Expansion

In recent years the miniaturisation and increased portability of professional IR and UV spectrometers have allowed these instruments to become more widely available. However, their costs are still prohibitively high for secondary schools to purchase their own instruments. Therefore, the SIAS programme gives Higher Level Institutions a platform for visiting schools via the Scientist in a



Classroom model [4], which provides a much-needed service for chemistry students and maximises the use of each kit by visiting multiple schools with the same spectrometers.

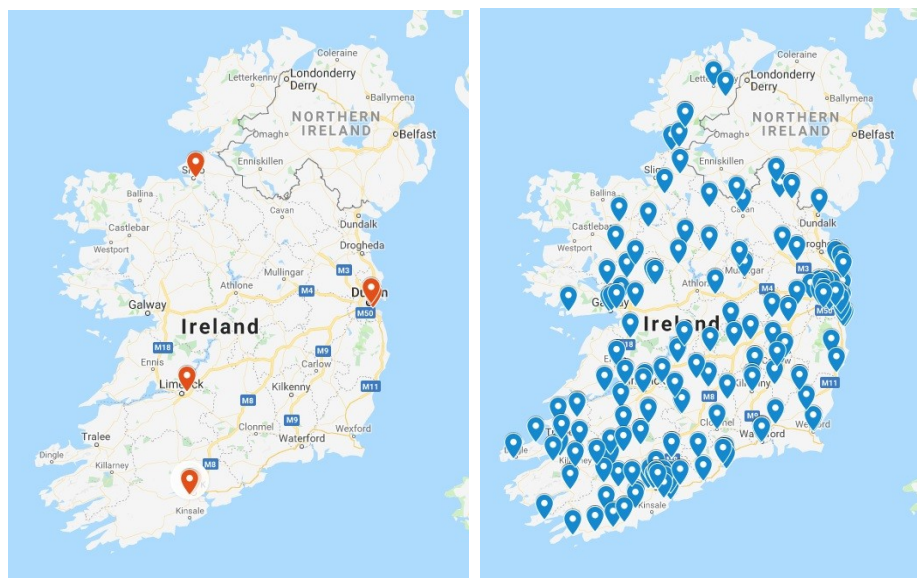


Fig 2. Left: location of all six SIAS Higher Level host Institutions with two each in Cork and Dublin, and right: schools in the Republic of Ireland that have received a SIAS workshop to date.

Over time the number of SIAS kits available to Irish hosts has increased from two up to six with successful grant applications. Host institutions generally visit schools on a regional basis as determined by their location, with some overlap between hosts from time to time. Initially some kits were shared between partner host institutions, but the costs and logistics involved in moving the kits between the hosts meant this needed to be changed in favour of each host having their own kit. With one kit per host, it has increased the flexibility of the host ambassadors to match their timetables with local school timetables which has resulted in a greater number of school visits. Although some SIAS workshops are run in labs on a host institutions' campus, the vast majority are run in school labs during school time which reduces the workload, logistics and requirements for schools to participant. This has hugely contributed towards the continuous expansion of the programme with increased demand from schools year on year.

4. Public Engagement

In addition to the school based, curriculum specific workshops, the Irish SIAS programme also provides public engagement opportunities. Public engagement with the SIAS kits has varied from interactive demonstrations to shortened workshops designed specifically for each event. Public events that are generally themed around science such as the BT Young Scientist and the Kerry Science Festival involve ambassadors providing demonstrations using the IR spectrometer with various over the counter pharmaceuticals. However, SIAS demonstrations have also been very well received at non-science themed events such as the annual Irish National Ploughing Championships which is one of the largest outdoor events in Europe and is based around food and agriculture among other activities. For this event the IR spectrometer was used to demonstrate the difference between petroleum based road diesel, agricultural diesel and biodiesel. The response was hugely positive with hundreds of the public engaging with the activity and asking questions about the chemistry behind the various fuels.

The SIAS programme in Ireland has also successfully engaged with younger audiences at computer and technology based aimed at primary students. The IR spectrometer was used in these cases for a quick demonstration involving the sorting of similar looking plastics. Various similarly coloured plastics made from different polymers were differentiated using the IR spectrometry into recyclable material and non-recyclable. This was very well received by the students and teachers since it tied chemistry into the Green Schools programme already run in schools.



5. Conclusion

For the Spectroscopy in a Suitcase Ireland programme 40% of teachers whose students received a workshop responded to the post workshop survey. 100% of the respondents stated they would recommend the service to colleagues and 88% attributed their score to positive student outcomes and increasing their confidence in teaching analytical chemistry. When asked, 94% of teachers thought the workshop significantly increased their student's understanding of spectroscopy and 97% said that it significantly increased their students' knowledge of its real-world applications and their chemistry career options.

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References

- [1] P. E. Childs, M. Sheehan, *What's difficult about chemistry? An Irish perspective*, Chem. Educ. Res. Pract., 2009, 10, 204-218
- [2] Central Applications Office (CAO) statistics, www.cao.ie
- [3] State Examinations Commission (SEC) statistics, www.examinations.ie
- [4] S. Laursen, C. Liston, H. Thiry, and J. Graf, *What good is a scientist in the classroom? Participant outcomes and program design features for a short duration science outreach intervention in K-12 classrooms*, CBE-Life Sciences Education, 2007, 6, 49-64
- [5] B. Haines *et al*, *Evaluation of 'Spectroscopy in a Suitcase'*, National Foundation for Educational Research (NFER), 2009
- [6] J. O'Donoghue *et al*, *Expansion of Spectroscopy in a Suitcase Final Report*, Science Foundation Ireland Reports, 2018.
- [7] State Examinations Commission (SEC), *Report on the Trialling of the Assessment of Practical Work in Leaving Cert Biology, Chemistry and Physics*, Nov 2018, 1-141.
- [8] National Council for Curriculum and Assessment (NCCA), *Leaving Cert Chemistry Syllabus (Ordinary and Higher Level)*, 2009, 1-73.
- [9] Cambridge International Examinations, *Cambridge International AS and A-Level Chemistry Syllabus*, 2014, 45