“You never know until you ask…”

The story of the UK inspireSTEM SEM in schools programme

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When I was growing up there were two things my parents always told me; 1. Just try something new, you might like it and if you don’t, well, then you know. 2. “Ask”: what’s the worst that can happen? Not only has this stayed with me but as a teacher it’s the most useful advice that I can give to my students. When I made the leap from research scientist to physics teacher I was passionate about the idea of students getting really meaningful, inspirational experiences at school. It was easy for me to bring in ex-colleagues to give a talk and even to get the odd lab tour, but it was always a fleeting experience without that depth of impact that work experience or family connections might bring. How could they experience real research and/or the use of state-of-the-art equipment that wasn’t stuck behind a window, or worse, with a big ‘do not touch’ sign.

Luckily, working in a private school I put the case forward and sought funding (including from The Worshipful Company of Armourers and Braziers, A&B) for a tabletop electron microscope; the Hitachi TM3000plus. All of a sudden, the curriculum was enhanced and the sessions I ran for local state (USA translation: public) schools about materials science had a focus and context that was otherwise unavailable. I needed to see how unique this was and how it could be done more widely - after all, very few schools would be able to purchase such equipment nor have the expertise to use it properly. The expertise bit was important as it turns out.

With a couple of years under my belt working at St Paul's and the local partner schools, the Royal Microscopical Society invited me to sit on their Outreach and Education Committee to represent secondary schools. This is a fantastic group who are passionate about promoting microscopy and characterisation both in schools and the wider community. It was here that Dr Alex Ball (Head of Imaging and Analysis at The Natural History Museum, London) and I started thinking about how the tabletop electron microscope could be a touchstone for deep-impact outreach and engagement with schools.

Growing up in Canterbury, Kent, I was really lucky to have some incredible teachers. Whilst mine was a boys' school, with our sister school, we ran regular joint trips to CERN (a couple of the first schools to do so) and indeed set up a research project with scientists at NASA and CERN for students. One of those teachers subsequently transformed how UK schools thought about research in schools: It was around 2015 that Professor Becky Parker founded the Institute for Research In Schools (IRIS), a gateway for interested school-age students to get involved in science research and connect with academics. This was the perfect opportunity for my interests to dovetail with those of Becky and I began to look for opportunities to study what had been done elsewhere in the world. I was successful in applying to become a Winston Churchill Memorial Trust Fellow, which provided funding for me to travel. My school granted a sabbatical and the scene was set to gather best practice knowledge and understanding about how to use state-of-the-art research equipment and expertise at a high school level. Mike Dixon and Patrick Marks (Hitachi UK) were a fantastic resource, explaining about the Hitachi HTA outreach programme and that the person to speak to was Bob Gordon….

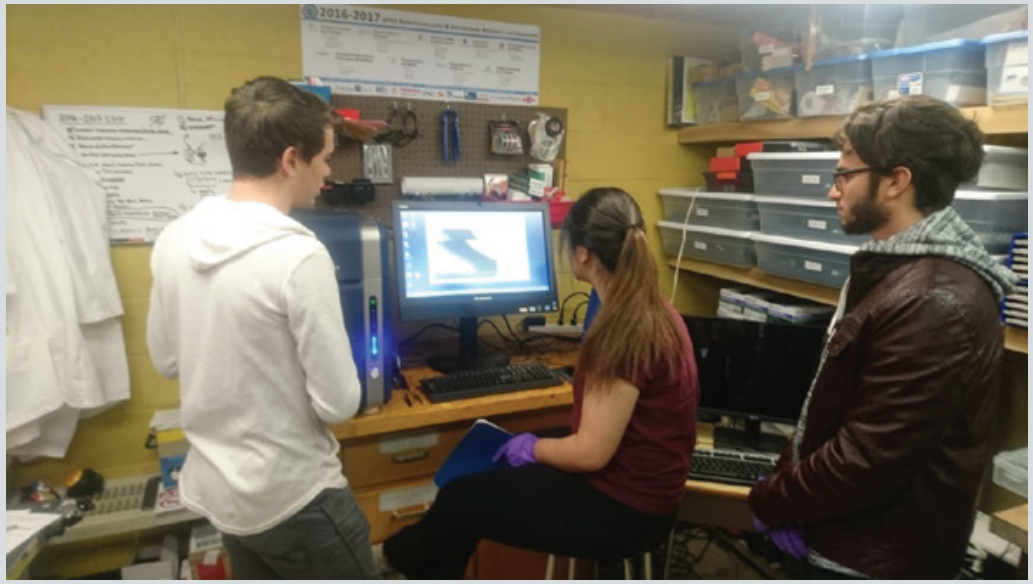
Bob is a whirlwind, deeply passionate about his job, which for him is a calling rather than a career. I remember an amazing phone call where my notepad was on fire scribbling down the details of what seemed like an entire rolodex of relevant contacts! Indeed, Bob helped me plan my fellowship travels in the sure knowledge that some of the schools I was going to visit in the USA and Canada would be able to provide the information I was looking for. For four months in the Autumn of 2016, it was a privilege to visit some of the most inspirational people and places on the planet. Countless kindred spirits who talked of '21st century skills', 'opportunities to fail', 'not just for the most able', 'how can we engage the most disadvantaged', 'pathway changes' and more - deafening agreement on what was needed in education and plenty of examples of how scaffolded, project-based learning with science research and/or equipment/expertise at its core could play a part. Not only that, but anecdote after anecdote about past or present students who had experienced life changing opportunities.

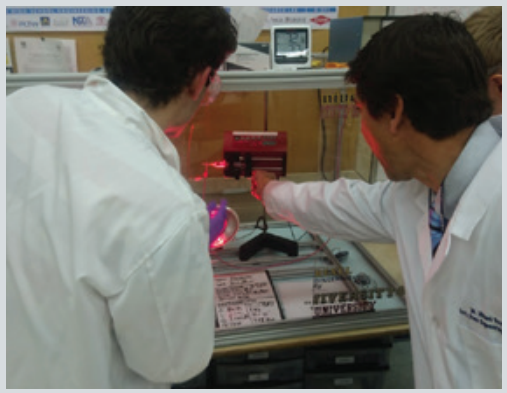
It became clear that one of the key challenges in transferring this learning to the UK was the very different education systems. For example in England, the National Curriculum is a rigid scaffold for schools where terminal exams provide the focus for all teaching and learning through secondary education. Whilst many schools also provide a strong extracurricular programme, the funding and teacher time is not always available, so where USA schools can really embed research into the local curriculum, it makes it much more difficult to do in the UK. Hence the need for a way of supporting schools and providing equipment, expertise and logistics to enable long-term deep-impact experiences to happen. An additional barrier for a busy teacher is expertise; the most successful implementation of advanced technology and equipment was in parallel with great support or indeed 'in-house' expertise. In many schools this came from academics-turned-teachers but was not necessarily the case. Mike Boyer at North Penn High School had spent CPD time at Drexel University effectively gaining a Master's Degree by research and learning the ropes. Bergen County Academies had great links with NYU and Columbia University who provided academic support. Princeton School for Science and Maths actively recruited ex-academics and the public schools in NYC were able to 'buy in' the 'Biobus' during the year with whole lessons and activities led by post-doctoral level academics. In addition, a number of schools leaned on the support provided by the manufacturer of the equipment as part of their CSR programme.

Some particularly notable visits have had a genuine lasting impact on me both personally and professionally...trying something new; after seeing the biotechnology research in lessons, the student research class and yes, a tabletop SEM in action in a school, Director of Science Greg Stoehr at Los Altos High School took me surfing for the first time in my life - at Cowells beach, Santa Cruz! Greg and his colleagues have stayed in contact and we've since hosted a visit from them for a teacher fact-finding visit in 2017 as well as bringing their students to the Tonbridge School's International Science Conference to present their research work. At my new school where my students have an active research programme, they are now collaborating with Los Altos students on plastic-eating bacteria!

Mike Boyer and his amazing family hosted my family at their home during our visit to North Penn HS, where Mike has been a whirlwind of enthusiasm. The 4am early riser is an educator to his core, running a research class as well as engineering projects in the community. Mike's students were the best gauge of outcomes; eloquent, enthusiastic and (as it turns out) incredible post-high-school outcomes through hands-on genuine research work - again, boosted by the loan of a tabletop SEM for characterisation of their nanomaterials. Mike and I quickly set up an International Collaboration with Dr Marcus Johns (University of British Columbia, then University of

The tabletop SEM microscope at the Natural History Museum's Hintze Hall, demonstrating its portability; just a single plug socket required to get going.





Top, middle and bottom: Students from North Penn high school - Mike Boyer's nanotechnology class - using electrospinning as a basis for their work.

Bristol) on the electrospinning of cellulose via ionic liquid co-solvents.

From Dave Menshew (James Enochs HS) and his forensic science, to Dr David Reeves university lab-quality set up, where research is the foundation of the whole school system (Bergen County Academies) as well as Dr Ben Dubin-Thaler's incredible SEM on the move (Biobus), every person and location had their take on the common aims of engagement and depth of experience which would inspire and ultimately improve the lives of the students.

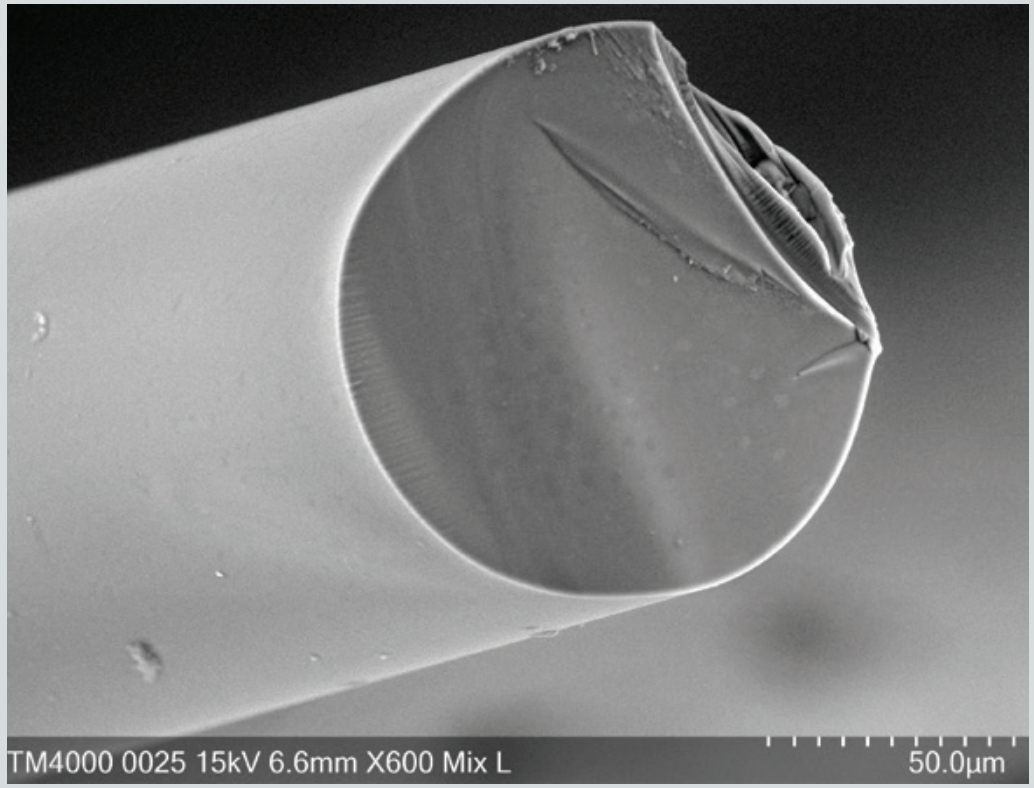
Which brings us back to IRIS, RMS and the NHM. At the end of the sabbatical, Bob and I met once more and talked through what I had seen and learned. It was clear that what was happening in the USA could very well happen back home but there were challenges to overcome. With the landscape for CSR and funding remit for this sort of programme being so different in different countries, the right group of organisations and people were needed to set up a pilot project. Dr Ball and I worked on some ideas of how a tabletop electron microscope could be loaned to schools and I ran a month-long loan of the St Paul's SEM to Simon Langton School in Canterbury. The project was a great success with several technicians becoming trained on the use of the SEM as well as the work of one student being submitted for an Extended Project Qualification (EPQ; a level three certification, equivalent to half an A-level). In addition, they used the SEM in lessons and the wow factor meant that many informal experiences for other classes provided an additional "hey, come see this" moment for several students. It was that last point that got us thinking; the 'long-term loan' model made most sense - the benefit of deep-impact for a group of students as well as exposure to many, many more. An additional unexpected outcome was the opportunity to fully train a group of 'expert users', which turned out to include students, teachers and technicians. The depth of impact beyond the proposed user group was obvious.

Reporting this back to Bob and in parallel, discussing the logistics with the RMS, Alex and I came up with a model that would provide long-term loan of an SEM during school term time, with the instrument living at the NHM during school holidays as an open access tool (and for checking and servicing as required). The key thing was to have all of the jigsaw pieces in place to support a loan; the expertise for training (Dr Ball and Dr Perkins), support from Hitachi for instrument consumables (e.g. filaments) and tech support beyond Dr Ball/Perkins' expertise, a common message (sometimes harder than you

Nanotec on the road: US collaborator Mike Boyer's car.

think!) and a way for schools to apply for a loan. The application was key - we wanted to mirror the research process where students have a question or activity they wish to pursue and really have to think about it carefully. This is where IRIS was perfect; having been set up to assist schools with specific research projects as well as provide advice and guidance on original research, they a) had a huge network of keen schools from across all sectors and geography and b) had the administrative capacity to process applications and promote the project. The RMS agreed to fund and arrange shipping (thus solving the logistics question) and obviously Dr Ball/Perkins' time for support and instruction needed to be agreed in advance by the NHM and Queen Eizabeth's Grammar School respectively.

With the ducks all in a row, by early 2020 Hitachi HTA were in a position to supply an SEM to the UK to run the pilot for the InspireSTEM program in the UK. Much had developed since my visit in 2016 and it demonstrated how much our discussions of what I'd seen (and my report) was able to feed back to the inspireSTEM programme itself. We were thus able to run a pilot for the project in the UK, with great success. The numbers [of participants] speak for themselves, but it is (as always, and as indicated



A selection of images taken from student projects: Grains of pollen (above and top); metal wire and glass fibre fracture section (opposite, top); a fruit fly emerging from its pupa (opposite, bottom).

Pupils from Queen Elizabeth's Grammar School, Faversham, examine an image of a fruit fly.

that really bring the experience to life. There are several students for whom genuine pathway changes have occurred and the pipeline to STEM careers has been widened. With the addition of full remote-control capabilities and the generous loan of EDX systems from Oxford Instruments, we have a pair of well-equipped, well-supported and market-leading tabletop SEMs out in schools 100% of term time, and which are fully booked for the next academic year already! We have developed a hub-spoke model whereby more affluent schools, or schools with more resources are able to engage with other local feeder schools and/or those with less support available, and we are continually training more and more expert users. Remote access means that schools can collaborate easily, undertake training prior to their loan, or indeed, follow up work after their loan. Links between schools and their local universities/industry are developing (again, organic unexpected positive outcomes!) and we are getting more and more interest as schools find out about the project.

Collaboration is the key; bringing together what you would do in 'professional' research, whether it is a video call between students working together from different schools, connecting teachers with academics or linking industry with schools to help develop a professional qualification (for example, one of the school technicians is now undertaking the RMS diploma).

If we all dive into the sandbox it's amazing what you can do...after all, you never know until you ask.

Dr James Perkins