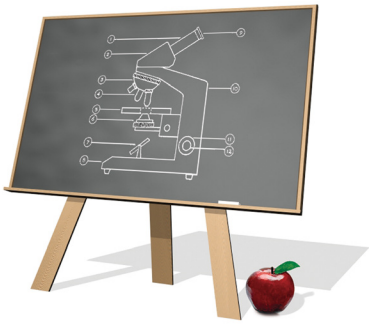
STEM Education Pilot a Resounding Success: Project Lets Young People Experience World-Class Scientific Equipment and Training



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Abstract: As part of the Hitachi High-Tech America Inspire STEM Education Outreach Programme in the UK, a successful STEM (Science, Technology, Engineering and Math) education pilot has seen over 5000 students from 80 schools given the opportunity to use scanning electron microscopes (SEMs) for their own experiments. The collaborative project allowed students to design, propose, and execute experiments to give them hands-on experience with scientific research. Feedback from the project has been resoundingly positive, with many students gaining new skills and an interest in STEM, and it looks set to grow further to allow more students access to high-level scientific equipment.

Keywords: STEM education, scanning electron microscopy, energy dispersive X-ray, STEM outreach, Royal Microscopical Society

Introduction

What do antique coins, flour, and aquatic life have in common? Each have played a part in inspiring the next generation of scientists. As part of the Hitachi High-Tech America Inspire STEM Education Outreach Programme in the UK, Oxford Instruments has contributed to a successful project. To date, over 5000 students from 80 schools have taken part in the program. They were given the opportunity to use scanning electron microscopes (SEMs) for their own experiments (Figure 1). Here's how the AZtecLive One Xplore energy dispersive X-ray system (EDS) used with the SEMs provided these students with a glimpse into careers in STEM.

STEM Outreach Program

Outreach and engagement in STEM are valuable tools for generating public interest, raising awareness of important scientific information, and inspiring new generations of scientists and engineers. This is particularly true in education, where introducing young people to STEM and how fascinating it can be could spark an interest that may then lead to an exciting career path. This project was proposed by Dr. Alex Ball of the Natural History Museum (NHM), London, and Dr. James Perkins of Queen Elizabeth Grammar School in Kent. The aim was to provide access to portable SEMs for schools and for the amateur natural history research community (Figure 2), and to provide teacher training to allow them to deliver world-class teaching. It was hoped that this would support research opportunities through direct access to an advanced scientific instrument and to encourage an interest in careers in science.

Eighty schools in total have taken part in the program, either directly as host schools, or indirectly through visiting other schools or facilities for interactive sessions, or by using the microscopes remotely. The schools include Queen Elizabeth Grammar School, Tonbridge School, London Southbank University Academy of Engineering, St. Dunstan's College, Liverpool Life Sciences UTC, Sutton Grammar School, Folkestone School for Girls, and St. Paul's School. Over 90 teachers and technicians have been trained to use and maintain the microscopes, and over 5000 students have been introduced to electron microscopy through the pilot program.

Program Collaboration and Instrumentation

The project was a collaborative effort between several institutions. The Hitachi High-Tech America Inspire STEM Education Outreach Programme (inspirestemeducation.us), as well as Hitachi High-Tech Europe GmbH, provided the SEMs and the remote training and technical support. Both project leads are also part of the Education and Outreach committee for the Royal Microscopical Society (RMS), which acted as an organizational base to coordinate the instrument loan program and to assist in the logistical elements of the project. The Institute for Research in Schools (IRIS) provided a point of contact for schools wishing to engage with the program through accepting and evaluating research proposals and offering students the chance to participate in their summer conference. Finally, Oxford Instruments provided an AZtecLive One Xplore EDS system for use with one of the SEMs, along with training and technical support on their analytical software, to ensure that the schools could effectively use the features to their full potential.

Electron microscopy allows the operator to visualize samples at much higher magnification than traditional light microscopy. Using a beam of accelerated electrons, with much shorter wavelengths than photons, can illuminate far smaller objects in greater detail, giving clearer images of samples such as organic and inorganic materials, microorganisms, and cells. They are widely used in a range of STEM disciplines to investigate structure and composition and are an advanced piece of equipment with many research applications.

The instrument provided to the schools was the Hitachi TM4000Plus portable SEM with secondary and backscattered electron detectors. The microscope can magnify samples up to 250,000× and has a variable pressure, low-vacuum design. This reduces the amount of sample preparation required. Often samples

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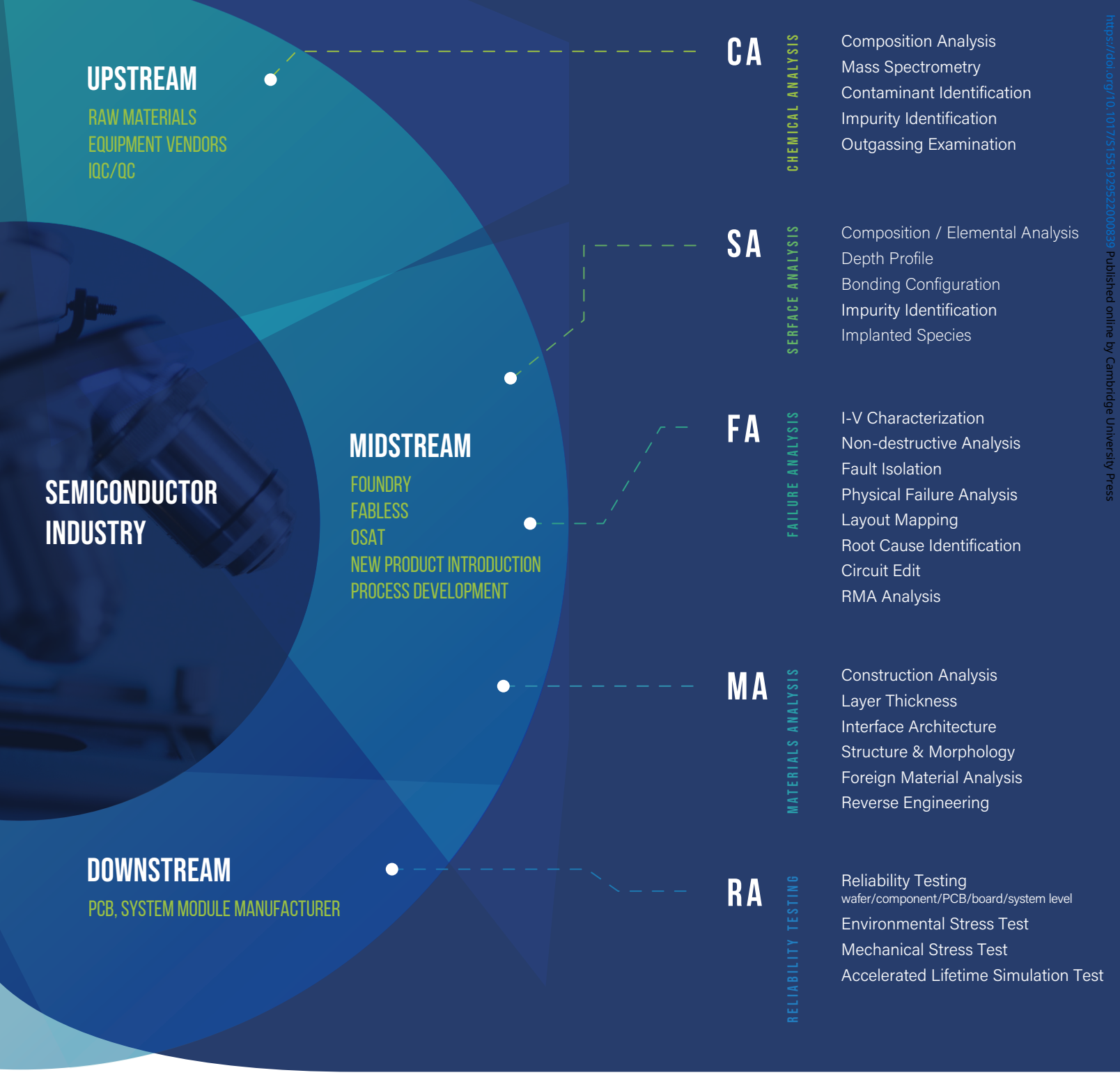

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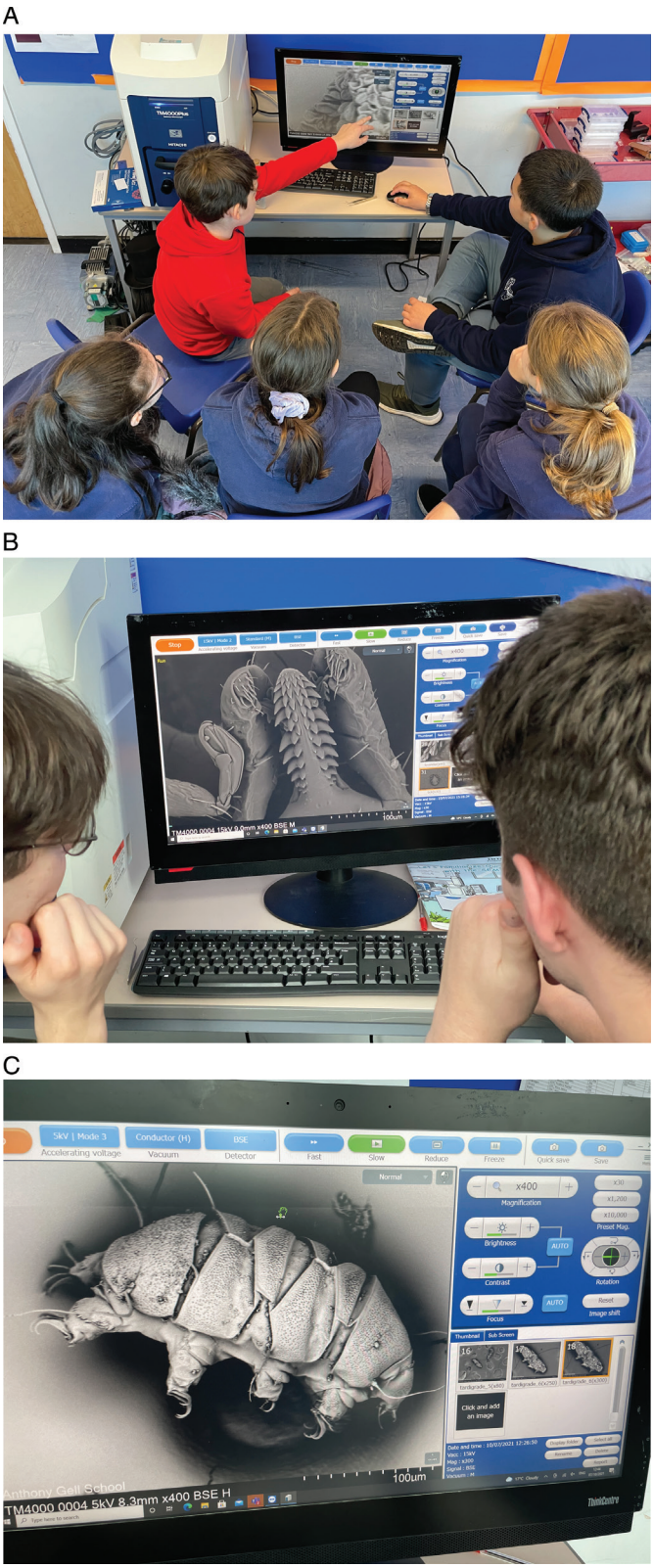

Figures 1A–C: The SEM in use by students in workshops at the Anthony Gell school.

for electron microscopy must be preserved or coated to produce high-quality images, so by removing this step, the process was simplified and more images could be produced in shorter timescales.

Scanning electron microscopy is an invaluable tool for examining sample surfaces, but incorporating EDS capabilities allows operators to chemically analyze a sample, facilitating the integration of chemistry, physics, and forensic sciences into experiments. The technology works by analyzing unique X-rays generated by displacing the electrons within an atom using an electron beam. EDS can both qualitatively and quantitatively analyze the chemical composition of an object by detecting both the elements present and the amount of each. The AZtec-Live One Xplore EDS system provided by Oxford Instruments requires minimal training, allowing students and teachers to benefit from additional experience in scientific analysis.

Delivery of the program was coordinated by the partner institutions. The application process was overseen by IRIS, who reviewed all school applications and selected the successful candidates from the submitted proposals. The applicants selected to host the SEMs then agreed to a five-to-six-week slot on the calendar. Ahead of the delivery of the SEMs, rigorous preparation was carried out, with comprehensive information packs that contained key information on setup requirements, general advice, and important questions and answers sent to the schools in advance.

On arrival at the host schools, remote supervision of unpacking the microscopes, setup, and training of teaching staff was carried out over Microsoft Teams. This typically took around 90 minutes, with follow-up training, lasting around two hours, two days later. The thorough preparation and collaborative effort between the host schools and the project staff meant that of each six-week loan period, support was only required for roughly the equivalent of a day. Providing up-front information and the expert support and advice of the participating institutions meant that the project could be run smoothly with minimal external input, further increasing the number of students who could engage.

The host schools were able to propose their own projects, and they used the SEMs in a variety of ways, highlighting the diverse uses of electron microscopy and chemical analysis. Sutton Grammar School investigated diatoms as environmental indicators in water systems, with NHM staff showing the students the diversity of aquatic life in bodies of water. Folkestone School for Girls focused on determining if flour is truly vegan, by examining commercially available flour for identifiable traces of insects.

The SEMs have also been used to study biomimicry in biological structures and in comparative studies of insects on a microscopic level. Other experiments carried out by teachers and students included spectroscopic analysis of antique coins, and investigations into microstructures and failure modes of different metals.

Discussion

The project was an overwhelming success, with no adverse incidents reported, no serious technical issues, and resoundingly positive feedback from all who took part. The project has been confirmed to run until September 2022, and the SEMs have been used in museums participating in the NHM's Real World Science project to give staff and the public the opportunity to use them (Figure 3).

The pilot highlighted how crucial the comprehensive preparation and planning was to the overall success of the project,

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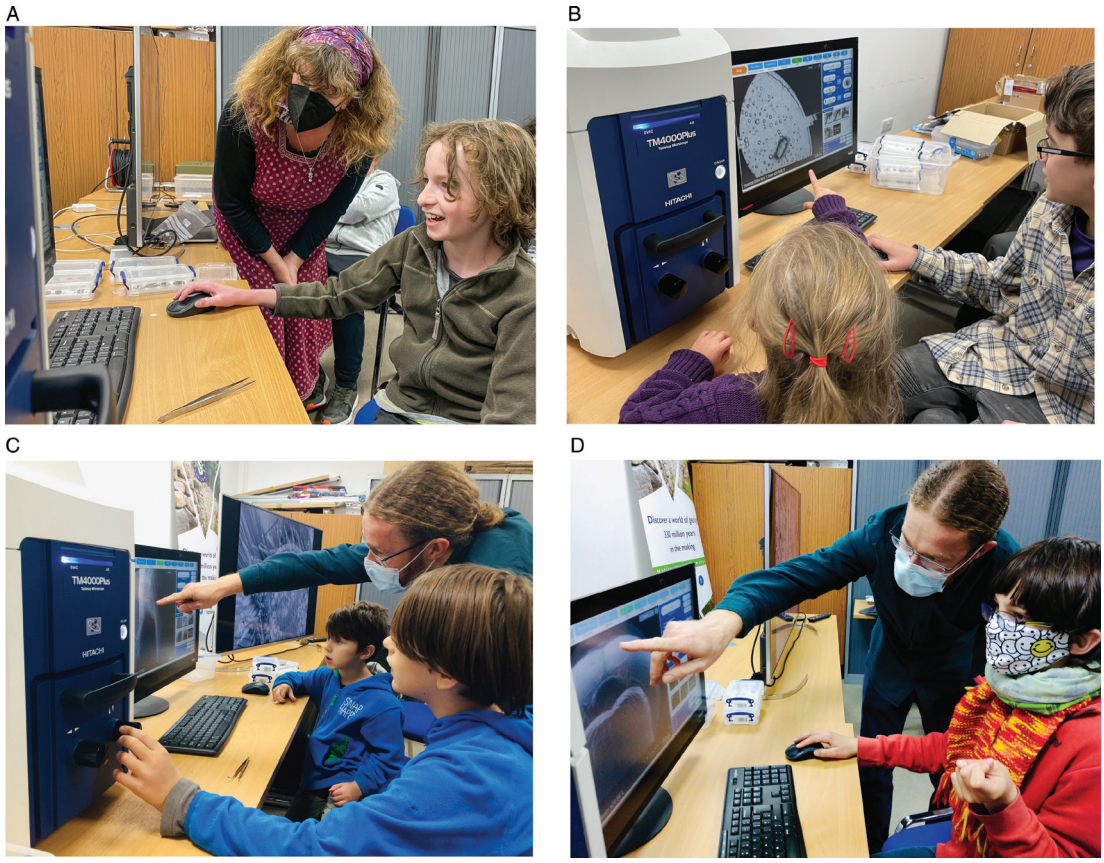

Figures 2A–D: Students getting hands-on experience of the SEM at workshops held at the National Stone Centre.

Figure 3: The Hitachi TM4000Plus portable electron microscope at Hintze Hall in the National History Museum, London, UK.

but also the importance of EDS as an analytical tool and what a valuable addition this was to the experience.

"EDS is massively important, and our support from Oxford Instruments means that both the UK microscopes will now have EDS installed moving forward," explained project lead Dr. Alex Ball. "Simply measuring spectra from a range of known materials and being able to adjust the acceleration voltage and seeing the immediate effect of additional lines appearing on the spectrum provides such a compelling demonstration of the physics behind the organization of the periodic table that in some cases students understood the periodic table for the first time."

Beyond the deliverables, the level of engagement and the positive feedback from the students, teachers, and technical staff proves just how exciting and important this experience was. Schools reported students queuing to use the SEMs even in their spare time and influxes of new members of their science clubs. Projects such as this can help to break down the barriers to STEM that young people often experience, either through limited opportunities to interact with scientific equipment or feeling like it is inaccessible.

Giving young people the opportunity to practically engage with STEM subjects at an earlier age outside of a classroom setting can give them new skills and inspire them to look at the world in a different way. The project not only gave the participants a new set of skills and the ability to think more analytically, but it also gave them an insight to just how exciting science can be.

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