

## **Educational Electron Microscopy over the Internet**

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**Abstract.** The images produced by the scanning electron microscope are a powerful tool for introducing school students to the role of microscopy in science. A joint project between the CSIRO in Australia and the Western Pennsylvania School for the Deaf in the USA has been carried out to image and analyse hair samples. This project introduced students to the electron microscope as well as the scientific disciplines of experiment planning, sample collection, sample preparation, imaging and analysis. The use of email and the world wide web was crucial to successfully planning and carrying out this project which involved collaboration across two continents.

### **Introduction**

The ability to observe familiar objects with a resolution that exceeds capabilities of the human eye provides an exciting science experience for students [1,2]. The objective of the project was to introduce students to the electron microscopy technique as well as to the scientific disciplines of planning experiments, preparing samples, gathering data and analysing results. This objective was achieved through a project to image and analyse a sample of hair from each student in the fifth grade class at the Western Pennsylvania School for the Deaf in Pittsburgh, USA. The students who participated in the project range in ages from 10 to 12 years and have varying degrees of hearing impairment from hard of hearing to profoundly deaf. All of the electron microscopy was carried out at the CSIRO Radiophysics Laboratory of the Telecommunications and Industrial Physics Division in Sydney, Australia.

The text and graphical nature of the world wide web has proved a useful tool in communicating between the scientist and the teachers and students [3]. The students were able to view photographs of the scanning electron microscope equipment as well as electron micrographs of a variety of samples by accessing images placed on the world wide web. The use of email enabled the entire project to be planned and carried out without any voice communication. The physical and temporal separation has also provided an additional lesson in the use of modern communications to undertake collaborative scientific work. The project was carried out as part of a unit entitled "Microworlds" over a 9 week period. During this unit the students had a science lesson of 90 minutes each day.

### **Sample Preparation**

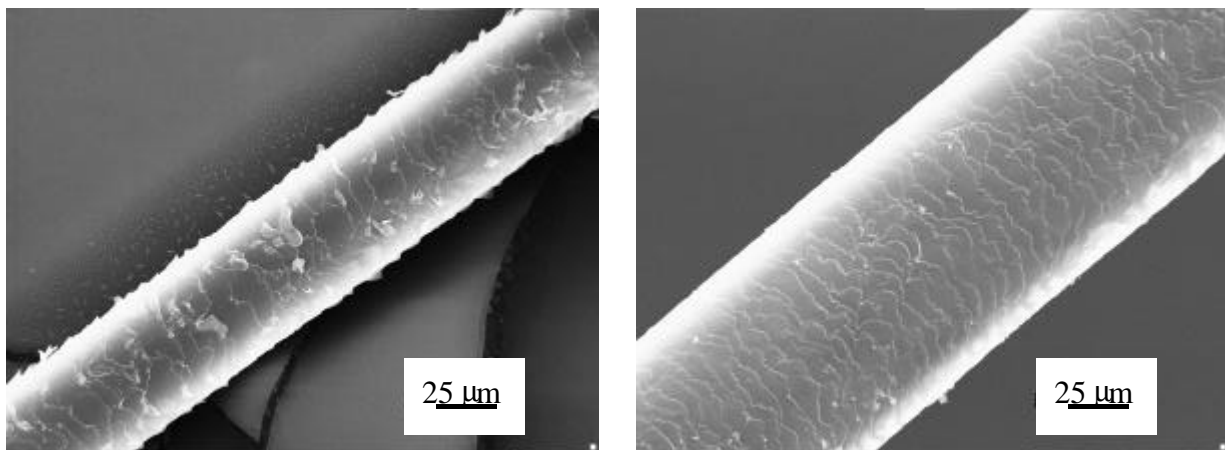
The students were involved in the sample collection as a strand of hair was taken from each student and also from the teachers. The importance of tracking the samples for identification in the imaging and data

analysis phase was emphasised as each hair sample was carefully attached to cards and labelled with the names of the students. The samples were carefully packed and posted to Australia.

Small pieces ranging from 5 mm to 20 mm in length were cut from each of the hair samples and fixed to an adhesive carbon tape and then attached to two electron microscope specimen stubs. An identification letter was engraved onto the carbon tape to preserve the hair identification. As hair samples are non conducting they may pose imaging difficulties due to charging under the electron beam [4]. To overcome this problem a thin layer of gold was sputter coated on the hair samples. This ensures a thin even conducting coating which preserves the underlying structure of the hair. Throughout this period frequent correspondence by email maintained to enable the imaging to be scheduled and to facilitate monitoring the status of the project.

### Imaging

The samples were placed in a LEO 440 scanning electron microscope [5]. The electron optics were configured for low magnification imaging and the reference marks were located to enable each hair to be identified and imaged. The various hair samples were imaged under the same beam conditions. This comprised a beam energy of 40 kV, beam current of 200 pA and working distance of 15 mm. The images were acquired using a secondary electron detector and digitally stored as tiff files on the microscope computer with a resolution of 1024 x 768 pixels. An image of each hair sample was taken at a magnification of 500 times, which corresponds to a field of view of 242 x 181  $\mu\text{m}$ . This magnification was chosen as it enabled the morphology of the hair to be studied in detail as well as facilitating a measurement of the hair diameter. The microscope was adjusted to ensure that the magnification was the same for each hair imaged in order to allow direct comparison of the images by the students. Examples of two of the images acquired are shown in Fig. 1.



**Fig. 1.** Scanning electron microscope images of hair from two students at the Western Pennsylvania School for the Deaf.

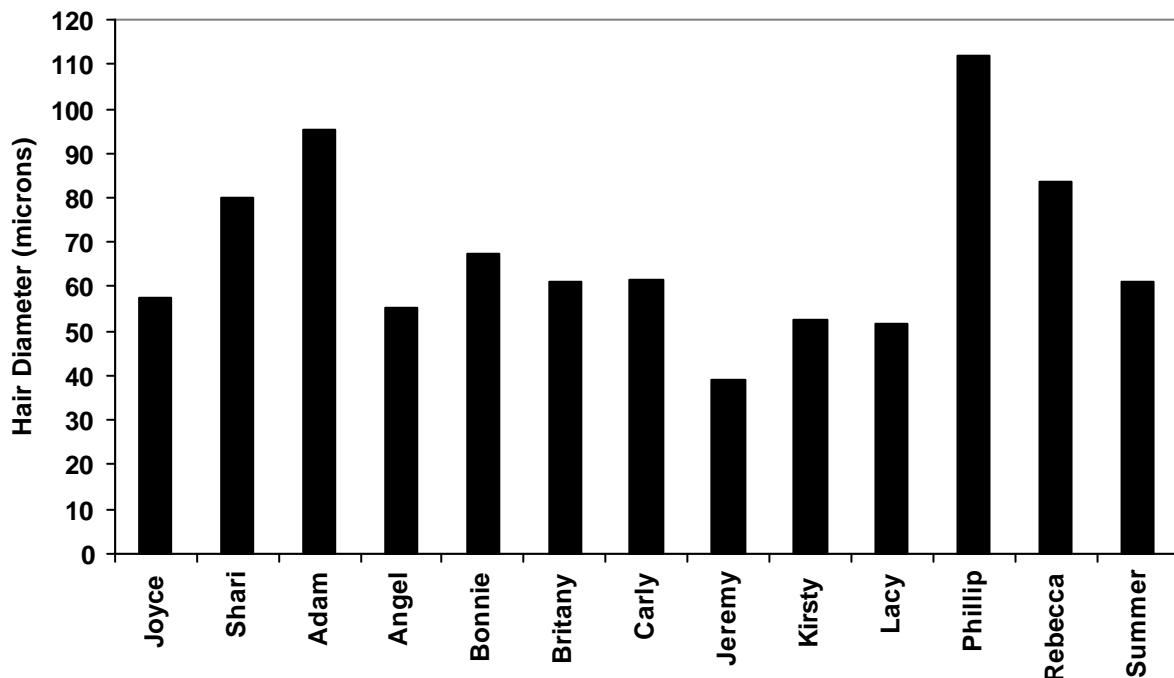
To ensure immediate communication of the electron microscope images to the students a lower resolution image of each hair sample was placed on the world wide web. A separate computer was available for each

of the students and so at the next science lesson they were able to arrange their computers and download the hair images for comparison and further analysis.

The visual impact of the microscope images was immediate as the students were fascinated by the quality and resolution of the images. They used American Sign Language to describe the shape, size and texture of their hair to each other. The students were able to directly compare the microscopic differences in their hair with the macroscopic differences they observed. As the magnification of each of the images was the same the students were able to make both qualitative and quantitative comparisons with their fellow students. All of the minute details of the hair samples were visible which prompted the students to raise a number of questions relating to microscopy, genetics and biology. The students were interested in differences in the hair images between genders, across age ranges and within families. They also explored any potential links between hair colour and hair diameter and were curious about the lack of colour in the images obtained from the electron microscope.

### Analysis

A scale bar was digitally inserted into each of the images so the students could use a ruler to measure and then calculate the diameter of their hair. The field size of the images was also used to enable the students to check their calculations. This provided important lessons in dimensional scaling and magnitude comparison as well as the units of measure used in science. The measured data from each image was collated to produce a column graph of the hair diameter as shown in Fig. 2.



**Fig. 2.** Column graph of hair diameter from students at the Western Pennsylvania School for the Deaf.

The analysis of the hair samples continued with email dialogue between the students and teachers and the scientist. A high resolution laser printed hardcopy image was produced for each hair sample using the original high resolution images from the electron microscope. These high resolution images together with the graphs were posted to the school so that the students would have their own copy of the electron microscope image of their hair. The students were also able to check their observations with the measurements and calculations made by the scientist. The hair diameter ranged from 39  $\mu\text{m}$  to 112  $\mu\text{m}$  with an average thickness of 68  $\mu\text{m}$  and a standard deviation of 20  $\mu\text{m}$ .

Two graphs were produced using different units. The first was in microns to introduce the SI units of measure commonly used in microscopy. The second column graph was in thousandths of an inch so that the students could comprehend the diameter of their hair in a familiar unit and also to allow an appreciation of the relative size of a micron. These units are commonly used in various areas of science and technology. As a result the students were able to comprehend the size of other specimens studied during the "Microworlds" science unit relative to the diameter of their own hair. The students had made predictions about their hair diameter in millimetres by naked eye observations and using a 3 times optical lens. They made some useful relative size measurements but appreciated the difficulty of making accurate measurements without a more powerful microscope.

### Summary

The use of images acquired in the electron microscope has proved an invaluable resource for teaching science to school students. The choice of imaging the hair samples from the students themselves has been particularly effective in motivating interest and excitement in the science project. The students were able to easily relate to the images and observe and compare both microscopic and macroscopic features. The images have enabled the students to gain an understanding of the relative size of the scientific units of measure and how to use these units for comparative purposes. The project provided an effective introduction to the scanning electron microscope and microscopy in general. It has also provided practical exercises in collecting samples, generating data and analysing results. The use of email and the world wide web has enabled the project to be successfully carried out as a collaborative effort spanning two continents and nine time zones. Aside from the purely scientific goals the students learned to appreciate and understand the differences and unique characteristics of others and that students, teachers and scientists are all part of a community that aims to increase knowledge and understanding. It has been a rewarding and educational experience for all involved and it is proposed to run the project again in the future.

### References

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