Bugscope: A Practical Approach to Providing Remote Microscopy for Science Education Outreach

C.S. Potter, B. Carragher, L. Carroll. C. Conway, B. Grosser, J. Hanlon, N. Kisseberth, S. Robinson, U. Thakkar and D. Weber

Beckman Institute, University of Illinois at Urbana-Champaign
405 North Mathews Avenue, Urbana, IL, 61801

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Address correspondence to:
Clinton S. Potter
Beckman Institute
405 North Mathews Avenue
Urbana, IL 61801
Phone: 217-244-1958
E-mail: cpotter@uiuc.edu
Fax: 217-244-6219

"Giving students the opportunity to do "real" science using state of the art technology is about as exciting as education can get." This was one of the comments received from teacher Pam Van Walleghen following her participation in the Bugscope project during September 1999. Bugscope is a second-generation educational outreach project that provides remote scientific instrumentation to K-12 classrooms. Students participating in the project can remotely control an environmental scanning electron microscope (ESEM) from their schools using the Internet and a Web browser by connecting to the Bugscope web site (http://bugscope.beckman.uiuc.edu). The project is structured so that the instrument is provided as a resource while leaving the planning, execution and control of the experiment in the hands of the teachers and the students. The classroom plans the project, mails in a specimen and on a scheduled date and time takes control of the microscope from the computers in their classroom. They use control panels, as shown in figure 1, launched from a web browser to move the specimen stage, change magnifications and vary imaging parameters in order to interactively acquire and view images required to fulfill the scientific goals of their proposed experiment.

Remote operation of scientific instruments has been available for some time (Mogran et al., 1998 provides a good review) and has obvious benefits in providing unique resources for education and engaging students in the scientific process. In general the scientific community is enthusiastic about providing these resources, not only for their obvious societal benefits but also because research groups have been encouraged to do so by their funding agencies. However, while there have been several pilot projects demonstrating the use of interactive remote instrumentation in the classroom, most of these projects have not proved to be sustainable and the technology has been difficult to transfer to the general scientific community. An important aspect of projects of this type is that the resources be predictably available over a long term. This allows teachers to plan projects that incorporate these resources into their teaching curriculum rather than to approach the project as a technology stunt.

In general, the problem of sustainability is not simply associated with providing remote access to the scientific instrument. Typically, once the software to provide the instrument control has been developed it does not need continuous ongoing support. Many groups would donate a few hours of instrument time each week to educational activities if this could be achieved with minimal impact on the primary research mission of a group. Rather, the problems arise in the administrative aspects of the project: evaluating, scheduling, managing and supporting hundreds of applicants a year. It is extremely difficult for a small research group to support activities of this sort without significant allocation of personnel resources.

One of the aims of the Bugscope project was to specifically address issues of cost, and sustainability of a remote instrumentation project supported by a small research group. The long-term goal of the project is to provide access to the ESEM for up to 100 classrooms a year using minimal human and instrument resources. To achieve this goal, up to two classrooms a week are provided with access to the instrument during a single two hour session (including setup time). Classrooms apply to be selected for participation in the project by submitting a small proposal outlining the type of experiment they would like to perform using the ESEM. For example, the project description might include the type of insect to be studied, details on how they intend to examine or compare structures, and plans for integrating this project into their classroom curriculum. Once selected, an access time must be negotiated and scheduled, the mailed in specimen must be prepared, and on the allocated date the instrument must be setup for remote access. The classrooms then have control of the microscope for an hour, during which time they will typically acquire approximately 100 images of their specimen.

In order to meet the goal of serving 100 classrooms a year using only one session a week at the microscope, the remote interface to the instrument supports multiple simultaneous sessions which can be controlled by independent groups (Carragher and Potter, 1999). This is achieved by keeping track of the state of the instrument for each session independently so that it appears to each classroom that they have sole use of the instrument and are unaware of the activities of the competing sessions. This scenario is feasible in practice because it takes advantage of the “dead” time of the instrument during which a classroom examines their current image and decides what to do next.

The Bugscope project was implemented and launched six weeks after the environmental scanning electron microscope was delivered and installed in January 1999. Since the first classroom accessed the instrument in March 1999, the project has supported approximately 1500 students from 49 schools, ranging from elementary to high school, in 21 states across the USA. Participants have represented the diversity of schools in the nation in that they have ranged over rural, suburban and inner city schools and included both wealthy and low-income districts. Systems used by the classrooms to access the instrument and the Bugscope site have ranged from sophisticated computer labs connected to the Internet using high-speed networks to a single computer using a modem connection. In 1999, the participants in the project collected over 4000 images from the ESEM.

In order to evaluate the impact and effectiveness of the project a number of evaluations are collected from the participating classrooms. In addition to the initial application, teachers submit a background report prior to their participation in the project, a feedback report immediately after their session and a final project report. These reports are used to assess how the classrooms use the remote access technology, how this technology is incorporated into the classroom curriculum and the overall effectiveness of the project. Information on each completed project is archived and made available through the Bugscope web site and this in turn provides a resource to help new participants plan their projects.

As an example of how Bugscope is integrated into the classroom, a 10th grade biology classroom used the ESEM to examine macroinvertebrate indicators as an assessment of water quality in the Ozark environment. The classroom is located in a rural agricultural area with local concerns about water pollution caused by runoff from chicken, hog and cattle operations. The classroom examined larva, daphnia and snail eggs collected from the local water sources. The students took turns controlling the instrument during the 1.5

hour session and acquired a total of 230 images. The final project report submitted by the teacher indicated that the session had been very successful and the images that were acquired have been integrated into other classroom activities.

The most obvious benefit of the Bugscope project is that is provides students with access to scientific instrumentation and expertise that would not otherwise be available to them. More importantly the project engages students in the scientific process and gives them some experience of the realities of conducting scientific research. In planning the experiment and providing the specimens, students have a sense of ownership of the project that would be very difficult to duplicate using a simulator or a virtual machine. This has been one of the principal benefits discussed in the final evaluations submitted by the participating teachers. They emphasized the excitement and motivation of the students who participated in the project and also commented on the power of the project to demonstrate an effective use of the Internet.

To achieve the goal of low cost, sustainable access to the instrument, it is clear that professional staff can not be involved in the weekly operational aspects of the project. The costs of professional staff of this caliber would be prohibitive and it is not reasonable to expect them to volunteer their time for the long term. In the Bugscope project this problem has been addressed by training several high schools students to prepare the specimens and perform the initial microscope setup. They are able to perform these tasks on a week to week basis with minimal supervision from the research group staff. An undergraduate student in entomology is also employed to participate in an on-line “chat” session with students during the interactive session at the microscope. Although this aspect of the project is not strictly necessary, teachers have reported a very positive response by the students as a result of being able to communicate with the Bugscope team during their interactive session. Ideally, support of this sort might be provided in cooperation with a university course in entomology.

Another key aspect of sustaining the project has been to automate many of the required project administration and data handling tasks. An infrastructure has been developed so that applications submitted by the teachers through the Web are automatically archived into a database. These are then reviewed and scheduled, using a Web based interface, by the project team and the results are automatically collected to provide an overall merit value for the proposed project. This information is then used to set up and schedule a session for the classrooms. During the session, the images that are acquired are also automatically stored and can be later retrieved by the classroom (or any other interested group) though the Web. Without this automation, sustaining this project in the long term would become an overwhelming task and would require the assistance of a full time project administrator. At this stage of the Bugscope project the weekly resources required are: 2 hours of instrument time, a few hours a week from a high school student and an undergraduate entomologist and less than 1 hour a week from the project administrator. The professional staff member who manages the instrument is also occasionally called upon to solve problems.

The infrastructure that has been developed in building the project could be readily adopted by other small research groups who wish to provide access to instrumentation for educational outreach. If large numbers of research groups donated small amounts of time on their instruments it is conceivable that the remote use of scientific instrumentation could be incorporated as an integral part of any teaching curriculum. If these activities could be supported and sustained we envision that scientific resources could potentially be provided to thousands of classrooms over the course of the year. Projects like these provide benefits not only to the students involved but also have the potential to provide the general public with better insights into the goals, techniques and instrumentation used by scientists.

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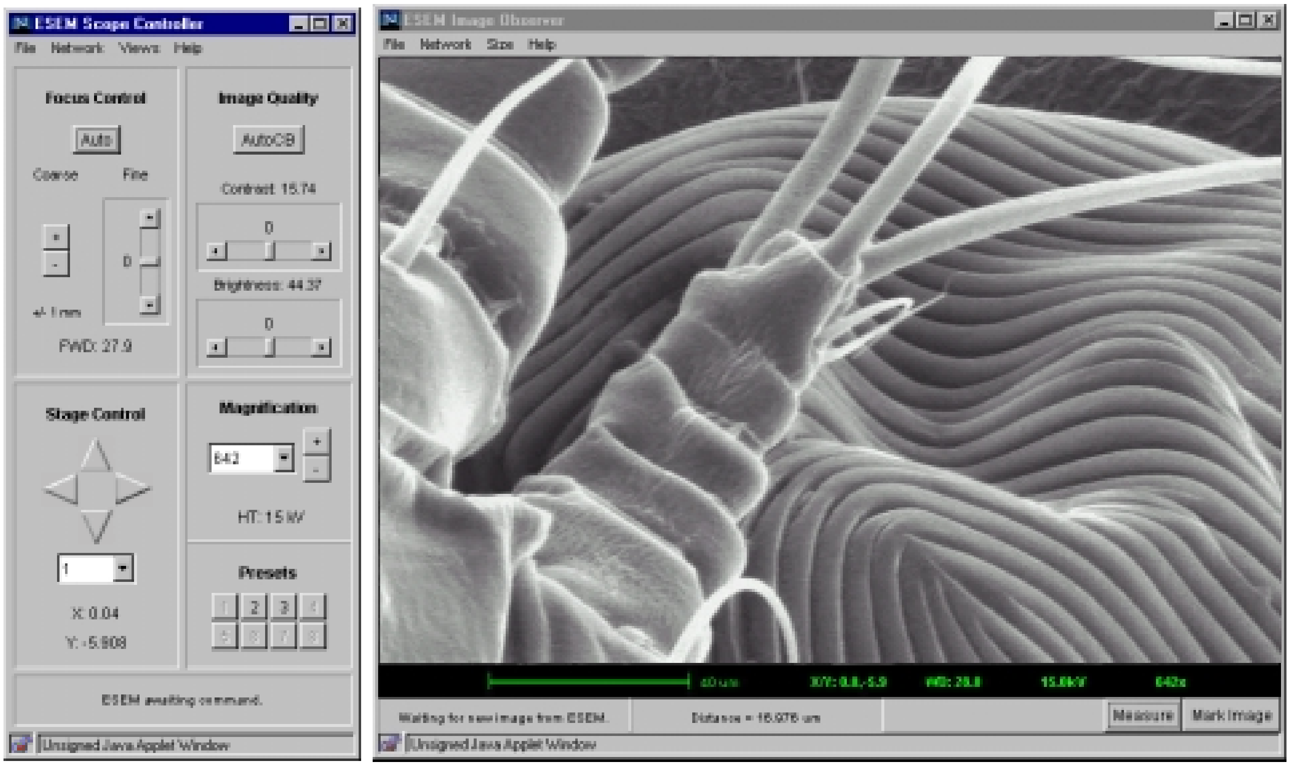

Figure 1: The microscope controller (left) and image observer (right) used for the Bugscope Project. These Java Applets are launched by a standard web browser from a classroom computer and used to interface the students to the instrument via the Internet. Access to the controller requires a password but the observer may be launched by any group interested in watching the progress of the experiment.