

→ In the latter case, WebCams are generally used for "snapshots" of items, usually not in real time and certainly not combined with interactive control of instrumentation and experiment. In contrast, TPM brings the three key elements of research and education (instruments, data, and people) together in an electronic space. By creating a permanent and interactive environment in which these resources are all available online, TPM frees its users to explore ideas, relationships, and experiments in new ways that are not possible with conventional linear interactions.

Bringing TPM into the Classroom

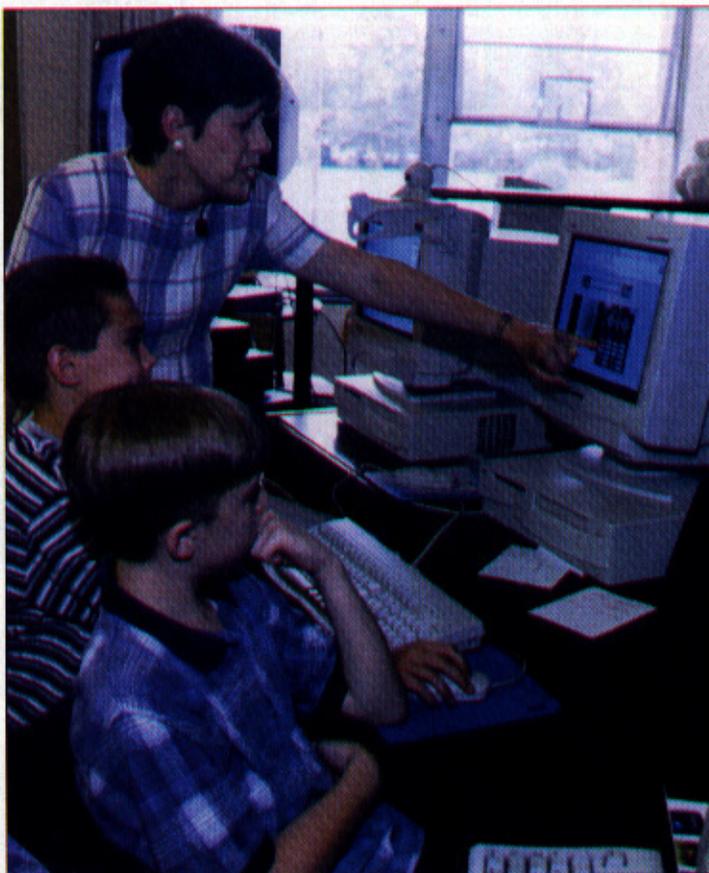
While the TPM Collaboratory was originally conceived to fulfill the needs of sharing resources between R&D facilities, the application of this concept to the educational community is both a natural and fruitful extension. This not only applies to the case of higher education, but also extends to the middle school level. In the middle school regime, the importance is not the technology of the Internet, or the fact that a microscope is being employed, but rather that teachers have access to resources to extend the learning experience beyond that which was available in the classroom. If anything, technology must be kept to a minimum. In the classroom, there is no time for problems solving; the concept either works seamlessly or it will not be used.

As an example, we have recently completed a series of lessons on technology with 6th grade students at St. Dominic Grammar School of Bolingbrook Illinois. Together with their science teacher (Mrs. Judith Bonkalski), the students had previously studied computers, their technology and at the end of the year dismantled several obsolete PC's to "see what was inside." Of course once inside they found lots of components, wires, and circuit boards and that would be normally the point at which the lesson would end.

Using a prearranged TPM session, the class together with their teacher was able to move forward to the next level in dismantling and understanding the technology within a computer. Using their classroom Internet connection (a Macintosh Power PC, Connectix QuickCam, Netscape, CuSeeMe and a high speed cable modem link courtesy

of the local cable TV company), the students logged in to a multisite TPM session (Figure 4).

Figure 4



Middle School Collaboratory Session

In this session Ron Anderson of IBM in New York provided a 64 MBYTE DRAM computer chip to the classroom. A sample of the same chip was simultaneously mounted in a scanning electron microscope by Samuel Jones at the National Institute of Standards and Technology in Maryland. Then a cross-section of the same component was mounted in the Advanced Analytical Electron Microscope at ANL.

In a one-hour, end-of-the-year lesson, the students discussed what they saw in their optical microscope as well as online in the two electron microscopes. They followed the technology from the macroscopic to the microscopic regime. Together with their teacher and three online scientists, one from IBM, NIST and ANL, they jointly view magnified areas of the semiconductor (Figure 5), remotely controlled the microscopes and, most importantly, talked about what they saw and what it meant. The online discussions ranged from how comput-

ers stored information, how small various features and components actually were, to how many jobs might be involved in the process of making the chip.

The key to the success of a session such as this was due to the fact that the students were allowed to interact with more than just their immediate teacher. They collaborated in a learning experience with remote scientists, individuals who had a desire to work with students in a constructive interactive environment. Active participation in the hands-on lesson was coordinated with items readily available in the classroom which was also important in peaking their interest.

The students were able to ask questions and view information in real time between locations hundreds of miles apart, using only their desktop computers and an inexpensive video-conference camera. They were able to sense that the individuals they were talking to online were more than just disembodied voices or text in a book. They saw faces, heard jokes, and realized that scientists also did more than just do research. They are real people. To a 6th grader that can be an education in itself.