

B. SCIENTIFIC REPORT

- 1. DOE award number; name of recipient; project title; name of project director/principal investigator; consortium/teaming members**

Contract # DE-FG36-08GO88147, Recipient FEI Company

Tools for Nanotechnology Education Development Program
Chemeketa Community College

- 2. Distribution limitations to this project.**

None

- 3. Executive Summary**

How the research adds to the understanding of the area investigated; the technical effectiveness and economic feasibility of the methods or techniques investigated or demonstrated; or benefit to the public.

The overall focus of this project was the development of reusable, cost-effective educational modules for use with the table top scanning electron microscope (TT-SEM). The goal of this project's outreach component was to increase students' exposure to the science and technology of nanoscience.

From an educator's point of view, undertaking the development of curriculum for use with the TT-SEM is a complex, time-consuming endeavor that will require future TT-SEM educator-owners to plan and prepare their learning activities with great care. As with any novel or sophisticated instructional tool or visual aid, the temptation for teachers is to over-rely on the tool's ability to "wow" or entertain students at the expense of providing rigorous, meaningful learning. The images captured by the TT-SEM certainly score high on the "wow" factor; to capitalize on resulting student interest, educators need to be prepared to guide students' inquiries, investigations, and analysis in a manner that deepens their understanding of science and nanotechnology.

As teachers develop their own reusable, cost-effective lesson modules, they will need to consider the pros and cons of the various techniques and approaches available for teaching with the TT-SEM: If a projection screen is available, the teacher can easily display captured images in front of the class for everyone to see. This "transmission" approach to instruction presents an easy, efficient use of time and space, and the teacher can control the exact concepts s/he wants the students to learn. With the teacher loading the samples and operating the touch screen, the likelihood of damage by students is greatly reduced. Unfortunately, the disadvantage to having the teacher "in control" of the knowledge and manipulation of the TT-SEM, is this: The students are forced to become passive receptors of knowledge, absorbing facts and ideas that have been developed by the instructor rather than constructing their own understanding of important concepts.

To mitigate against student passivity, the instructor might introduce foundational content or skill and then provide students the opportunity to work in small groups to actively apply their learning. This was the approach that worked well for the Beaverton High School teacher who borrowed Chemeketa's TT-SEM for six weeks. He developed various learning stations that his students rotated through, one of which centered on the operation of the TT-SEM. The learning stations worked well with the TT-SEM but only because the teacher had established clear boundaries for classroom management. The students were able to move smoothly through the room from station to station. A "directive" approach to teaching nanoscience with the TT-SEM is effective and highly recommended. However, if teachers are to teach via learning stations, they need to be prepared to develop meaningful, relevant activities for each station, including those beyond the physical boundary of the TT-SEM, a time-consuming, challenging affair for even the most seasoned, experienced teacher.

Teachers strong in methods of scientific inquiry with effective classroom management skills might also consider presenting their students with "real world" problems to solve using the various features of the TT-SEM. Determining which soils will prevent run-off, comparing the quality of electroplated materials, or identifying possible "criminals" by examining forensic evidence are authentic problems teachers might challenge their students to solve. But again, the greatest challenge for the teacher using the TT-SEM in the classroom is in the organization of the learning experiences. For deep learning to occur, students need to conduct the investigations in a way that allows them to *construct* their own understanding of the scientific concepts; using the TT-SEM as a classroom tool requires effective curricular planning and classroom management.

Probably the most powerful, motivating aspect of the TT-SEM will unfortunately remain "off limits" to most students, depending on grade and maturity level: Being able to simply gaze and explore common, everyday particles at one's leisure and to muse about the observations in an unhurried, wandering way without the threat of deadlines or homework assignments – this is a luxury most likely reserved for graduate students and classroom teachers. Views at the nanoscale are priceless, but repairs to the TT-SEM are quite costly.



A middle school student in Arkansas operates the Phenom during her Study Hall period. Managing large groups of students is a challenge when working with the TT-SEM in classroom settings.

The public's response to the TT-SEM

From the Oregon Museum of Science and Industry (OMSI), it was learned that when displayed for public use without a trained staff member immediately present, the TT-SEM presents itself very differently to patrons of differing ages and backgrounds: Very young children under the age of seven do not spend as much time with the microscope as do older children and adults, although they enjoy the physical accessibility of the touch screen and rotary knob. Children around ten years old are intrigued by the images displayed and enjoy moving the images via the touch screen; they seem to experience no fear or hesitation in manipulating the equipment. Teenagers, OMIS staff observed, were not as impressed with the TT-SEM's capabilities for high magnification as were their adult parents. Older adults also tended to express greater awe and curiosity than did teenagers and young adults, and were often seen following their children away from the TT-SEM with marked reluctance. OMIS staff also tell of the many conversations they shared with patrons who were inspired to make relevant connections between the TT-SEM and their own scientific understanding or background.

Economic feasibility

In regards to the economic feasibility of curriculum development: Although repairs to the TT-SEM are expensive, the materials needed for curriculum development and sample preparation are not: The carbon tabs and sample stubs are relatively inexpensive. Even the high school teachers agreed that for classroom purposes, samples that are not sputter-coated with gold will still produce images that are clear and "interesting" enough for student analysis.

4. Actual accomplishments

The primary objective of this project was the development of reusable educational modules for the TT-SEM as a tool for nanotechnology in education. The three outcomes are listed and described below:

Task 1.1 Methodology of Reusable Educational Modules

- Report defining "what is a reusable module?"

Educators use the term "reusable" in many different ways when describing learning objects or lesson modules. For purposes of this project, "reusable module" is defined as *a series of interrelated learning experiences available online for teachers to adapt and modify according to student interest and needs.*

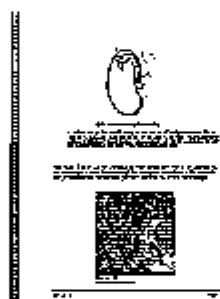
The reusable modules that were developed vary in content and format. For example, *Hair, Fiber, and the Fabulous Phenon* is a 130-page integrated lesson module consisting of about twenty interrelated lessons from several academic disciplines. *Shades of Glory* on the other hand, is a 29-page, multiple-lesson module that focuses exclusively on just a few fundamental artistic skills. The *OMIS Extensions* consist of

a number of unrelated chemistry extensions developed in collaboration with two Portland area high school teachers and created exclusively for the Oregon Museum of Science and Industry; *The Significance of Salt* combines content with several lesson suggestions, whereas *The Magnificent Seed* provides strictly background content for the teacher who wishes to develop her/his own lesson activities. Finally, the *Supplemental Phenom User Manual*, the *Sample Preparation for the Phenom*, and the *Phenom Tutorial* DVD were developed exclusively for use with the Phenom TT-SEM. The latter three products were proofed by the technical editor at *Phenom-World*.

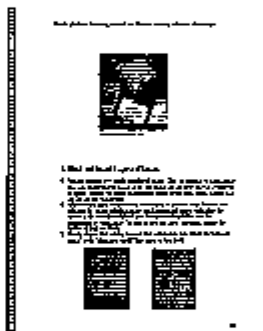
With the ease and accessibility of online research, it was determined that the best way to publish the developed educational modules was online. In March Phenom-World began discussing plans to create an educational website that would house the modules and other lessons submitted by future TT-SEM instructors. As of the date of this reporting, the website is still in the research and planning stages by the personnel at Phenom-World. Another option to consider is the publication of the documents on the Chemeketa website.



Sample pages from "seed" module

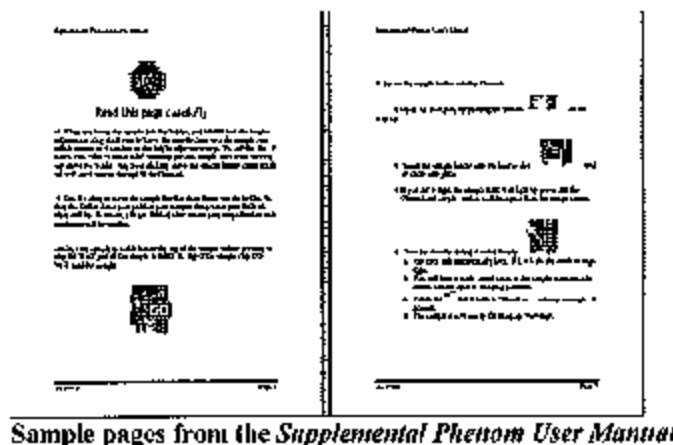


Sample pages from "art" module



Task 1.2 Development of Reusable Educational Modules

- Report containing a series of at least 6 reusable modules
 1. *Hair, Fiber, and the Fabulous Phenom: An Introduction to Forensics for Grades 6 – 12*
 2. *No Hassle Messy Science with a Wow, Chemistry in the K-8 Classroom: Lesson Extensions Using the Scanning Electron Microscope*
 3. *Shades of Glory: Teaching Art with the Phenom Scanning Electron Microscope*
 4. *The Magnificent Seed as Seen through the Phenom Scanning Electron Microscope*
 5. *The Significance of Salt: An Introductory Lesson Module*
 6. *Supplemental Phenom User Manual: A Guide for the Neophyte*
 7. *Sample Preparation for the Phenom: A Supplemental Guide*
 8. *Phenom Tutorial* (DVD developed by OMSI)



Sample pages from the *Supplemental Phenom User Manual*

Task 1.3 Outreach Programs

- Report describing training of educators on the use of the microscope in the education environment.
- Report describing work with Oregon Museum of Science and Industry to develop use of table top SEM in informal nanotechnology education networks

The University of Arkansas has integrated the TT-SEM into its GK-12 program, a program designed to provide graduate students the opportunity to teach directed science lessons in the public schools. The TT-SEM is moved from school to school all week long while the university's graduate students present nanoscience and nanotechnology to the area's 6th and 7th graders and their teachers. The middle school teachers associated with the GK-12 program also receive training on the microscope. While engaged in outreach activities in Fayetteville, Arkansas, the project coordinator was able to model teaching strategies designed to help students deepen their conceptual understanding of terms related to nanoscience.



Project coordinator teaching students associated with the University of Arkansas's GK-12 science program.

During the Spring, Chemeketa loaned its TT-SEM to Beaverton High School for six weeks. During that time the TT-SEM was used extensively by two area high school teachers and viewed informally by a handful of others associated with the two teachers. At Chemeketa, one high school teacher and one faculty member were trained in its use; two additional faculty members previously trained continue to use the TT-SEM for educational purposes. At the time of this report, plans are underway to present the TT-SEM to a broader faculty audience at one of the meetings held this fall. As for the Oregon Museum of Science and Industry, they have trained about a dozen paid and volunteer staff members to operate and teach informally with the TT-SEM.

5. Summary of Project Activities

Include approaches, problems, departures and their impact

The overall focus of this project was the development of reusable, cost-effective educational modules for use with the table top scanning electron microscope (TT-SEM). The goal of this project's outreach component was to increase students' exposure to the science and technology of nanoscience.

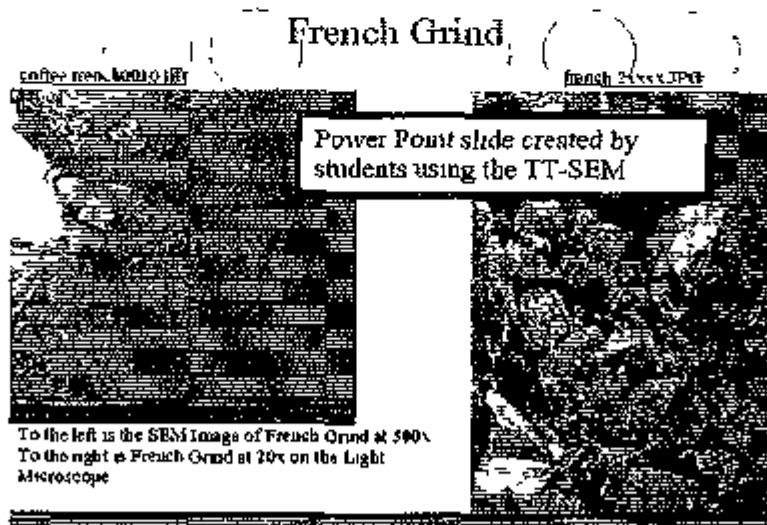
During the period of funding eight documents with approximately 60 lessons were created. Five of the documents are thematic lesson modules, two of the documents are instructional manuals for use with the Phenom TT-SEM, and one of the documents is an instructional DVD developed by OMSI and sent to the University of Arkansas per their request. Copies of the two instructional manuals were sent to OMSI and the University of Arkansas. The chemistry module was also sent to OMSI as extensions to their previously published teacher materials.

In March the project coordinator spent a week of outreach in Fayetteville, Arkansas. At the University of Arkansas she spoke with several professors connected to the project learning how the Phenom was used in research, outreach, and education. She also spent two days at Hellstern Middle School, one of several schools where the university has hired graduate-level science "fellows" to teach science lessons using the TT-SEM. During the two days at the middle school, the project coordinator team-taught three science classes to about 60 students, modeling and later discussing classroom teaching strategies to the graduate fellow with whom she team-taught. The project coordinator also spoke at length with three of the classroom teachers to learn about the strengths and pitfalls of using the TT-SEM as a teaching tool.



After watching the project coordinator model how to teach “scale” to 6th and 7th graders, University of Arkansas’s lead GK-12 graduate student prepares to teach using the same strategies.

Professional collaborations were also developed between Chemeketa and two high school science teachers from the Portland area. For six weeks during the funding period Chemeketa loaned its Phenom to Beaverton High School where 200 students received hands-on training and instruction in nanoscience and nanotechnology for two or three days each week. While the TT-SEM was at Beaverton High School, eleven additional students received one-on-one specialized training in a week-long after-school “Nanoscience Club.”



Chemeketa’s TT-SEM was loaned to Beaverton High School where 200 students received hands-on instruction in nanoscience and nanotechnology. Above is one of several slides created by a small group of students comparing different grinds of Starbucks’s coffee.

In order to expose more students to the science and technology of nanoscience, FEI configured Chemeketa's TT-SEM VNC server for remote viewing. As a result of FEI's work at Chemeketa, all of Chemeketa's several campuses are now capable of accessing and viewing images displayed on the screen of the TT-SEM. Plans to test the campuses' remote access capabilities were interrupted, however, when on November 3rd FEI announced the sale of its TT-SEM rights to Phenom-World, a subsidiary of NTS Group B.V. (NTS) of The Netherlands. As a result of the sale, the marketing, selling, and service of the Phenom TT-SEM was switched from the original FEI personnel to those employed by Phenom-World, shifting the original vision of the TT-SEM away from its "Phenom Anywhere" goal. Although the original FEI working relationships changed, the new ones formed between Chemeketa and Phenom-World proved to be just as positive and productive.

During the fourth quarter of the funding period Chemeketa's TT-SEM received extensive maintenance service, vastly improving the image quality and operational ease of the microscope. TT-SEM related materials requested by the University of Arkansas and OMSI were also ordered and sent.



Phenom Tutorial DVD developed by OMSI