

Project ExCEL – Web-based SEM for K-12 Education

S. Chumbley, K. Constant, C.P. Hargrave, T. Andre
Iowa State University

Abstract

The goal of Project ExCEL, the Extended Classroom for Enhanced Learning, is to bring the capabilities of Scanning Electron Microscopy (SEM) into elementary and secondary classrooms. We have developed an entirely web-based interface to allow schools to control a modern SEM. The web interface allows a remote user complete control of all the operating parameters of the microscope, including stage movement and x-ray chemical analysis. Such total control currently is not available on any other system. Since pioneering the idea of remote SEM use for K-12 education in the early 1990s, we have learned that merely providing schools and teachers access to high technology equipment does not ensure that it will be used. Many teachers are too busy and their curriculum too structured to allow incorporation of the WebSEM into their lessons. Many lack knowledge in the area of SEM and do not possess confidence in their abilities to operate the instrument. To overcome these problems, MSE is working with the Department of Curriculum and Instruction (C&I) to train future teachers in the use of the WebSEM. Science Education professors are incorporating the WebSEM into their courses and having selected students receive training on its use. These students then prepare lesson plans and present their work to the remainder of the class. Evaluation data from students is positive. In-service teachers receive instruction and training in the WebSEM through summer workshops. By using this integrated approach, it is hoped that all science teachers in Iowa will eventually gain the information, expertise, and confidence to use the WebSEM in their respective classrooms.

I. Introduction

In the last 40 years, the scanning electron microscope (SEM) has become an essential scientific tool in Biology, Geology, Botany, Engineering and the basic sciences. More recently, it is being considered as a valuable learning tool not only for student of the above disciplines, but also to secondary education students. With its ability to deliver crisp images with the appearance of three dimensions at high magnifications, the SEM can open a window into the microscopic world never before available. The addition of the EDS (energy dispersive spectrometer) can provide rapid chemical information to supplement the visual. Because the SEM has long been used as a single user instrument, widespread use in education has been very limited. In the early 1990's the Materials Science and Engineering Department at Iowa State University received a National Science Foundation grant to develop new instructional methods in the SEM, making use of rapidly improving computer and computer connectivity technology. Using a computer based interface, and existing SEM was modified to allow control of the instrument from a series

of remote workstations^{1,2}. This laboratory allowed a number of students to simultaneously view and control the image using a series of TV monitors and a large screen projector. This effort was limited by the need to retrofit an SEM that was never designed to be operated remotely. Nevertheless, clever engineering and network development allowed the SEM to be operable by individuals off campus using modems. The success of this classroom was widely disseminated and the rapid development of remote-control, computer-based microscopes began. The next logical step was to make these Web-accessible. While the number of Web-SEM sites has increased, one segment of the education population has largely been unaffected – K-12.^{3,4} Despite the SEM's potential to provide a powerful teaching tool to K-12, and the high degree of interest of the teachers, involvement has been low. In examining this situation, it is evident that a number of problems must be addressed before remote-control SEM will reach its potential as a teaching tool at this level.

II. The Problem

Having had a significant history of working with teachers using a remote SEM, we have identified a number of barriers to using the SEM as a teaching tool:

- Computer facilities vary widely and expertise/technical support is not readily available. Money to purchase additional computation facilities is not available.
- Most teachers are not familiar with the SEM or how it might be used for teaching. Some are apprehensive about using the complex, expensive equipment, even remotely.
- Teachers often feel that they do not have the time to experiment with new, untried teaching tools and methods
- Faculty and staff in the Materials Science and Engr. Department do not have the time to instruct in-service teachers in the use of the SEM or the computer interface.

Removing these barriers requires a more comprehensive approach that incorporates teacher and curriculum development. Thus, from the inception this project, faculty from the both ISU College of Education in the department of Curriculum and Instruction (C&I), and the College of Engineering have taken a team approach to solving these problems.

III. A Solution

Project ExCEL (the Extended Classroom for Enhanced Learning) has evolved from a NSF-sponsored CCLI (Course, Curriculum and Laboratory Improvement) project.⁶ ExCEL is an integrated approach that takes advantages of the strengths of engineers and educators while building on the lessons learned from earlier programs. The goal is to develop, design and conduct lessons for use in K-12 classrooms through the use of pre-service teachers from the College of Education at ISU. (Proposal Title: Incorporating Inquiry-Based Science Modules Involving an Environmental Scanning Electron Microscope into Pre-service Teacher Education Classes).⁶ These C&I students then work with MSE students who have significant SEM experience and this team is paired with an in-service teacher who is interested in using the SEM in their classroom. The MSE department is responsible for maintaining the equipment and scheduling the lessons while the C & I department is responsible for designing lessons and assessing both the pre-service teacher performance and the utility of the lessons. In this way,

continuous improvement of the teaching strategies and methodologies used are integrated into the activities of a year's cycle. Both departments share responsibility for conducting summer workshops for in-service teacher training. The partnership between the two departments is effective because of the close match between the goals of the C&I department and the project goals. The education program at ISU has an emphasis on involving pre-service teachers with educational technology as a tool for learning and as a tool for promoting the development of inquiry skills. Pre-service teachers take a course on educational technology early in their sequence of teacher education courses. In this course they learn about educational technology in the context of using it as a tool to promote student learning. The emphasis is on learning about technology as a tool for getting their students involved in learning activities that involve creative and critical thinking, inquiry, and communication. The **ACTIVE** model, developed by Grabe and Grabe (1998) serves at the basis of the course.⁸ In this model, educational technology is integrated into education as part of instructional activities in which students are cognitively **A**ctive, **C**ooperate in their learning and communicate about their understandings. The instructional activities are **T**heme-based in meaningful problems or issues, the activity **I**ntegrates across subject matter domains such as language-arts, mathematics, science, etc. Technology learning emphasizes tools that are **V**ersatile or can be applied in a variety of situations. Students are taught to self-**E**valuate their learning and to gain the skills to be self-motivated and regulated lifelong learners. The use of the WebSEM is consistent with this educational model used in this preliminary course. Because of the developing importance of the WWW as a tool for learning, the course includes considerable emphasis on the WWW. The WebSEM represents the kind WWW-based inquiry tool that the course wants to promote. ISU also offers a technology minor within teacher education. More advanced courses in educational technology are available. These courses allow students to pursue in greater depth topics and issues that are introduced in the initial class. We also involved the WebSEM in an advanced courses. However, this report focuses on the use of the WebSEM in CI201, Introduction to Instructional Technology.

PHASES

The project has three separate phases.

Phase I The establishment of a web-based SEM laboratory .

Phase II. The training of pre-service teachers in the SEM through science teaching methods and instructional technology courses offered by the C&I department.

Phase III. The offering of summer workshops for in-service teachers.

Phase I has been completed and the results described elsewhere.⁷,(Fig. 1) Phase II is described in further detail below. Phase III is in the planning stage, although pilot workshops have been conducted.



Figure 1 The Web SEM at ISU

IV. Approach

Equipment

Although a detailed report has been published elsewhere, a brief description is useful in this context. An R.J. Lee “Personal SEM” was selected as the appropriate equipment considering both the functionality of the instrument, but also, the willingness and interest of the manufacturer to develop hardware and software for educational uses. The Personal SEM has a simple point-and-click interface and is a low pressure SEM, which reduces sample preparation. Access to the WebSEM is through a web page: <http://www.mse.iastate.edu/excel/>. Note that the site includes an overview, a description of the equipment, a session schedule, lesson plans tutorials, photographs, as well as the connection to the WebSEM itself.



Access to the WebSEM is controlled through a password that is assigned to a teacher who has reserved a session. With access, a teacher can move the sample, change magnification, focus and acquire elemental information using the EDS. Images taken can be

saved and downloaded to their own computer after the session is completed. The integration of SEM into teacher education courses will ensure that a cadre of new teachers possess the skills and experiences to effectively integrate SEM into science curricula.

Images taken can be saved and downloaded to their own computer after the session is completed. The integration of SEM into teacher education courses will ensure that a cadre of new teachers possess the skills and experiences to effectively integrate SEM into science curricula.

Use with Preservice Teachers

This report focuses on a preliminary study of the use of the WebSEM in the introductory educational technology course. This course is divided into 2 lectures and one 2 hour laboratory per week. There are two large lecture sections of 150 students each taught by the same instructors. The laboratory sections, limited to 25 students, intermix students from both lectures. The students in this course include elementary and secondary teacher preparation students. In addition, a relatively small number of students come from non-teacher preparation majors. For example, many students in Exercise and Sport Science, who are not seeking teacher licensure take the course. Our goal in this study was to introduce students to the use of the SEM as an inquiry-learning tool and to determine their reactions to the experience. We planned an educational experience that involved one lecture and one laboratory session. The lecture preceded the lab activities. The lecture content focused on failure of materials as a result of external physical forces and the underlying structural changes that accompany application of such forces. We labeled this general contact fracturing and breaking processes for the students. During the lecture students received demonstrations and information from a material scientist and also carried out exploratory activities with simple commonly available materials. The

purpose of the lecture was to provide some basic information, to engage students in inquiry about fracture, and to stimulate their interest. The lecture activities were followed up with more exploratory activities in the laboratory and then demonstration of the WebSEM to explore fractured materials that were related to the hands-on activities the students had carried out.

The outline and content of the lecture were as follows. The students had been divided into learning teams as a normal part of the class. As students entered the classroom, each team received a packet of envelopes that contained the materials for the activities. When the students were seated, they received a 5 minute introductory lecture that covered the purpose of the activities, i.e. a demonstration of a particular example of the use of the WWW for exploratory inquiry lesson. This topic was explained as the kind of desirable Web-based activities that would become more available and represented an approach to using the Web for education that we hope they would adopt and that was consistent with the ACTIVE model they had been studying. It also demonstrated a particular tool that would be available to them as teachers. To arouse interest we then showed about 5 minutes of videos of spectacular failures, the Challenger explosion, the Tacoma Narrows Bridge, and a segment from the movie Titanic of the ship breaking in half. We then introduced the basic questions we wanted them to explore and think about in their learning teams; why or how do things break when forces are applied to them? Why do some things break and others not? Why does an object not break one time when a force is applied and break another time? What can we observe as we break things? Next students had about 10 minutes to carry out three activities in the packets and to record observations while they did the activities. One activity was to bend a paper clip several times and to observe the change in temperature by placing it against their cheek before and after bending. Students then continue to bend their paper clip until it broke. They were asked to observe the broken ends. A second activity was to observe the change in temperature of a rubber band as it was stretched by touching against the cheek before and after stretching it. The third activity was to break 1 in. by 8 in. strips of black plastic garbage sack by rapidly pulling apart and by stretching with a slow pull. We asked students to record their observations. At the end of the activity, as a large group activity, we ask students to share their observation. Then we raised the question of what can account for the differences and changes observed. At this point we introduced the concept of structure of materials and that the arrangements of atoms and molecules in the materials relates to what they observed and accounts for the way things break. We introduced the SEM as a way of studying the structure of materials. Next, we explained the SEM and compared it to light microscopes. We show some examples of SEM micrographs and then explained that the WebSEM was available as an instructional tool and that they would explore it in their laboratory the following week. To end by stimulating their interest again, we did a demonstration of shattering a racquetball dipped in liquid nitrogen. The total class occupied 50 minutes

In their laboratory, we had one hour of a two hour laboratory to allow students to conduct some additional hands-on activities and to explore the WebSEM. Students did three activities. The first involved bending a normal and a brittle bobbi pin. The brittle bobbi pin had been created by heating the curved end of the pin to orange hot in a torch and then rapidly quenching in a cup of cool water. The second activity involved stretching a clear flexible plastic ring of the type used to hold pop cans together. The final activity involved rapidly pulling apart and slowly stretching normal and "hairy" silly putty. Hairy silly putty was created by intermixing approximately 1/4 in to 1/2 in cut lengths of artificial hair used for inexpensive wigs with the silly putty. Next students were given a demonstration of the WebSEM. A graduate assistant or professor in Materials Science used the WebSEM and demonstrated how to control the SEM.

Previously prepared samples of normal and brittle metals were used. In addition, samples of metal broken by rapid pulling apart and by slow stretching were used. (These latter metal images were related to the plastic and silly putty experiments they had completed.) Finally, students explored a series of previously prepared SEM images of these materials and compared differences in the images. At the end of the lab, there was a general discussion of what they had observed in the images. A brief description of what they observed was related to the breaking activities followed.

In the first lecture class of the following week, students then completed a short post questionnaire. One half of the students completed an objective opinion questionnaire in which we asked them to report their degree of agreement with statements related to their experience, to the use of the WebSEM in education, and to the use of the WWW and inquiry-oriented science in education. Table 1 lists the items in the objective questionnaire. Students responded on a 6 point Likert scale ranging from 1. very strongly disagree, 2. disagree considerably, 3. somewhat disagree, 4. somewhat agree, 5. agree considerably, 6. very strongly agree. The other half of the students completed an open response questionnaire. We are still analyzing responses to the open response questionnaire and focus this report on the objective responses.

V. Results

How did students react to this learning experience? For simplicity in this report, we classified the responses as agree or disagree and report the frequency and percent of students agreeing or disagreeing with each item. We also report the mean responses to the items. In calculating the mean, negatively worded items were recoded so that across all ten items, the scale direction would be consistent. This recoding was done to allow us to compute an average score across all items. Cronbach alpha, a measure of internal consistency, was .8 for the whole scale. This value indicates a substantial degree of consistency in the scale; students were quite consistent in the way they responded to the items. Table 1 summarizes this data.

Overall, students were quite positive to the learning experience involving the WebSEM. Across the ten items, the average degree of positive reaction was 1.8 on a six point scale where 1 represents the most positive response (negatively stated items were reverse scored in computing this average). The percentage responses for the individual items are quite telling; 99% of the respondents wished they had had the opportunity to use the WebSEM in their K-12 science courses; 92% reported they were excited by the possibility of future students using hands-on WEB-based learning, 87% agreed that science teachers should make more use of the WWW in teaching, and 73% reported they found the WebSEM experience interesting. For the negatively stated items, 94% disagreed that the WWW should not be used in teaching, and 83% disagreed that they could not see a way to use the WebSEM in their own teaching, 95% disagreed that giving students the opportunity to use advanced technology over the WWW is a bad idea, and 80% disagreed that students given access to advanced technology over the WWW would just fool around and not learn anything.

Table 1. Percent of agreement and mean level of agreement for each of the posttest opinion items¹.				
Item	Number and (Percent) Disagree	Number and (Percent) Agree	Mean	Standard Deviation
1. I would like to be part of a team of teachers that would develop and teach an integrated unit WebSEM based unit that involved science and other subject matters.	67 (52.8)	59 (46.5)	1.47	.50
2. The World Wide Web should NOT be used in teaching. *	119 (93.7)	7 (5.5)	1.94	.23
3. I CAN'T see any possible way that I could use the WebSEM or a similar type project in my teaching even as part of an interdisciplinary team of teachers.*	105 (82.7)	21 (16.5)	1.83	.37
4. I wish I had had the opportunity to use equipment like the WebSEM when I was taking science classes in K-12 schools.	11 (8.7)	115 (99.2)	1.91	.28
5. Inquiry-based and hands-on teaching DOESN'T promote real learning.*	119 (93.7)	7 (5.5)	1.94	.23
6. I am excited by the possibility that future American students will use hands-on WEB-based learning in science classes.	9 (7.1)	117 (92.1)	1.93	.26
7. Science teachers should make more use of the WEB in teaching.	16 (12.6)	110 (86.6)	1.87	.33
8. Giving students the chance to use advanced technology over the WEB is a BAD educational idea. *	121 (95.3)	5 (3.9)	1.96	.20
9. I found the hands-on activities that were part of the WebSEM demonstration interesting.	33 (26.0)	93 (73.2)	1.74	.44
10. Students given access to advanced technology over the WEB will just play around and NOT really learn anything.*	101 (79.5)	25 (19.7)	1.80	.40
Average of items			1.84	.16

¹ For the frequency and percentage agreement or disagreement, the counts are based on the original responses . Responses 1-3 coded as agree, Responses 4-6 coded as disagree. Because we wanted to compute a mean reaction score over the items, we recoded negative items so that the positive and negative items would have a consistent scale (e.g. 6. greatly disagree was recoded as 1. greatly agree). The means are based on the recoded scores. For the combined score across all items, Cronbach alpha, a measure of internal consistency, was .8 indicating a high degree of internal consistency to the 8 item scale. An asterisk indicates the recoded items.

VI. Conclusions

It is important to place these results in a context. Many of the students were elementary teachers or secondary teachers who were not pursuing science degrees. Elementary teachers traditionally have been less interested in and knowledgeable about science. They tend to underteach science. To obtain this high level of positive response across our whole sample of students is quite remarkable. The results indicate that a majority of our participants found they WebSEM learning experience interesting and that they perceived considerable value in the inquiry-oriented learning experiences over the WWW that made use of high technology available in schools.

Our primary goals in working with CI201 were to excite and interest pre-service education students about the WebSEM project, to demonstrate the feasibility of using the WebSEM with pre-service education students, to make students aware of the project and the possibility that they could use this resource as a teacher, to allow them to participate in an inquiry-oriented learning experience involving the WebSEM and to help them understand a little more about structure of materials and materials science. Because of the constraints of the class, we only had a limited time, two hours, to work with students. Given the limitations on this experience, we believe our results suggest that our project was quite successful in achieving these goals. These students will enter teaching with an awareness of the WebSEM and of WWW based inquiry learning that they might not have had without this experience. Our preservice teachers will enter the profession with a set of experiences using technology that most practicing teachers have not had. Because they found the experience motivating and exciting, they will be more likely to have positive attitudes towards utilizing this resource and similar resources in their own teaching.

While we believe that this short-term experience had positive results with the CI 201 students, we fully recognize the limitations of a single two-hour exposure to this resource. If this CI201 experience were the only experience students had, its effects would probably be sporadic as individual teachers remembered the experience or choose to avail themselves of the resource. In addition to this awareness experience, we have involved students in elementary science methods classes and advanced instructional technology classes in other WebSEM experiences. In an advanced instructional technology class, students receive a two-week experience involving the SEM and then plan specific instructional units based around the WebSEM. In the elementary science methods of teaching classes, students also received a weeklong unit involving the WebSEM and then planned an inquiry-oriented teaching experience using the WebSEM. We believe these long-term experiences build on the awareness activity provided in CI201 and are more likely to impact the teachers' future use of the SEM. We are currently analyzing the initial evaluation data from these uses of the WebSEM. In the future, we will seek funding for a more extensive and intensive involvement of the WebSEM in pre-service and inservice teacher education.

VII. Acknowledgements

The authors are especially grateful to Gary Casuccio, Dan Kritikos, and Hank Lentz of R.J. Lee Group for their continued interest and support of this project. Without their assistance this project would not be possible. Chris Mannes and Kautul Mehta are also acknowledged for their support in developing and implementing the software for the web interface. The authors also

acknowledge the support of the National Science Foundation (DUE-9972370) for funding various aspects of this project.

Bibliography

1. L.S. Chumbley, M. Meyer, K. Fredrickson, and F.C. Laabs, "Computer Networked Scanning Electron Microscope For Teaching, Research, and Industry Applications," *Micro. Res. Tech.*, 32:330-336 (1995).
2. L.S. Chumbley, M. Meyer, K. Fredrickson, F. Laabs, "A New Paradigm - Multi-user Scanning Electron Microscopy", *JOM*, vol 47, no. 9, Sep. 1995.
3. URL:<http://tpm.amc.anl.gov/>
4. URL:<http://bugscope.beckman.uiuc.edu/>
5. NSF proposal # DUE-9851284, Extended Classroom for Enhanced Learning
6. NSF proposal #. DUE-9972370, Incorporating Inquiry-Based Science Modules Involving an Environmental Scanning Electron Microscope into Pre-service Teacher Education Classes
7. L. S. Chumbley, G. Cassucio, D. Kritikos, H. Lentz, C. Mannes*, K. Mehta*, Development of a Web-based SEM Specifically for K-12 Education, accepted *Micro Res. and Tech.*
8. Grabe, M, & Grabe, C. (1998). **Integrating Technology for Meaningful Learning**, Boston: Houghton-Mifflin.
9. Anderson, R. D. and Mitchener, C. P. (1994). Research on science teacher education, In D. Gabel, (Ed.) *Handbook of Research on Science Teaching and Learning*. (pp. 3-44), New York: Macmillan.
10. Tobin, K., Tippins, D. J., Gallard, A. J., (1994). Research on instructional strategies for teaching science, In D. Gabel, (Ed.) *Handbook of Research on Science Teaching and Learning*. (pp. 45-93), New York: Macmillan.

L.S. CHUMBLEY

Scott Chumbley is an Associate Professor in the Materials Science and Engineering Department at Iowa State University (ISU) and a Scientist at Ames Laboratory, the Department of Energy national laboratory located on the ISU campus. His expertise is in the field of electron microscopy. He teaches the undergraduate Materials Characterization class and graduate level classes on electron microscopy.

C.P. HARGRAVE

Connie Hargrave is an Assistant Professor in the Department of Curriculum and Instruction at Iowa State University. She conducts research on teachers' conceptual development in instructional technology and science education. She teaches undergraduate educational computing courses and graduate instructional technology courses.

K. CONSTANT

Kristen Constant's is an Associate Professor in Materials Science and Engineering Department at Iowa State University. Her field of study is the novel processing photonic materials. She has gained national attention for her work in developing computer-based instructional modules for undergraduate education in materials science.

T. ANDRE

Tom Andre is a Professor of Curriculum and Instruction at Iowa State University. He conducts research on conceptual change in science learning and instructional technology. He teaches graduate courses on educational psychology and instructional technology.