Day 1

Session I. Instructional Materials: Designing and Developing Classroom Resources

Framing Questions:

- What nano topics and learning goals should guide the development of classroom materials?
- What areas of secondary (grades 7-12) science support the integration of nano concepts?
- How can instructional technology enrich nano classroom resources?

This session began with four formal presentations. Dr. Joseph Krajcik, University of Michigan, presented guidelines for the design of materials; Dr. Patricia Schank, SRI, talked about her group's early drafts of materials for secondary chemistry classes and the obstacles they encountered; Dr. Thomas Moher, University of Illinois-Chicago, focused on technology applications for middle school students that would enhance understanding of nanoscale phenomena; and Dr. Kenneth Klabunde, Kansas State University, reviewed nanoscale science content.

Krajcik emphasized three lessons learned through his work on a new middle school science curriculum that are directly applicable to developing instructional materials in nano science. First, focus on learning goals. Developers must help teachers recognize what it means to understand a scientific idea and answer the question, "how do we know if students understand?" Second, scaffold complex tasks. Krajcik emphasized the importance of helping students develop the skill of presenting evidence-based explanations and providing data to support explanations. As a scaffolding example he described a structure for student explanations: make a claim, provide evidence, present reasoning, and consider alternatives. His third lesson is that instructional materials must be educative for teachers. Krajcik emphasized the importance of providing teachers with adequate understanding of content and the appropriate pedagogy for introducing complex topics to their students.

Schank described her Nanosense project that is creating instructional units to use in high school chemistry courses. Each unit will emphasize core concepts underlying nanoscale phenomena and employ computer visualizations of the behavior of nanoscale particles to enhance student understanding. Schank convened a group of teachers, scientists, industry representatives, and education researchers who developed the following list of core concepts: scale, energy, quantum principles and probability, relation between structure and properties, surface phenomena, unique properties, self-assembly, and control of fabrication.

Shank also stressed the need for authentic tasks and tools to promote student understanding, citing as an example a virtual atomic force microscope (AFM). She emphasized the importance of teaching that properties depend on scale but cautioned that there are limitations to models and simulations that may be informative at one scale but irrelevant at another.

Schank presented several challenges she and colleagues are confronting: (1) defining a curriculum for nano science; (2) situating this inherently interdisciplinary field within traditionally single discipline courses; and (3) designing professional development for teachers. She concluded by posing a set of research questions related to the teaching of nano content:

- Will students' understanding of nanoscale science concepts (effects of size, significance of high surface-to-volume ratios, etc.) improve over time?

- Will students' understandings of the process of science and the interplay between science and technology improve?
- Will students' interest in science increase?
- Will students appreciate how technologies can alter their lives and society?
- How will teachers use these tools and activities to support student discourse and understanding?

Kenneth Klabunde, a Professor of Chemistry at Kansas State University and nano researcher, proposed that "nanotechnology is really an extension of chemistry, but it reaches into physics, biology, [and] earth science." As previous presenters, he emphasized the importance of presenting nano in the context of existing classroom materials at levels that are developmentally appropriate for different grades. He proposed several nano concepts that might become the basis for classroom materials:

1. Size-dependence of solid state properties.
2. Properties that change with nano-sizing.
3. Uses of nano-scaled applications and devices.
4. Changes in physical properties at the nano-scale (example–magnesium oxide).
5. Increase in surface area/volume at the nanoscale.
6. Chemical properties of nanoscale materials.
7. How changes in size and shape of nanocrystals affect chemical and consolidation properties of magnesium oxide.
8. Preparation and manipulation of gold nanoparticles.

Moher discussed the roles of virtual experiences in student learning and new technologies his group is developing for classroom use. He talked about the value of placing a student in the middle of phenomena, rather than as an external observer. Describing several successful simulations in which students use hand-held devices and interface with laptops, he emphasized that these technologies would offer students an affordable simulation of the nano world. Talking about the importance of providing students with an understanding of scale, Moher offered examples of simulations that would allow students to "control phenomena" at the nano scale.

These presentations were followed by a more global audience discussion about instructional resources: what content to include, how to link nano content to the standards, defining "understanding" in the realm of nano content. The discussion moved toward looking for "hooks' that might make nano "cool" to young audiences.

Session II. Teacher Professional Development

Framing Questions:

- What nano content should be included in professional development?
- What models of professional development can be scaled to meet the needs of a large and diverse teacher population?
- How can a teacher leadership cadre capable of supporting nano professional development be recruited and prepared?

This began with presentations by Nancy Healy (NNIN, Georgia Institute of Technology), Monica Plisch (NSEC, Cornell University), and Christine Morrow (NIMD, McREL and University of Colorado).

Healy described professional development projects sponsored by the NNIN at some of its 13 centers across the nation. One example was about teachers visiting nano research labs and, with the help of graduate students, designing materials for student use. At subsequent 1-2 day workshops, materials are shared with other teachers. A workshop was described to help teachers tie specific nano concepts to topics they currently teach in secondary science courses.

Plisch also described specific professional development offerings. With examples from the education outreach efforts at her research facility, she talked about an institute for physics teachers and a program combining lectures, laboratory tours and hands-on activities, all intended to build teacher content knowledge. She described a lending library created to provide materials and activities for classroom use.

Morrow, representing the instructional materials development community, focused on the design principles for effective professional development and for the preparation of teacher leaders. With specific reference to her NanoLeap project currently developing a secondary curriculum covering properties of matter, forces, energy, measurement and size, ethical issues, and the interdisciplinary nature of nanoscale science, she reviewed standards-based teacher professional development guidelines. She emphasized the importance of a focus on essential understandings and learning goals for students in both teacher professional development and student materials. She described the multi-media teachers guide currently under development that would employ video clips illustrating demonstrations and animations, background information rich in content and pedagogy, and suggestions for embedded assessments of student learning.

These presentations introduced several critical issues that were, along with the framing questions, topics for the subsequent discussion. The SRI project adopted the approach of developing short focused lessons for key insertion points in the secondary curriculum, since high school teachers are reluctant to include longer units in an already over-crowded curriculum. Many were critical of existing high school curricula, describing its adherence to single discipline courses as “rigid” and “archaic”. Participants considered the option of introducing nanoscale science in middle school classrooms, as they have fewer constraints with respect to content and are more welcoming to interdisciplinary topics.

The education outreach efforts from the research centers mostly involve small numbers of teachers who volunteer for these programs. They have opportunities to visit research labs and participate in the design of instructional materials that they take back to their students and frequently share with colleagues. At the present time, these programs lack formal evaluations, and evidence of impact is largely anecdotal.

Participants suggested additional profession development strategies such as lesson study, classroom support for teachers, and peer study groups and emphasized the importance of better instructional materials, particularly those that would meet the needs of diverse student groups.

Session III. Nanoscience Education beyond the Classroom: Exhibits, Media & Special Programs

Framing Questions:

- What models of informal nano education have been successful in your projects?
- How can formal and informal efforts in nano education be integrated?
- What has been learned about making nano accessible to young students? To the general public?

The session began with introductory presentations by Anna Waldron, Cornell University, Chang Ryu, Rensselaer Polytechnic Institute, and Michael Melloch, Purdue University, describing outreach efforts in their projects and some of the obstacles associated with the work.

Waldron talked about *Too Small to See,* an exhibit designed for children and adults that is intended to engage viewers in thinking about atoms as building blocks. As part of the project evaluation audiences of different ages were interviewed about what they understood. Few were able to comprehend scale. High school students associated "small" with a spec of dust or a grain of sand. Some of the adults interviewed heard of "nano" and "nanotechnology", but, as Waldron noted, awareness is different than understanding. *It's a Nano World* is a traveling exhibit for children age 5-8. Like *Too Small to See*, the exhibit tries to push viewers' understanding from small to smaller, but, according to Waldron does not succeed in conveying understanding of the nano level.

Some of the challenges Waldron encountered in her work include engaging the public in the topic and providing interactive learning experiences that might enhance understanding.

Ryu described the Molecularium, a portable dome for presenting a musical simulation in which cartoon-like figures with facial features model atomic motions and molecular interactions to help K-5 students understand molecular behavior. The animation conveys the message that everything is made of atoms. A first installment features figures representing hydrogen, oxygen, and water. The next episode will focus on carbon and atoms in living things. There were several concerns about the implications of this approach, in particular the impact of anthropomorphizing atoms on a child's understanding of science. Ryu explained that this 7-minute show engages both children and adults.

Melloch described a LEGO simulation of a scanning probe microscope and an exhibit about The Science of Making Things Smaller.

A key challenge confronting the informal education community is finding ways to reach audiences with minimal knowledge of nano science or background on which to build meaningful understanding. Participants agreed that their work is complicated by the absence of a clear set of essential understandings and desired outcomes. The need for effective materials was stressed repeatedly—materials that are based on best practices and have been subject to rigorous evaluation.

Chemistry was mentioned as a possible introduction to nanoscale science. However, critics noted that since public understanding of chemistry is generally limited it is not an adequate entry point and properties of chemical systems are quite different from those of nano systems

Ultimately, effective resources for informal education must evoke a "wow" to attract audiences. There was general agreement on the goal of raising public awareness. Under this general heading, came issues such as using nano as a vehicle for showcasing the interdisciplinary nature of science and introducing the tools that are advancing the frontiers of science. Participants acknowledged the importance of developing age-specific learning goals and conducting systematic evaluations of informal education programs, reporting both what works and what doesn't.

The discussion moved to nano education in museum settings. Larry Bell, director of Boston's Museum of Science, emphasized that museums have fewer constraints than classrooms. Although most discussions of NSEE content started with teaching size and scale, Bell proposed a different starting point. At the nanoscale, the properties of matter are different than at the micro or atomic scale. Atoms can be manipulated and new molecules assembled atom by atom. Bell suggested that this is the "wow" that will attract the audience.

Teachers and parents bring children to museums to supplement what they learn in school. They want exhibits that are "cool" but can be related to the curriculum. Although emphasizing size and scale came up repeatedly, Bell proposed not focusing on size, but rather on the fact that the critical properties are different and things are manufactured in a different way---bottom up assembly, atom by atom.