K-12 & Informal Nanoscale Science and Engineering Education (NSEE) in the U.S.

Workshop Report
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Cover Image:

Wrapped around a human hair, a 50nm silica nanowire conducts red light.

Photo credit:

Dr. Eric Mazur
Harvard University.

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In October 2005, the National Science Foundation brought members of its nanoscale science and engineering education (NSEE) projects to Arlington, VA for a 2-day workshop to explore the status of on-going efforts and to forge collaborations at the national level that would facilitate future efforts. NSF currently funds NSEE projects through the Division of Elementary, Secondary, and Informal Education (ESIE), the Directorate for Engineering as part of the Nanoscale Science and Engineering Centers (NSEC), National Nanotechnology Infrastructure Network (NNIN), the Network for Computational Nanotechnology (NCN), and the Division of Materials Research as part of the Materials Research Science and Engineering Centers (MRSEC). This report refers to projects developing instructional materials for inclusion in grades 7-12 science courses, providing professional development and research opportunities for secondary teachers, and engaging in multiple forms of outreach to schools and general audiences through exhibits, media presentations, and traveling programs. NSEE workshop participants included project leaders, scientists, instructional materials developers, museum designers, professional development providers and NSF program directors. The workshop agenda focused on several basic questions:

- What are the core NSEE ideas?
- Who are the audiences for NSEE?
- What are appropriate NSEE goals for each audience?
- What evidence of impact exists for current NSEE efforts?

Dr. Mihail C. Roco, Senior Advisor at the National Science Foundation, in his opening address, established the themes that framed the workshop. Research is rapidly advancing knowledge about nanoscale phenomena, in contrast to the scant progress in bringing nanoscale science into school curricula and public awareness. Fueled by 2006 government funding of over $1 billion, research on matter at the nanoscale will "lead to a revolution in technology and industry" according to Dr. Roco. Emphasizing that a robust nanoscale science and engineering infrastructure depends on greater progress in education and public outreach, Dr. Roco stressed the importance of early education to prepare American students for future careers in nanoscale science, engineering, and technology. He proposed several objectives for NSEE:

- Developing a coherent longitudinal learning sequence extending from K-12 to college and graduate programs.
- Stronger collaboration between NSE researchers and educators.
- Focusing on better preparation of teachers.
- Enhancing public outreach efforts.
- Partnering across institutions working on NSEE.
- Increasing emphasis on engineering and systems.

Prior to the workshop, participants identified their major areas of interest. These topics were the subjects of plenary sessions and provided framing questions for the discussion groups. A plenary presentation by Dr. Angelica Stacy, University of California-Berkeley, offered design principles for effective secondary science instructional materials. She described her new learning-goals oriented secondary chemistry program in which students are introduced to organic functional groups by experiencing characteristic aromas and solubilities rather than memorizing structural formulas. She shared research supporting its positive impact on student understanding. Dr. Frances Lawrenz, University of Minnesota, delivered a plenary presentation on design principles for program evaluation. Citing evaluation plans of three current NSEE projects as specific examples, Lawrenz described several evaluation strategies, stressing the importance of aligning the evaluation plan with program goals. Dr. Robert Chang, Northwestern University, described international efforts in NSEE based on his recent travels in Europe and Asia.

Participants from the nano research centers met for in-depth discussions with those from the materials development projects during the Day 1 breakout sessions. The topics were: Design and Development of Instructional Resources; Teacher Professional Development; and Nanoscience Education beyond the Classroom.

During the Day 2 sessions, attendees regrouped for further networking and exchange of ideas. Participants from the nano research centers[1] met together to discuss the content and design of their education outreach efforts, while attendees from the projects funded through the Division of Elementary, Secondary, and Informal Education[2] shared their experiences and concerns related to bringing nanoscale content into classrooms and public venues and proposing topics for future research. Both groups discussed strategies for increasing collaboration across formal and informal NSEE programs.

As reported in the closing session both groups, although serving different audiences and educational purposes, share their commitment to the value of nanoscale education programs for introducing both students and the general public to contemporary science. The interdisciplinary nature of the topic, its myriad applications, and the economic impact of nanotechnology provide an excitement that has great potential for engaging learners of all ages and interesting students in career opportunities. Although challenges abound, participants reported some success, including workshops for educators, research opportunities for high school teachers, teacher-graduate student collaborations to develop classroom materials, traveling exhibits for elementary students, computer simulations to aid in visualizing nanoscale phenomena, and recently developed instructional packages currently in pilot test mode in secondary classrooms.

However, more discussion time was devoted to challenges than to successes. The general public and students, in particular, lack fundamental background knowledge upon which to build an understanding of nanoscale phenomena. While exhibits focus on public awareness, there is no evidence that they are promoting understanding. Instructional materials developers are keenly aware of the difficulty of introducing any new topic in existing science curricula, particularly an interdisciplinary topic that cannot be readily linked to state or national standards. The informal education community emphasized concern over combating public misconceptions and fears resulting from science fiction accounts of nano critters who take over the world. Ultimately, most discussions turned to seeking:

♦ Entry points for an introduction to nanoscale phenomena
Do units have to start with a discussion of scale and/or new behavior?

♦ Instructional resources that would appeal to secondary teachers
Will two week units or1-day lessons be more acceptable?

♦ Strategies that emphasize the uniqueness of nanoscale properties
Must students understand atomic, molecular and supramolecular structure and properties first?

♦ Representations and models to make nanoscale phenomena visible
Will virtual representations of nanoscale behavior and self assembly be meaningful?

♦ Strategies to share materials and expertise across programs
Will NSF support a national clearing house for nano education resources?

[1] Nanoscale Science and Engineering Centers (NSEC), National Nanotechnology Infrastructure Network (NNIN), Network for Computational Nanotechnology (NCN), and Materials Research Science and Engineering Centers (MRSEC).
[2] Nanoscale Instructional Materials Development (NIMD), Nanoscience Center for Learning and Teaching (NCLT), and Nanoscale Informal Science Education Network (NISE).

- Assessment strategies to evaluate current efforts

Where will projects find funding and expertise for assessment?

Participants articulated a common set of needs to move current efforts forward more rapidly, including:

- Quality instructional resources that would engage students and support meaningful learning goals.
- Content-rich professional development programs for teachers.
- Guidelines for a standards-based K-12 nano learning sequence.
- Innovative technologies to support visualization of nanoscale phenomena.
- Strategies for integrating interdisciplinary nano content in discipline-oriented curricula, and better connecting researchers and educators.
- "Hooks" that capture public interest and combat negative misconceptions.
- Clearinghouse to disseminate resources and share best practices across projects

Summaries of all of the workshop sessions follow.