Nanotech 2006:
A Symposium for Educators
Year Two Summative Evaluation Report

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Nanotech 2006: A Symposium for Educators

This professional development event was held on November 6 and 7, 2006, at the Museum of Science, Boston, under the direction of the Museum's Director for Strategic Projects, Carol Lynn Alpert. This event was sponsored by the Center for High-rate Nanomanufacturing NSF Nanoscale Science and Engineering Center (NSEC) headquartered at Northeastern University and the University of Massachusetts – Lowell, and by the "Science of Nanoscale Systems and their Device Applications" NSF NSEC headquartered at Harvard University. Research and evaluation of the Symposium was funded independently by the Massachusetts Technology Collaborative through the University of Massachusetts-Lowell.

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EXECUTIVE SUMMARY

Program Description and Objectives

On November 7, 2006, the Museum of Science hosted its second Nanotech Symposium for Educators. The event was designed to provide community college, middle, and high school science and engineering teachers with an introduction to nanoscale concepts and a selection of standards-based curricula units to incorporate into their classrooms. Leading professionals in the field presented and conducted workshops throughout the day.

As a prelude to this event, the Museum hosted a Nano Education Developers' Day on November 6, 2006. This event was intended to bring workshop leaders, other nano curricula developers, and university research center professionals together with informal science educators to provide an opportunity for them to learn about each other's work, share ideas and feedback, and prepare for the symposium the following day. While 2006 was the second time the Museum offered the Symposium, it was a first-time experiment with offering a full Developers' Day on the day prior to the Symposium.

Evaluation Goals

- Measure the extent to which the Symposium and Developers' Day programs met their overall goals,
- Seek additional specifics on particular elements of the programs, and
- Help the team define more clearly the most valuable aspects of the programs.

Methods

During the Symposium, mixed methods of data collection were used: a) on-site registration demographic questionnaire; b) workshop evaluation forms; c) on-site surveys administered to workshop leaders and educators at end-of-day. Six months after the Symposium, longer-term impact was assessed through follow-up educator Web surveys. Also, during Developers' Day, on-site surveys were administered at day's end to all participants.

Main Findings

Findings were largely consistent with those reported in the 2005 Symposium evaluation. Educators increased their basic understanding of nanoscale concepts; maintained their interest in nanoscale science and technology, even six months afterward; remained likely to seek out more information on nanoscale science and technology; and identified familiar challenges for integrating nanotech into their curriculum (e.g., time, mandated standards, space in curriculum, resources, age-appropriateness, and their own comfort with the topic). Educators found the general presentations and the afternoon workshops the most interesting and valuable components of the Symposium as well as contributing most to their learning. They also varied in their preference for workshops, with some preferring content-based formats, and others looking to receive classroom applications, activities, and ideas. Six months after the Symposium, one third of respondents to the follow-up survey reported that they had brought up nanotechnology in their classroom and/or would most likely introduce concepts into future curriculum (although, generally, these were their own modules/units, not ones from the Symposium). This finding is a marked increase over the amount of follow-up reported after the 2005 Symposium.

Symposium workshop leaders are interested in leading a workshop again; likely to make changes to their materials based on teacher feedback; and likely to keep in touch with teachers or look for teachers to test their materials and activities. They felt that their workshops were successful and that the Symposium was a worthwhile experience for them, for their organizations, and for educators. In particular, direct access to and feedback from teachers, as well as from other content developers, was consistently cited as the most valued aspect of the leaders' experience and the most likely reason for their attendance at the Symposium.

Developer Day participants valued the full day focused on sharing best practices in nano curriculum development. They were most interested in learning about what other developers were doing and wanted future developers' events to allow even more time to share, discuss and ask questions. They felt that the day-long format should continue and would be interested in participating again in a Developers' Day the following year (or other developer events). Their primary request for MOS was that it acts as a central resource for keeping them current with all the work being done by other curricula content developers in the field.

Recommendations

For teachers:

The primary implication of these findings is that it is of the highest importance that the Symposium's structure, content, and overall organization should focus on facilitating the ability of participants to select those workshops that are most appropriate for their own level of knowledge and for the grade level that they teach and, further, that it enable their desire to strike a balance between increasing their own learning and acquiring new classroom activities. Other trends, such as providing more general focus on educators' own learning and on directly addressing links with curriculum standards and frameworks should also be addressed.

For workshop leaders:

Workshop leaders were generally very satisfied with their experience. Their primary concern was their inability to participate in the overall symposium events due to time constraints or the fact that they were the only person administering a given workshop. Future Symposia should look for ways to allow the workshop leaders to participate in the day more fully.

For developers:

Developers want and need more forums that help them keep abreast of all that is being done in the field. To that end, a future Developers' Day should include ample time for sharing, Q&A, and open, facilitated discussion, rather than focusing mostly on presentations. Further, annual events are not sufficient means for keeping up with developments across the field, and MOS should seek to serve more effectively as a clearinghouse and disseminator of ongoing, regular updates.

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I. INTRODUCTION

1. PROGRAM HISTORY

Nanoscale science and engineering integrates chemistry, molecular biology, physics and engineering on the level of molecules, electrons and photons, and thus requires a more interdisciplinary approach to teaching and research. Rapidly increasing technical capabilities to detect and manipulate matter on the nanoscale level are allowing nanoscale scientists and engineers to develop new ways to transform information technology, medicine, manufacturing and energy. In response to these trends and in recognition of a corresponding need for greater educator awareness and knowledge of these developments, the Museum of Science (MOS) organized, in collaboration with two National Science Foundation-funded Nanoscale Science and Engineering Centers (NSEC), *Nanotech 2005: A Symposium for Educators.* The chief sponsors of the Symposium, the Center for High-rate Nanomanufacturing NSEC, headquartered at Northeastern University and at the University of Massachusetts-Lowell, and the "Science of Nanoscale Systems and Their Device Applications" NSEC headquartered at Harvard University, are engaged through subcontracts to the Museum of Science in a variety of collaborative nanoscale informal science education activities. The Nanotechnology Center at Boston University also played a role in helping to catalyze and contribute content to the Symposium. Several other NSF-funded nanoscale science and education research centers contributed professional development staff and curricular resources, including: the National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT), National Nanotechnology Infrastructure Network (NNIN), SRI International, the Interdisciplinary Education Group of the Materials Research Science and Engineering Center and the Institute for Chemical Education at the NSEC, both headquartered at the University of Wisconsin-Madison.

From the outset, the Symposium was designed to give middle school, high school and community college educators an introduction to nanoscale science and engineering and a toolkit of classroom teaching modules and activities. Symposium organizers and stakeholders shared an interest in exploring new ways of bridging the gaps between current science and engineering education and research in university environments and grades 6-14 curricula and standards. Although initially conceived primarily as an opportunity to provide professional development for educators, the 2005 Symposium was expanded to include a half-day session (on the day prior to the Symposium for Educators) for the curriculum developers and workshop leaders, with the intent of providing them with an opportunity to learn from each other, network, and receive valuable feedback from the attending educators.

1.1 2005 Symposium Evaluation Results

The results from the evaluation of the 2005 Symposium demonstrated that the Symposium met many of its original goals. Overall, it was a valuable experience for educators, workshop leaders and stakeholder institutions in raising awareness of an important, emerging field and in providing an opportunity for learning. Educators increased their understanding of and interest in nanoscale science but foresaw challenges as to where and how to fit nanotech into their curriculum, given a mandated curriculum and nanotech's interdisciplinary nature.

Workshop leaders benefited from receiving educator feedback and from networking with other curriculum developers. Stakeholder organizations felt that their participation in the Symposium was valuable.

Based on the evaluation of the 2005 Symposium, the following areas for possible improvements were identified: addressing educators' varied preferences regarding workshops (some preferred content-based workshops to build a foundation of content knowledge, whereas others desired and appreciated receiving classroom and curriculum ideas); addressing the desire of educators with previous background knowledge of the field for more advanced offerings; and addressing workshop leaders' desire to view their peers' workshops and provide suggestions to one another about their nanotech curriculum. Educators also indicated an interest in more handouts and a pre-existing Web site being made available and a desire for workshop leaders to address directly how to integrate their materials into the school year, especially given the constraints of a tightly regulated curriculum.

1.2 Implications for 2006 Symposium Design

Based on the evaluation findings from the 2005 Symposium, the 2006 Symposium made several important changes to the program design, the most important of which were the addition of a Developers' Day preceding the Symposium and the increased emphasis on workshops related to classroom integration strategies. The research/current science presentations, the most highly valued components of the 2005 Symposium, were maintained.

2. PROGRAM PARTICIPANTS

By expanding the pre-Symposium, brief afternoon workshop leaders meeting to a three-quarter day Developer's Day the focus of the day also expanded and took the form of a professional symposium on nano curricula development generally, rather than simply a logistical preparation and sharing across the sub-group of workshop leaders for the teacher symposium the following day. In 2006, Developers' Day participants included directors of stakeholder organizations, curricula developers, workshop leaders, informal science educators, and participants from Research Experience for Teachers and GK-12 programs associated with the Boston and Cambridge-based NSECs.

Developers' Day 2006
Developers' Day presenters represented a range of nano education development groups nationally, and included the following:

- Yvonne Spicer, National Center for Technological Literacy, welcoming participants to the Museum of Science;
- Robert Chang, National Center for Learning and Teaching (NCLT) in Nanoscale Science and Engineering, presenting the framework for a new curriculum for grades 7-12;
- Robert Tinker, Concord Consortium, demonstrating the Molecular Workbench software program and its connection to nanoscale education;
- Tina Stanford, SRI International, presenting the SRI Nanosense curriculum under development for grades 7-12;

- Nancy Healy and Diane Palmer, presenting the educational development work of the thirteen National Nanotechnology Infrastructure Network partner organizations;
- Aura Gimm and Ken Gentry, presenting the educational products being produced in association with the Materials Research Science and Engineering Center at the University of Wisconsin at Madison;
- Larry Bell, Nanoscale Informal Science Education Network, presenting NISE Net activities and forums; and
- High school teachers, who had developed nano curricula units as part of their Research Experience for Teachers programs at the Harvard NSEC and at CHN and GK-12 students from Northeastern University, were also invited to present their work with posters and materials during the afternoon Developers' Materials Tour.

Symposium for Educators 2006

- Workshop leaders were from among the same presenting organizations (listed above) that participated in Developers' Day. (For complete descriptions of the workshop teams, their works, and their workshop content, see Appendix F).
- Similar to the 2005 Symposium, educators attending the 2006 Symposium were predominantly Massachusetts public high school teachers. There were also a fair number of middle school teachers and teachers from New Hampshire. The Symposium was broadly promoted to educators through a range of channels including the Museum's public Web site, educator newsletters, flyers, and contact with principals/science coordinators. Registration was by phone and was open to any teachers from middle, high school, or community college level.

3. SCHEDULE OF EVENTS

Developers' Day 2006

11:30am-noon	Check-in
12:00-12:30pm	Lunch
12:30-1:00pm	Welcome and Orientation
1:00-1:30pm	Briefing from the National Center for Learning and Teaching (NCLT) in Nanoscale Science and Engineering
1:30-2:50pm	Developers' briefings
2:50-3:45pm	Developers' materials tour
3:45-4:45pm	Developers' roundtable discussion
4:45-5:00pm	Briefing on NISE Network Activities and Forum
6:30-9:00pm	Optional participation in NISE Net and ICAN/Fred Friendly Seminars dinner/forum event "Nanofuture: Privacy and Security"

Symposium for Educators 2006[1]

8:00-8:30am	Registration and Continental Breakfast
8:40-8:50am	Welcome by Ioannis Miaoulis, Museum president and director
8:50-9:50am	Professor George Whitesides presents Keynote Address
10:00-11:30am	Workshops: Session One
11:40-12:00pm	Current Science & Technology presentation: Nanotech Today
12:10-1:00pm	Lunch with Special Emphasis Gatherings
1:10-2:40pm	Workshops: Session Two
2:50-4:00pm	Concluding Activities and Debriefing with Refreshments

4. PROGRAM GOALS FOR EDUCATORS, WORKSHOP LEADERS, AND STAKEHOLDERS

In developing this Symposium, organizers set complementary goals for educators, workshop leaders, and participants in the newly created Developer's Day. (Note: Goals for the stakeholder institutions were also set, but they were not measured through this evaluation study.)

Educators

- Increase teacher understanding of and interest in nanoscale science.
- Provide teachers with tools they perceive to be helpful for incorporating ideas about nanoscale science and technology into their classroom.
- Increase teacher awareness of nano-related information resources, research opportunities, and classroom materials.
- Provide a professional development experience that teachers would recommend to other educators as time well spent.
- Equip participants to successfully implement one or more of the ideas they gained during the workshop in their classrooms

Workshop Leaders

- Will feel they and their organizations gained something of value through their participation in the Symposium.
- Will feel that the Symposium was well organized and that the organizers were respectful of their needs and appreciative of their contributions.
- Will be willing to participate again the following year.

Developers' Day Participants

- Will feel they and their organizations gained something of value through participating in the Developer's Day activities.
- Will have a better understanding of various approaches being undertaken to develop nano education curricula and integrate it into school classrooms.

[1] Select contents from the registration packets distributed to teachers at the Symposium can be found in Appendix G, including biographies of the speakers, full descriptions of the workshops, listings of partner and sponsor organizations, and follow-up resources.

- Will value the opportunity to discuss units they have developed with professional curricula developers and will appreciate having teacher feedback.
- Will have suggestions for improving the Developers' Day gathering and would be willing to participate again next year.

Stakeholders

- Will feel their interests and their funders' interests were served by the two events.
- Will feel positively about the way the event was organized and their organization's participation in the event.
- Will be interested in repeating the Symposium again next year, although perhaps with improvements.
- Will offer helpful suggestions for improving the Symposium.

II. METHODOLOGY

1. EVALUATION GOALS

- Measure the extent to which the Symposium and Developers' Day programs met their overall goals,
- Seek additional feedback on particular elements of the programs, and
- Help the MOS team define more clearly the most valuable aspects of the programs.

Results from this year's investigation and analysis will be used to determine whether to continue offering one or both events in coming years and, if so, how to improve upon them.

2. DATA COLLECTION METHODS

A mixed methods approach, described below, was employed to provide a more holistic representation of the impacts and outcomes of the program for participants. Instruments are designated as either new for 2006 or the same as were used in 2005. Wherever possible, the same or similar instruments were used from the prior year's Symposium evaluation to allow for cross-year data comparisons. (Note: Follow-up interviews with either educators or stakeholders were not included due to low response rate from 2005 participants and budgetary constraints.)

2.1 On-site instruments for the Symposium

- Registration survey (new for 2006): This data sheet collected all demographic information from participants separate from the overall program questionnaires at the end of each day. A cover sheet allowed for survey ID numbers to be assigned to ensure participants' anonymity. This survey also helped fill in the gaps from incomplete data collected by MOS Science Central staff as part of the telephone registration process. (See Appendix A.)

- Educator questionnaire (used in 2005): This two-page survey, provided in the teachers' packets, was completed at the end of the Symposium and contained both closed and open-ended questions. As can be found in Appendix B, the educator survey measured respondents' learning, interest, and likelihood to continue learning about nanoscale science and engineering before and after attending the workshop. (Changes from prior year's version: demographic questions moved to new registration sheet; separate cover page with name/contact info added; two new questions added; two questions combined into one.)

- Workshop leader questionnaire (used in 2005): This two-page survey, provided in the workshop leaders' packets, was completed at the end of the Symposium and included both closed and open-ended questions to measure their satisfaction with their participation and what they perceived gaining from the workshop. (Changes from prior year's version: separate cover page with name/contact info added.) See Appendix C.

- Individual workshop evaluation form (new for 2006): This five-question survey was distributed to participants in each of the workshops. It asked participants to assess the overall value, amount of learning, and likely classroom use for the workshop content. See Appendix D.

2.2 On-site instrument for Developers' Day

- Participants' Survey (new for 2006): This two-page survey was provided in the packet for Developers' Day participants and collected at the end of the day. It included both closed and open-ended questions to measure their satisfaction with their participation and what they perceived gaining from the experience. See Appendix F.

2.3 Follow-up instrument

- Educator Follow-up Surveys (used in 2005): Surveys were emailed six months after teachers participated in the Symposium to gauge impact, if any, of attendance on: 1) teacher classroom practice; and/or 2) learning/inquiry about nano. Surveys also solicited feedback from participants on potential formats for 2007 Symposium. See Appendix E. The Web survey measured their current level of interest in and understanding of nanoscale science and engineering, and their likelihood of seeking out research and learning opportunities. Open-ended questions explored whether or not educators incorporated nanotechnology into their classroom and in what ways.

III. RESULTS AND DISCUSSION

The first section of the results contains findings related to the Teacher Symposium: 1) registration data; 2) workshop evaluations; 3) end-of-day surveys for both teachers and workshop leaders; and 4) teacher follow-up surveys six months after attending the Symposium. The final section of the results presents findings from the Developers' Day participant surveys.

1. TEACHER SYMPOSIUM REGISTRATION DATA

Of approximately 100 teacher attendees, 85 (85%) filled out registration questionnaires as part of the morning check-in process on the day of the Symposium. Of those completing questionnaires, the typical attendee was a female public high school biology teacher with a master's degree and between one and ten years of teaching experience. She had a moderate incoming interest in nanoscale science, but a low level of basic understanding. She was looking for a professional development program that would help her to keep up with the latest developments in science and technology. She had found out about the Symposium through work or a MOS email, and this was likely her first professional development program at MOS.

1.1 Educator survey respondents were largely female, public high school teachers with graduate-level educational backgrounds and one to ten years of teaching experience.

In addition to the higher number of teachers attending the 2006 Symposium than attended in 2005 (100 vs. 64), the percentage of attendees for whom demographic data were collected was also higher (85% vs. 67%).

Keeping in mind that the results represent reported data only, the demographic profile of 2006 attendees was largely similar to that of 2005 attendees across all categories except two: gender ($p<.05$) and grade level taught ($p<.0035$). (See Table 1.) Of those reporting demographic information in 2006, the gender make-up was approximately two-thirds female to one-third male; whereas in 2005, the reported gender make-up was slightly more than half male. In the case of grade level taught, both years had approximately 50% of attendees who reported being high school teachers, but the percent of middle school teachers increased from 14% in 2005 to 37% in 2006.

Of the 2006 educator participants reporting demographic information, nearly two-thirds (n=54) noted that the Nano Symposium was their first MOS professional development program. There were four participants who had attended the previous 2005 Nanotech Symposium for Educators. Most respondents (39%) indicated having heard about the Symposium at work and/or in an email from MOS (27%). As noted above, the results in these demographic categories are similar to those reported for the 2005 Symposium.

TABLE 1. Demographics of Educator Survey Respondents.[2]

	Count	Percentage
GENDER		
Male	29	34%
Female	50	59%
N/R	6	7%
Total	85	
AFFILIATION		
Middle School	33	37%
High School	46	52%
College/University	9	10%
Other (k-6)	1	1%
Total	89	
YEARS TAUGHT		
Average	11 yrs.	
Standard Dev.	10 yrs.	
Median	8 yrs.	
Range	1 year - 39 yrs.	
No Response	8	
Total Responses	77	
SCHOOL TYPE		
Public	77	91%
Private	2	2%
No response	5	6%
Other (home school)	1	1%
Total	85	

	Count	Percentage
HIGHEST EDUCATION LEVEL		
College coursework	5	6%
Associates degree	0	0%
Bachelors degree	15	18%
Graduate coursework	24	28%
Graduate degree	40	47%
No Response	1	1%
Total	85	
SUBJECT(s) TAUGHT		
Biology	30	21%
Physical Sciences	24	16%
General Science	20	14%
Chemistry	16	11%
Engineering	14	10%
Physics	13	9%
Math	10	7%
Computer Science	3	2%
Other[3]	16	11%
Total	146	
Respondents listing multiple subjects	37	25%
SUBJECT WITH HIGHEST TRAINING		
Biology	27	29%
Physical Sciences	4	4%
General Science	10	11%
Chemistry	11	12%
Engineering	10	11%
Physics	5	5%
Math	5	5%
Computer Science	3	3%
Other[4]	17	18%
Total	92	
Respondents listing multiple subjects	8	9%

[2] Percentages do not necessarily add up to 100% because they are rounded or because respondents listed more than one answer.

[3] Responses included: lang. arts; social studies; technology; anatomy; forensics; marine science; environmental science; earth science; astronomy; and aerospace science

[4] Responses included: earth science; education; technology; environmental science; medicine; anthropology; psychology; art preservation; theology; computer design

2. TEACHER SYMPOSIUM WORKSHOP EVALUATION RESULTS

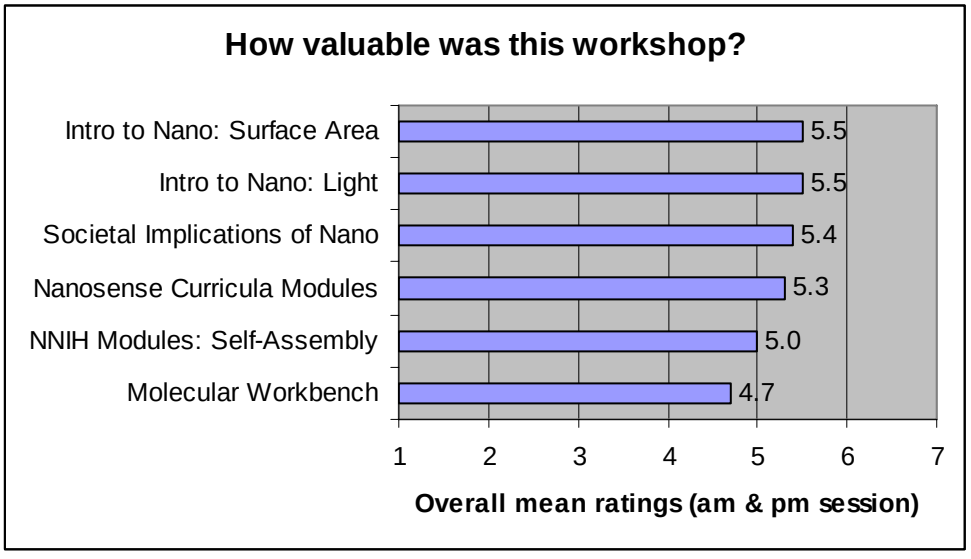
As noted under "Methods" in Section II of this report, individual workshop evaluations were not administered during the 2005 Symposium and, as such, the data reported below represents participant-reported data from the 2006 Symposium only.

Teachers in all workshops generally felt that the workshops were valuable and enjoyed the opportunity to learn something new. Interestingly, for 8 of the 18 overall mean ratings collected for the workshops, there was a statistically significant difference in ratings given by the am and pm sessions of the same workshop. Since the content of the am and pm sessions of the same workshop was identical, these rating differences suggest that some characteristic of the participants was different. The most likely of these participant characteristics are: 1)background knowledge; 2) grade level taught; 3) effect that attending the am workshop had on level of comfort with nano concepts/content in the afternoon sessions.

2.1 Participants largely felt that the workshops were valuable.

With respect to "value," all workshops received mean ratings of 5 or higher on a scale of 1-7 (see Graph 1). The exception to this trend was "Molecular Workbench," which had a mean rating of 4.7 (which is statistically significantly lower than the ratings for the two "Intro to Nano" workshops, but not for the others). The drivers behind the lower mean rating for "Molecular Workbench" were a feeling among some participants that the workshop was not appropriate for the middle school grade level they taught and a feeling of not enough time to become familiar with the software.

GRAPH 1. Workshop Participants' Mean Ratings of Workshop Value.[5]



[5] Scale ranges from 1 to 7, with 1 representing "Not at all valuable" and 7 representing "Extremely valuable."

2.2 Participants Valued Elements That Support Their Own Learning and Their Students' Learning.

Across all the workshops, the valued workshop elements cited most frequently by participants fell into one of five general categories (see Table 2); however, more broadly, they relate to one of two thematic areas: 1) support for teacher learning and 2) support for classroom implementation. These findings mirror the important trend captured across all data instruments: teachers' needs from professional development programs encompass both their own learning and the likelihood of taking that learning and applying it to their classrooms. Future symposia may consider providing teachers with an indication *before the workshop* as to which of these two goals the workshop supports, so that teachers can choose the workshop that best meets their perceived needs.

TABLE 2. Elements of Symposium Workshops Most Valued by Participants.

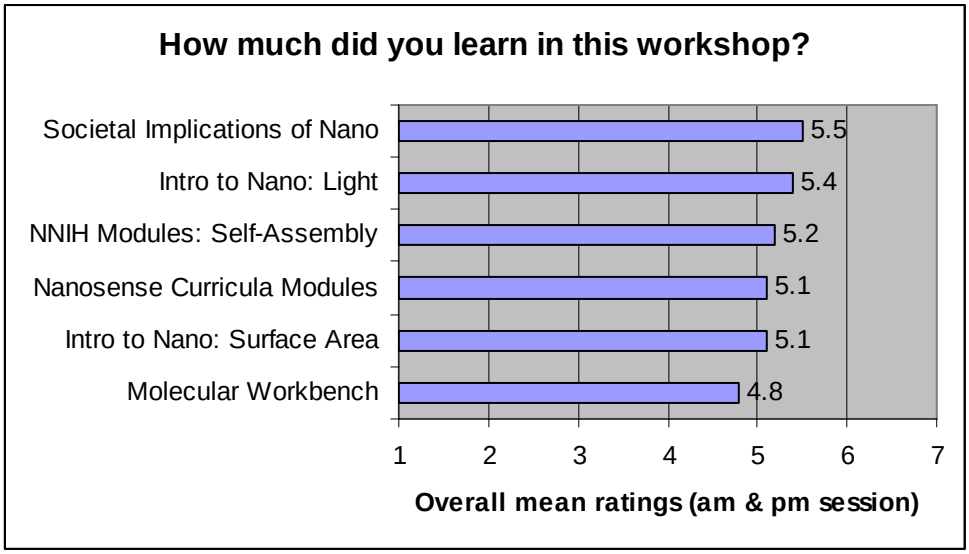
Category	Sample Open-Response Comments
Classroom applicability	*"activities that can be done in the classroom inexpensively" (#P95); "relevant to help me integrate nanotech into my chem classes" (#P105); "useful examples and lessons for use in classroom" (#P163)*
Chance for own exploration	*"the ability to explore the material" (#P16); "thinking about new possibilities" (#P26); "actual opportunity to experience it as a student" (#P159)*
Learning new information, hearing new ideas	*"becoming aware of the programs available" (#P14); "learning about new technology" (#P136); "exposure to modeling which could help me understand more about atoms/molecules energy/heat relationships" (#P2)*
Hands-on activities to try during workshop	*"It was activities-based" (#P44); "the hands-on aspect of all the activities -- plenty for everyone to do all at the same time" (#P92); "the demonstrations and trial activities" (#P58)*
Something physical to take back	*"materials to use and share with others" (#P106); "trying out the activities was helpful, but having all of the activities on paper to take home was great" (#P46); "the free, practical activities to bring back to class" (#P20)*

2.3 Participants Largely Felt That They Learned Something From The Workshops.

There was no significant statistical difference between the overall mean ratings given by participants in all six workshops for amount of learning (see Graph 2). Similar to the ratings given for perceived workshop value, the overall mean ratings for all workshops in terms of participant-reported learning were approximately equal to 5 (on a scale of 1-7). These results are in keeping with those noted in "What Contributed to Their Learning" in section 3.3 of this report: the mean ratings given to workshops on the end-of-day surveys completed by educators were either 4.9 or 5.1.

In light of the importance teachers place on achieving a degree of content understanding or mastery at the end of workshop, it is important for future Symposia to consider what can reasonably and effectively be covered in the time limits of a workshop.

GRAPH 2. Workshop Participants' Mean Ratings of Workshop Learning.[6]



2.4 What did participants learn?

When asked what they learned by participating in the workshop, respondents indicated learning that fell into one of two broad categories: either facts/concepts or teaching activities/techniques. A greater proportion of the responses indicated factual/conceptual learning which suggests that, while participants did learn applications and techniques for the classroom, the primary learning they identified was content-based. See Table 3.

[6] Scale range 1 to 7, with 1 representing "Did not learn anything" and 7 representing "Learned a great deal."

TABLE 3. What Workshop Participants Learned.

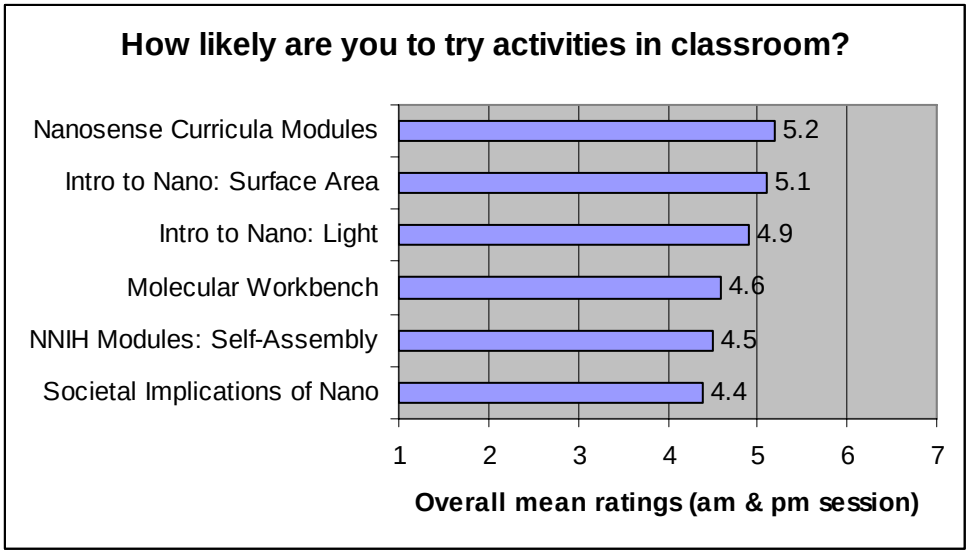
Category	Example Open-Response Comments
General nano-related facts and concepts	*"properties of matter change in many ways at the nanoscale" (#P102); "polarity of molecules" (#P162), "I learned about the structure of nano carbon tubes" (#P133); "that surface area can change properties" (#P50); "importance of Van der Waals forces" (#P22)*
Workshop-specific facts and concepts	*"much about color and light and structure" (#P79); "about clean rooms and people working on nano (#P183); "the process of building these small silicon discs" (#P155)*
Nano applications and implications	*"many uses of nanotechnology" (#P144); "how to weigh the ethical decisions on nanotechnology use" (#P145); "better understanding of nanotechnology implications [and] uses in every day life"*
Activities and methods to use in classroom	*"activities to do with students that show the nano-scale" (#P58); "great activities to use in class to help students understand/conceptualize" (#P68); "learned various activities to get concepts across to my students" (#P120)*

2.5 How likely are participants to try Symposium methods in the classroom?

In contrast to the other overall mean ratings categories, only two of the six workshops ("Intro to Nano: Surface Area" and "Nanosense Curricula Modules") received an overall mean rating for likelihood to try in classroom of ≥ 5 (see Graph 3). However, the only difference in overall ratings that was statistically significant was between the highest rated (Nanosense Curricula Modules) and the lowest rated (Societal Implications of Nano).

When assessing these findings, there are two important points to bear in mind. First, "likelihood of trying activities in classroom" is a complex metric, influenced by a range of factors external to the workshop. Second, asking for predictive measures from participants can prove to be a relatively unreliable measure. Perhaps a more valuable measure would focus on collecting data around what participants identify as those aspects that make activities more or less likely to be tried in the classroom or what they are looking for in the activities they choose to implement.

GRAPH 3. Workshop Participants' Mean Ratings of Likelihood of Trying Workshop Activities In Their Classrooms.[7]



2.6 Factors affecting likelihood to try in classroom

Participants' listed grade level appropriateness, time, resources, fit with curriculum/standards, and their own comfort with the material as the factors most likely to affect whether they would implement nanoscale science concepts/activities into their classrooms (see Table 4). These were the same set of factors as were identified by workshop leaders and as were reported in the evaluation of the 2005 Symposium.

[7] Scale range 1 to 7, with 1 representing "Not at all likely" and 7 representing "Extremely Likely."

TABLE 4. Factors Affecting Likelihood of Applying Symposium Workshop Material in Classroom.

Category	Example Open-Response Comments
Suitability for level of students taught (too basic or too complex)	*"need to find level appropriate for 6th graders. How much to teach/expect without overwhelming" (#P2); "too low a level" (#P48); "this is too advanced for middles school students" (#P7); "too easy" (#P87); "not sure if my kids could handle it" (#P179)*
Time	*"great choices, [but] can only do so much" (#P81); "not sure if time is available for activities where a lot of time is spent deciding what to do" (#P168); "mandatory curriculum makes it difficult; not enough time" (#P165); "since we went to block scheduling we lost time with the students and do not have enough time to cover the core material now" (#P107)*
Resources	*"computer availability" (#P17);"resources" (#P148); money & time to make all the demos for students*" (#P84)
fit with curriculum &/or standards	*"difficulty fitting in with existing curriculum" (#P131); "if they fit into my curriculum they would be interesting for the students" (#P50); "much of this does not fit into my 6th grade science classes" (#P86)"; "light is no longer in Mass Standards or the MCAS test in middle school" (#P82)*
educator comfort with material	*"I'm still taking all this in!" (#P182); "I need to understand more myself first" (#P174); "want to explore software more on my own [first]" (#P22)*

2.7 Suggestions for Improvements

The final question on the workshop evaluation survey asked "How could this workshop have been improved?" Participant suggestions for improvements fell into five major categories that, again, pick up on themes already discussed in prior sections:

- Ensuring a match between session length/format and content complexity (i.e. enough time)
- Addressing/noting grade-level appropriateness of the content for the participant's students
- Addressing/noting level (i.e. beginner or advanced) of the content for the participant
- Addressing link with State teachings standards/frameworks
- Providing physical take-homes/paper copies

3. SYMPOSIUM END-OF-DAY SURVEY: EDUCATOR-REPORTED RESULTS

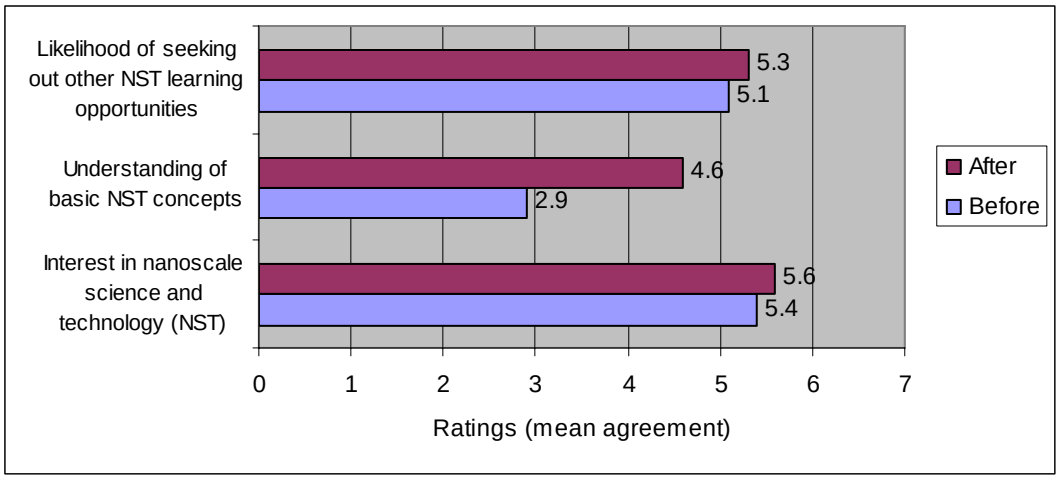
Of the approximately 100 Symposium educators in attendance, 69 (69%) completed end-of-day surveys. According to survey responses, the Symposium was most successful in increasing participant understanding of basic concepts of nanoscale science and technology, and all program elements (except lunch) were rated as having contributed to that learning. Data provided further support for the trend captured across other instruments that teachers attending professional development programs are interested in both their own learning and in classroom applicability. Teachers were most interested in and, correspondingly felt they had learned most

about, nano applications, implications, and concepts. They cited the same likely challenges to implementing nano-related activities and concepts into the classroom that were noted in workshop evaluations and in the 2005 Symposium evaluation, namely, time, resources, fit with standards/curriculum, grade-level appropriateness, and their own understanding of the material.

3.1 Participants reported greatest gains in their understanding of basic nanoscale science.

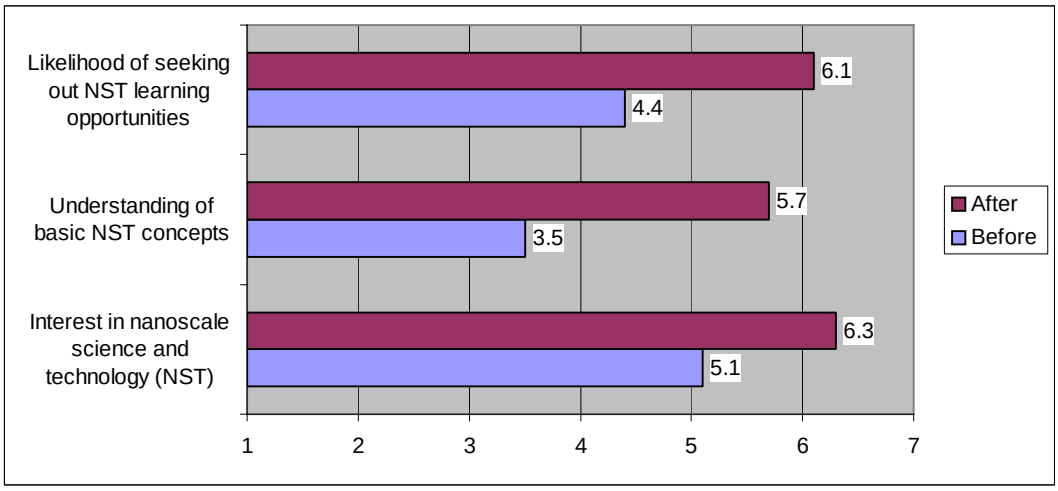
At the end of the Symposium, attendees provided ratings on a scale of 1-7 for the same three ratings categories included on the registration questionnaire: their interest in nanoscale science and technology; their understanding of it; and their likelihood of seeking out further nanoscale science and technology learning opportunities (see Graph 4). Comparing their responses after attending the Symposium to their responses before attending the Symposium, only one category – understanding of nanoscale science – showed a statistically significant difference. These results are in contrast to the 2005 results, which showed statistically significant differences for all of the same three before/after ratings categories (see Graph 5). However, one must bear in mind that there was no pre-symposium survey in 2005; participants were asked to provide both their after ratings *and* their before ratings on the end-of-day survey.

GRAPH 4. Effects of 2006 Symposium Attendance on Educators' Attitudes and Actions.[8]



[8] Scale ranging from 1 to 7, with 1 being low and 7 being high.

GRAPH 5. Effects of 2005 Symposium Attendance on Educators' Attitudes and Actions.[9]



The effect of asking for both before and after ratings at the same time (and at the end of the event) may, potentially, be seen in the statistically significantly higher "after" ratings across all three categories from 2005 respondents.

3.2 Educator Motivations for Attending the Symposium showed split between personal learning and desire for practical classroom applicability.

Teachers were asked to rate on a scale of 1-3, with 1 being the most important, their reasons for attending the Symposium, the most highly ranked reasons included: "keep up with new developments in science and technology" and "practical tips/tools." See Table 5.

TABLE 5. Participants' Reasons for Attending the Symposium.

	# of times receiving specific ranking			Mean Rank
	1	2	3	
Keep up with new developments in science	29	17	6	1.6
Practical tips/tools	23	16	6	1.6
Personal interest in nano	16	13	12	1.9
Improve teaching skills	16	8	10	1.8
Keynote speaker	6	7	13	1.7
Networking	6	10	9	2.3
Friend/colleague recommended	8	6	9	2.0
Principal/supervisor recommended	11	2	9	1.9

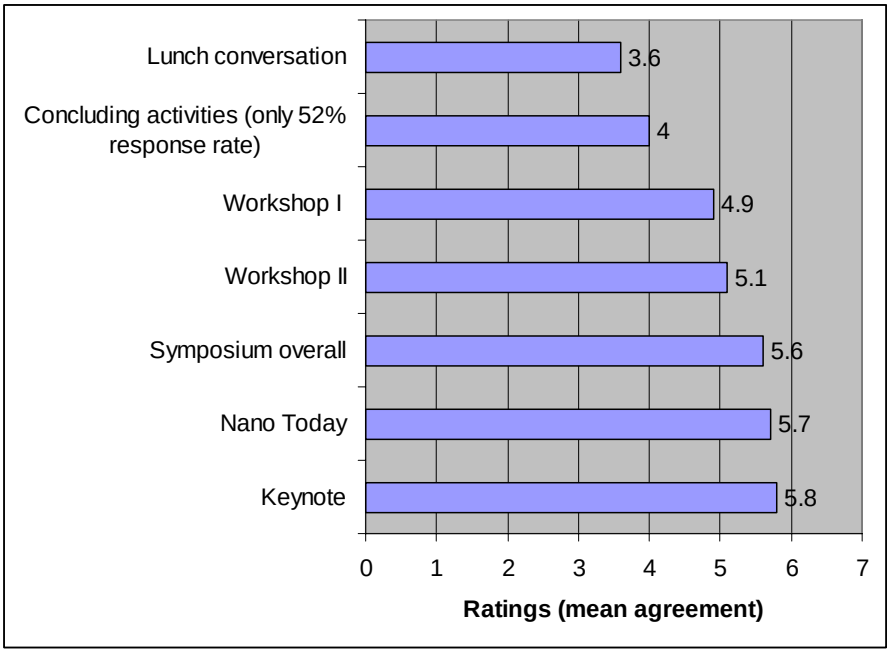
[9] Scale ranging from 1 to 7, with 1 being low and 7 being high.

These results corroborate the findings from the workshop evaluations (prior section), which suggest that teachers assign value to professional development programs that increase their own knowledge, and that this valuation can be independent of their assessment of value in terms of likely in-class application.

3.3 Educators rated most Symposium components as having contributed to their learning about nanoscale science and technology.

Overall, educators responded positively to questions about the Symposium's components and the components' contribution to their learning of basic nanoscale science and technology concepts (See Graph 6). The keynote address by Professor George Whitesides and the Nano Today presentation were perceived as contributing to educators' learning the most (although not statistically significantly higher than the Symposium overall or the afternoon workshop). No significant correlations were found between ratings respondents provided and grade taught.

GRAPH 6. Educator Ratings of 2006 Symposium Components' Contribution to Their Learning.[10]



[10] Scale ranges from 1 to 7, with 1 representing "Did not contribute" and 7 representing "Strongly contributed."

3.4 Educators found both applications and implications of nano to be most intriguing aspect of Symposium.

By far and away, the majority of educators who participated in the Symposium identified either learning about nano's current/future uses or considering the societal implications of nanoscale science as the most intriguing aspects of the Symposium.

TABLE 6. Most Intriguing Aspects of the Symposium to Educators.

Category	Example Open-Response Comments
Applications/products/uses (current and future)	*"potential uses in the future" (#P7); "new technologies for medicine" (#P17); "applications to consumer products" (#P24); "real world applications" (#P39)*
Social implications	*"impacts on society" (#P10); "the applications and societal implications of nano" (#P51); "how this technology will affect life in general" (#P72)*

3.5 Most educators learned concepts, implications, and applications for nano; some learned teaching techniques.

When asked what they had learned that they hadn't known before, many educators provided answers similar to the answers they gave for the most intriguing aspect of the day; that is, uses for and social implications of nanoscience and technology (see Table 7). Additional responses related to nanoscience facts or general concepts. A smaller percentage reported learning tips/techniques for teaching nano to their students (results that mirror those reported in the workshop evaluations [see Table 3]).

TABLE 7. What Educators Learned that They Didn't Know Before.

Category	Example Open-Response Comments
Current uses and applications	*"various applications of nanoparticles" (#P88), "how circuits are made" (#P73); "current products that use nano" (#P69); widespread uses" (#P14)*
General concepts of nanoscale science and engineering / Learned a lot	*"definition of nanotechnology" (#P83); "basic structure of nanoparticles" (#P87); "relative nanoscale sizes in relation to other things" (#P77); "I came in knowing nothing, so this was great!" (#P72); "I did not have a firm understanding of the surface area to volume impact at the nano level" (#P68)*
Specific nano items (buckyballs, carbon nano tubes)	*"what nanotubes are and applications and properties" (#P83); "what a nanotube is" (#P53); "what a buckyball is" (#P51); "buckyball and tube" (#P27)*
Social Implications	*"value of how many ways nanotechnology is already being used and the future implications" (#P111); "how intertwined nanotech actually is already in our society" (#P65); "how it will affect lives…in the future" (#P36)*
Overall field awareness	*"everything going on with it" (#P4); "variety of areas of research/activity" (#P3); "nice to learn about emerging technology from the people doing the research" (#P46)*
Teaching tips/techniques	*"Better way to describe to students what nanotechnology is" (#P32); "how to better incorporate into the curriculum" (#P38); "how to explain nanoscale more clearly to my students" (#P56); "I feel better equipped to do more research and incorporate ideas into my curriculum" (#P67)*

3.6 The time, curricular, and conceptual challenges to incorporating nanoscale in the classroom reported mirrored challenges reported at 2005 Symposium.

For the most part, educators reported the same challenges with implementing nanoscale into the curriculum as had been reported in 2005. These challenges were also corroborated by the findings from the workshop evaluations (see Table 4) listing factors affecting likelihood of implementing nano materials in the classroom.

TABLE 8. Biggest Challenges Educators Foresee in Integrating Nanoscale into Classroom.

Category	Example Open-Response Comments
Time	*"Time! Little opportunity to squeeze more info into our over-stuffed curriculum" (#P60); finding time" (#P49), "lack of time, both to develop the materials and for implementation during class time" (#P47);"time constraints" (#P88)*
Cost/Resources	*"resources" (#P54); "using technology (computers)" (#P53); "access to technology needed" (#P51); "administrative support for $ needs" (#P45); "expense of materials for class" (#P39); "budget cuts" (#P82)*
Curriculum constraints/Fitting into the curriculum	*"Finding time in the curriculum" (#P58); findings time with all the requirements imposed by the DOE's MCAS" (#P50); "where to fit it into the existing curriculum especially with the MCAS" (#P38); not included in MA Frameworks" (#P13)*
Students not developmentally ready	*"overcoming students confusion understanding the scale of nano in relation to the world around them" (#P46); "adapting / making accessible for 7th graders" (#P42); "grasping concepts around scale" (#P12); "may be too advanced" (#P8); "students not at high enough level" (#P77)*
Own lack of knowledge	*"finding someone who is familiar with the topic" (#P43); "time to get to be a subject matter expert in the topic, but I can introduce some basic introductory concepts" (#P16); "I still feel quite inadequate about a basic understanding" (#P9)*

3.7 Suggested improvements for future symposia

The suggestions for improvements for future symposia related broadly to the themes already noted, namely, facilitating educators' ability to select workshops most appropriate for their knowledge level and the grade level they teach (see Table 9). Other trends, such as providing more general focus on educators' own learning and on directly addressing links with curriculum standards/frameworks were also mentioned.

TABLE 9. Educators' Suggested Improvements to the Symposium.

Category	Example Open-Response Comments
Content level guides (for grades taught and participant knowledge)	*"Give level guides for topics/workshops so people don't end up in workshops inappropriate for their interest/knowledge level" (#P3); "Activities were all good but I found descriptions rather vague and could not decide which would be most appropriate for me" (#P50); "Be separated into grade level materials/resources. Need more at middle school level" (#P78)*
Applications to class/ links to standards	*"A focus on what/how to teach concepts to specific age groups. Does it tie into frameworks? How?" (#P6); "Teachers need to understand how to apply this" (#P24)*
Logistics	*"Possibly the final hour could have been made more productive with better use of teachers' time" (#P88); "Less forced conversation during lunch – it would have been nice to just eat" (#P11); "Keep the groups small" (#P46); "better lunch" (#P69); "water/snacks should be available" (#P80)*
More general info	*"Simplify the overall presentations. I have little background in chemistry or physics and it was difficult grasping the big picture at times when I lack the foundation. I heard similar comments from many other teachers." (#P60); "If the NanoTech Today presentation had been done first it would have been great. It would have filled in gaps earlier!" (#P7)*

Educators who responded to this question also wanted further opportunities for follow-up, through workshops, seminars, lectures, or summer institutes. Others suggested that the museum create or provide access to additional exhibits, programs, books, and on-line resources. A handout in the educators' packet listed resources.

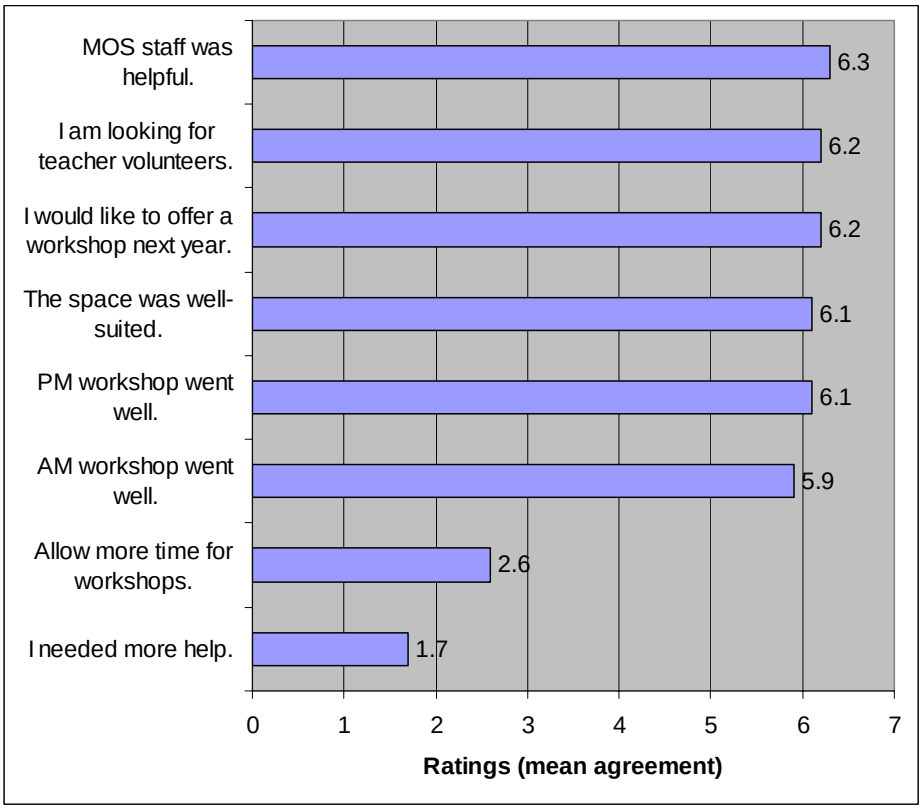
4. SYMPOSIUM END-OF-DAY SURVEY: WORKSHOP LEADER-REPORTED RESULTS

All eight symposium workshop leaders completed end-of-day surveys. Workshop leaders were, generally, interested in leading a workshop again, likely to make changes based on teacher feedback, and likely to keep in touch with teachers/look for teachers to test their materials/ activities. They felt that their workshops were successful and that the Symposium was a worthwhile experience for them, for their organizations, and for educators.

4.1 Workshop leaders felt that their workshops were successful.

Workshop leaders were asked to rate their agreement with a set of statements related to their workshops in general. All statements except "I could have used more assistance" and "The Symposium should shorten other activities to provide more time for workshops" had a mean rating of 6.0 (or above), suggesting that workshop leaders generally felt that their efforts to deliver a workshop at the Symposium were well supported (see Graph 7).

GRAPH 7. Workshop Leader Agreement to Workshop Overall Statements.[11]

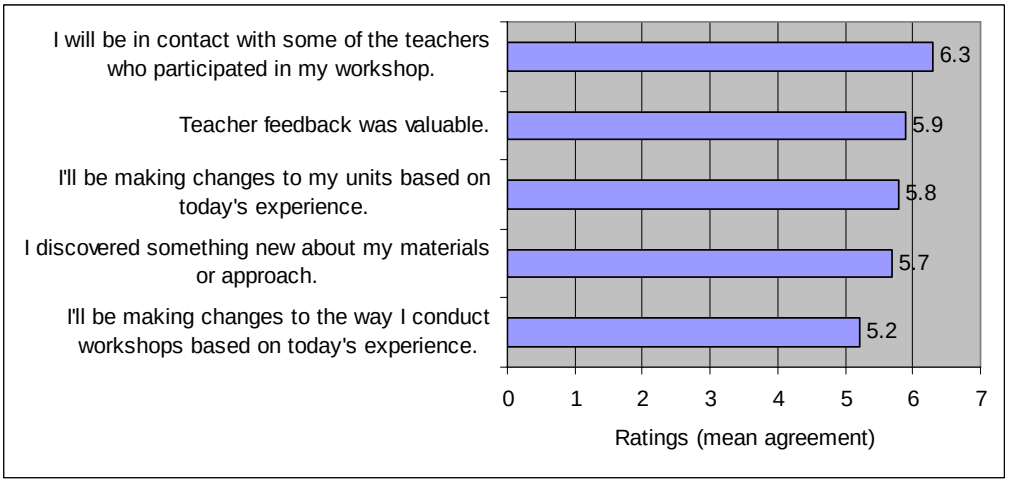


4.2 Workshop leaders benefited from discussions with teachers during workshops.

Workshop leaders were asked to rate their agreement with a set of statements related specifically to the discussions with teachers that took place in their workshops (see Graph 8). All statements received a mean rating of 5.2 or higher, suggesting that the discussions that took place in the workshops were valuable to the workshop leaders.

[11] Scale ranges from 1 to 7, with 1 representing "Strongly disagree" and 7 representing "Strongly agree."

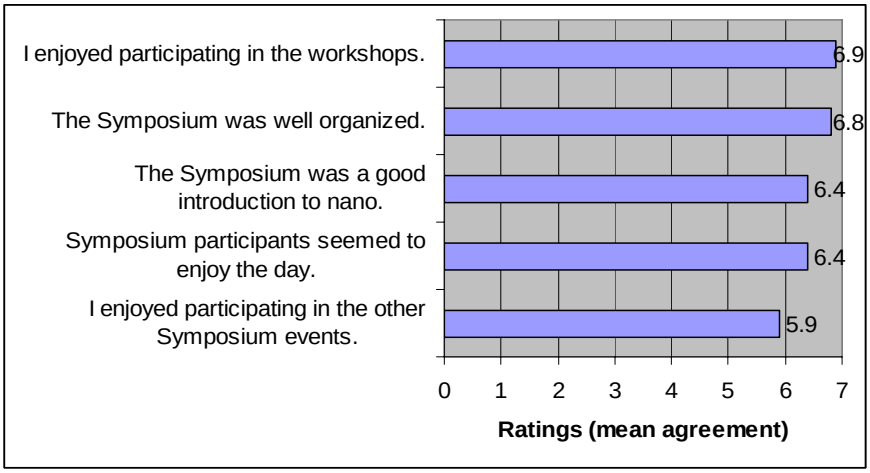
GRAPH 8. Workshop Leader Agreement to Workshop Discussion Statements.[12]



4.3 Workshop leaders rated symposium highly overall.

Workshop leaders were asked to rate their agreement with a set of statements related to the Symposium overall. All statements received a mean rating of approximately 6.0 of higher (see Graph 9). The mean rating for the lowest ranked statement ("I enjoyed participating in the other Symposium events") was significantly lower than the mean rating for the highest ranked statement ("I enjoyed participating in the workshops."). The primary reason for the lower rating was that many workshop leaders were unable to participate in the overall symposium events due to time constraints or the fact that they were the only person administering a given workshop. Future Symposia should look for ways to allow the workshop leaders to participate in the day more fully.

GRAPH 9. Workshop Leader Agreement to Overall Symposium Experience Statements.[12]



[12] Scale ranges from 1 to 7, with 1 representing "Strongly disagree" and 7 representing "Strongly agree"

4.4 Workshop leaders most valued direct interactions with and feedback from teachers.

Nearly all presenters cited direct access to and feedback from teachers as what they valued most about leading a workshop. Other answers included the enthusiasm of the teacher participants. See Table 10.

TABLE 10. Most Valuable Aspect of Symposium to Workshop Leaders.

Category	Example Open-Response Comments
Direct interaction/feedback from teachers	*"to discuss nano ideas w/some very motivated teachers" (#WL260); "hearing teachers' comments, concerns, etc. during the workshop" (#WL00)*
Awareness of what others are doing	*"I got a great overview of what different people are doing and the personnel needed to develop curricula and modules" (#WL258)*
Networking	*"networking to share info" (#WL252)*
Sharing/disseminating info about nano	*"able to share the importance and excitement of nanoscale science and engineering" (#WL261)*

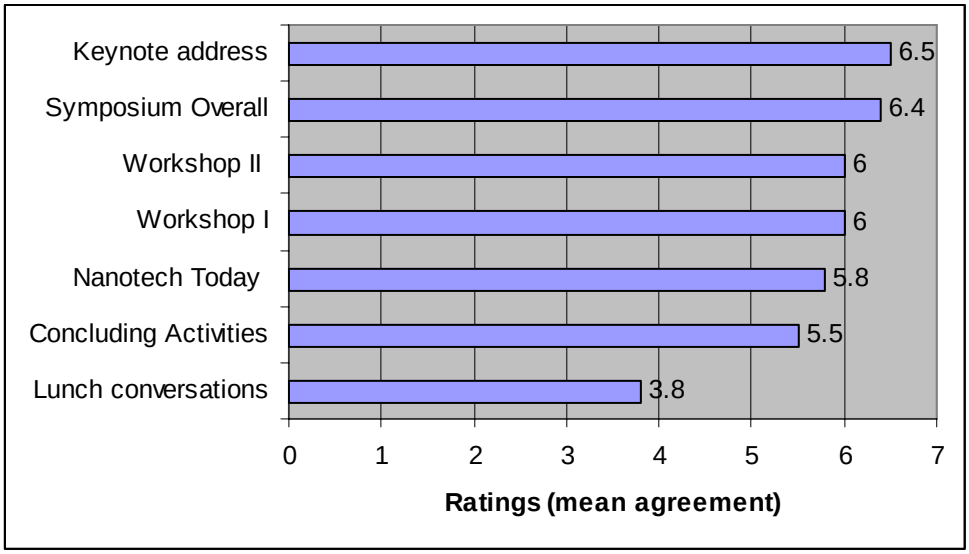
4.5 Workshop leaders' organizations most valued feedback from teachers about materials.

Nearly all presenters cited feedback from teachers about materials/activities as the main value to their organization in participating in the symposium. Other answers included raised awareness about their organization and its work/products.

4.6 Workshop leaders felt most Symposium elements contributed to teacher learning.

Respondents rated all aspects of the symposium except the "lunch conversations" as contributing to teacher learning about nanoscale science; all other aspects had mean ratings of 5.5 or above (see Graph 10). These ratings mirrored those given by the teachers on the end-of-day surveys.

GRAPH 10. Workshop Leader Ratings of Symposium Elements' Contribution to Teacher Learning.[13]



4.7 Workshop Leaders Identified Same Challenges For Integrating Nano Into The Classroom As Were Cited By Teachers.

Presenters enumerated the same main challenges to incorporating nanoscale science into the classroom that teachers noted in their surveys, namely time, fit within curriculum and state standards, limited resources/budget, and how to gearing activities to appropriate level (developmental and grade) for students. (See Tables 4 and 8 in prior sections of this report). Interestingly, the workshop leaders did not mention teacher knowledge as a potential barrier to integration of nano into the classroom.

[13] Scale ranges from 1 to 7, with 1 representing "Strongly disagree" and 7 represents "Strongly agree."

4.8 Suggested improvements related to logistics, support, and access to findings.

TABLE 11. Workshop Leaders' Suggestions for Change.

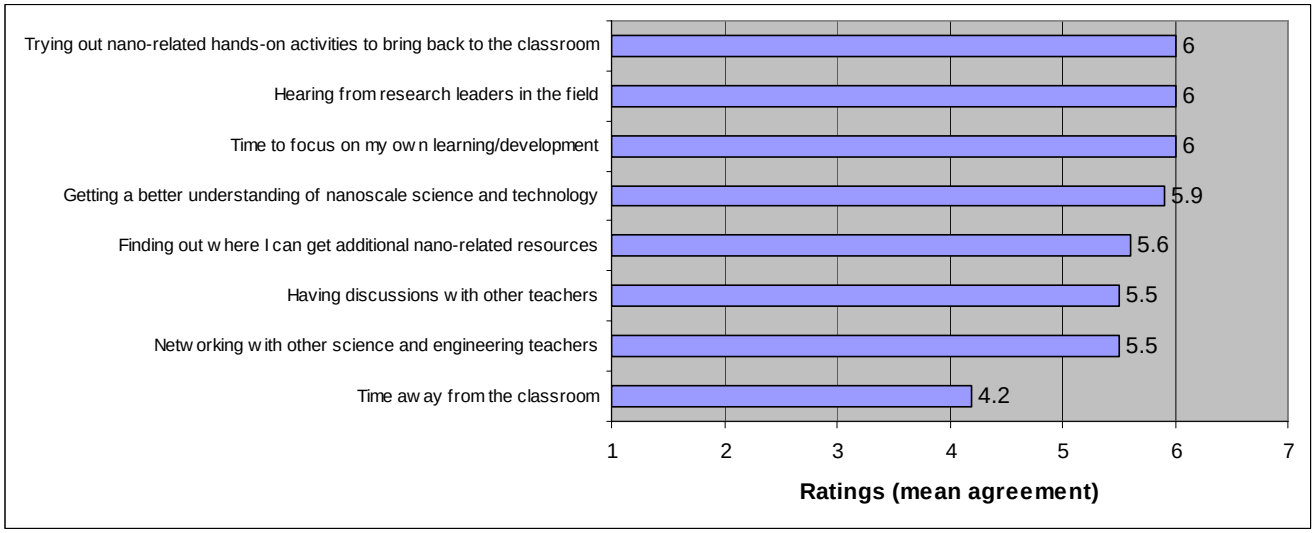
Category	Example Open-Response Comments
Logistics	*"bigger tables" (#WL255), "more time for workshops" (#WL261); "no time for presenters to see other presentations. No potty breaks!" (#WL260); "I did not attend Whiteside's presentation b/c I had to set up for the workshop." (WL#000)*
Support (staffing or financial)	*"Even though MOS picked up the hotel bill, the expense was relatively costly. [I] could only afford to support one team member attending. If MOS could pick up great proportion of costs, it would be more feasible to attend next year. As a single presenter with multiple lab set-ups, [it] would be helpful to be assigned a "helper" to be with presenter all day to assist with setup and break down, cover during bathroom breaks, etc." (WL#000)*
Access to Evaluation Data	*"I would like the ability to gather data on how workshop went. I know you collected the data, but would be nice to look at forms ahead of time so questions specific to presenters' workshop could be added. The feedback is critical to all of our projects and this Symposium represents a good opportunity to collect it. Perhaps, in coordination with the [MOS] evaluator, we could target feedback...to our goals. We…did not receive the evaluation report from last year. It would still be nice if it were made available to us."(#WL000)*

2. EDUCATOR FOLLOW-UP SURVEYS

In late April and early May 2007, the 43 educators who had provided their contact information were emailed a request to fill out a brief Web survey measuring their current attitudes towards nanoscale science and technology and seeing if they had incorporated nanotech into their curricula. A total of 26 educators (60%) responded.[14]

5.1 Educators valued a range of symposium elements.

GRAPH 11. Symposium Elements Most Valued By Educators.[15]



5.2 Educators talked about nanoscience/technology and noticed/accessed more information about it after participating in the Symposium.

After attending the Symposium, most educators reported:

- Discussing nanotechnology with other adults (92%),
- Accessing a Web site related to nanoscale science and technology (68%),
- Noticing related news in the mass media (68%),
- Searching for more information (64%),
- Recommending the workshop to others (64%),
- Discussing nanoscience with students (64%),
- Presenting nanoscience information to students (60%),
- Looking for nanotechnology products (40%)

[14] This higher response rate to follow-up emails in 2005 was likely related to the offer of two free OMNI passes upon completion of the survey.

[15] Scale ranges from 1 to 7, with 1 representing "No value to me" and 7 representing "High value to me."

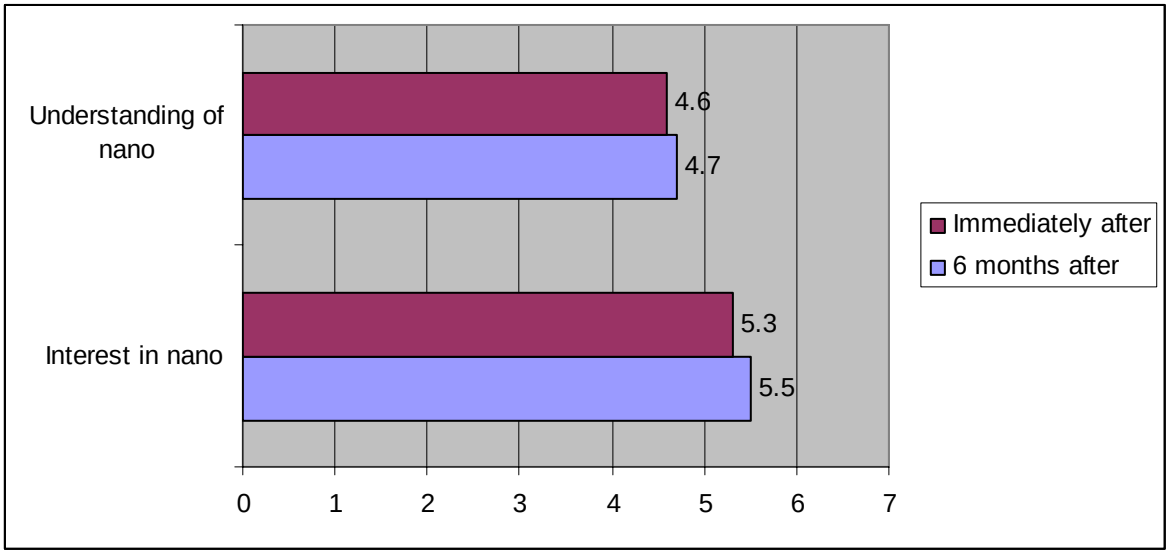
- Accessing the Museum of Science's Web site (nano section) (24%)

Other actions by one respondent each included the following: wrote to someone in the nanotechnology field, signed up for a related research opportunity or bought a book, or kept in touch with a Symposium participant or leader.

5.3 Six months after attending, educators' interest in and understanding of nanoscale science remained constant.

In the end-of-day survey educators filled out at the Symposium, they were asked to rate their interest in and understanding of nanoscale science and technology before and after attending the Symposium. Six months later, when asked to fill out the same questions, there was no statistical difference between their ratings for both measures. These findings are in contrast to the 2005 Symposium evaluation results that showed that, six months post-symposium, both educator interest and understanding levels had decreased. It is important to bear in mind that the respondents to the follow-up survey were a self-selected sub-group of educators who indicated interest in participating in follow-up evaluation studies and, therefore, more likely to anticipate having activity to report in such studies (although certainly the same would apply to the prior year's respondents as well).

GRAPH 12. Teacher-Reported Gains Related to Nano Six Months Post-Symposium.[16]



[16] Scale ranges from 1 to 7, with 1 representing "Strongly disagree" and 7 represents "Strongly agree."

5.4 More than a third of the educators reported having incorporated some nanoscale science concepts or activities into their classrooms.

When asked if they had incorporated nanoscale science concepts or activities into their classrooms, 9 of the 24 respondents who completed the question (38%) indicated that they had, and 4 of 24 (17%) indicated that they had plans to do so in the coming school year. This is a marked increase over the results reported six months after the 2005 Symposium. See Table 12 for types of nanoscale activities.

TABLE 12. Types of Nanoscale Science Concepts/Activities Educators Reported Implementing or Planning to Implement in Their Classrooms.

Category	Example Open-Response Comments
General discussions or articles	*"integrated it into many of our discussions" (#WS12); "I have brought in an article for my anatomy students to read about how nanotubes are being considered as a possible ideal scaffold upon which to grow new bone tissue" (#WS7); "In my AP physics class we discussed the possibility of the space elevator and on our field trip to the MOS we listened to a talk on nanotechnology" (#WS21); "I have created a PowerPoint on future technologies" (#WS24)*
Developed own classroom activities	*"I am the computer teacher and have introduced the concepts to all my classes up through fifth grade. My First Lego League Robotics team completed a research project on nano technology and a nano cure for diabetes" (#WS8); "I have developed a three week unit for my students. We produced a packet of information for them to take home and hopefully teach others. It was very successful." (#WS27)*
Used symposium-specific activities	*"I did the lab for making fruit fly prisons" (#WS5); "the Stanford group's 'nanosense'" (#WS3); "Molecular Workbench from the Concord Consortium" (#WS22); "I plan to use the UV beads" (#WS25 & #WS2)*

5.5 Reasons for not integrating nanoscale science concepts or activities into the classroom echoed challenges identified in workshop surveys and symposium end-of-day questionnaires.

As noted in previous results sections, the challenges for integrating nanoscale science and technology concepts and activities into the classroom remain consistent.

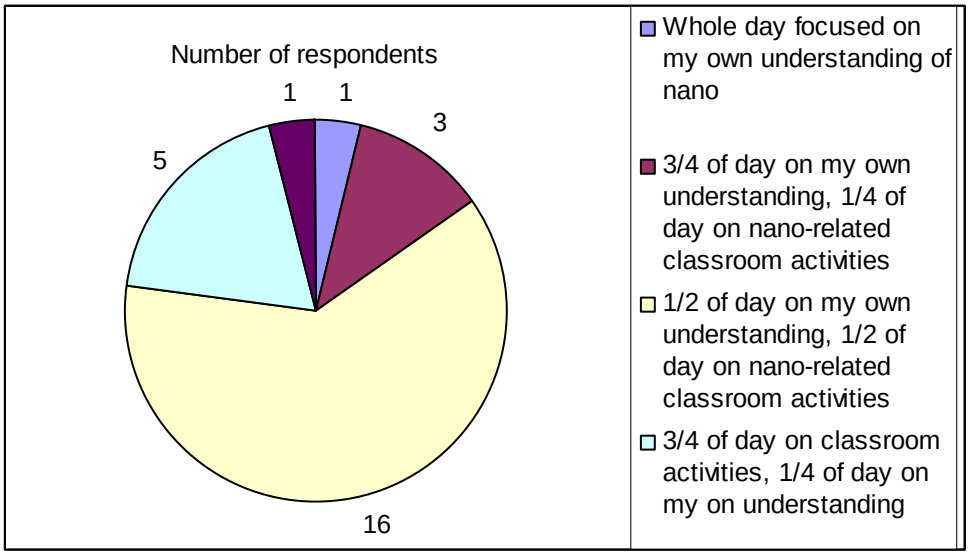
TABLE 13. Reasons for Not Integrating Nanoscale Science Concepts/Activities in Classroom.

Category	Example Open-Response Comments
Own lack of knowledge/ understanding	*"I do not have enough of an understanding of the technology to share with my students. I need a follow up course or a magazine or web site like 'Current Science' to break it down into manageable, teachable topics. I haven't given up on learning about nanotechnology, I just have not found an easy informative vehicle to learn from." (WS#16); "I feel as though I am not an expert regarding nanotechnology. I enjoy reading about new developments in the field. I try to bring information to my classroom when I can make a connection to what is happening in the classroom." (WS#13)*
Time	*"I simply ran out of time" (WS#14); "time restraints…I can only fit so much into the shoebox!" (WS#11)*
Fitting into curriculum/state standards	*"not sure where to fit it in" (WS#9); "It is not directly covered by the MA standards" (WS#6); "state and district mandated curriculum is very rigidly scheduled" (WS#4); "Curriculum is glutted with MCAS prep" (WS#20); "special needs of my students" (WS#17)*
Appropriateness for grade level taught	*"It is more of a high school topic than middle school, which I teach" (WS#6); "I was teaching younger students" (WS#4)*

5.6 Majority of respondents would prefer that future symposia focus equally on their own learning and on classroom activities.

When asked what emphasis they would give to the structure/elements of future Symposia, nearly two-thirds of the respondents indicated giving equal weight to both their own understanding and to classroom related activities (see Graph 12). It is unclear, however, whether the respondents viewed the 2006 Symposium as having had this distribution of focus. Nevertheless, the important point to recognize is that teachers view their own understanding of a topic to be as critical as having classroom activities to implement.

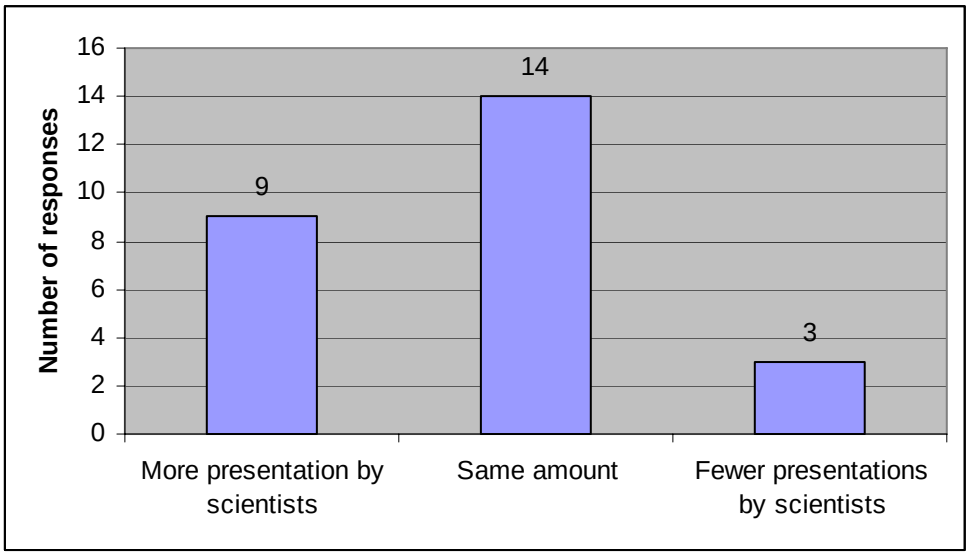
GRAPH 12. Teacher Preference For Symposium Program Emphasis.



5.7 Majority of respondents wanted same amount of lecture as was included in 2006 Symposium.

When asked whether they would like have heard more or less nano content during the Symposium in lecture or presentation format, slightly more than half of the respondents indicated that they wanted the same amount as was included in the 2006 Symposium (see Graph 13).

GRAPH 13. Teacher Preference for Percentage of Symposium Content in Lecture Format.



5.8 Ideas or suggestions

The final question asked participants to provide any further ideas of suggestions that they wanted to share with the event organizers. Responses echoed similar themes captured by other evaluation instruments.

TABLE 14. Ideas or Suggestions Shared By Follow-up Survey Participants.

Category	Examples of Open-Response Comments
Balance between own learning and classroom activities	*"Shorter, but more hands-on breakout sessions could have been really useful. It's very difficult to choose one or two sessions to attend, especially when one is still trying to build a knowledge base" (#WS4); "I thought it was really good. The biggest problem for me was trying to figure out how to put stuff into the curriculum" (#WS5); "Though I did not get a lot of strong classroom materials, I learned and that's always worthwhile!" (#WS23); "I am very thankful that industry and scientists want to have a role in helping teachers stay current and informed" (#WS16).*
Continue to offer similar/ more symposia	*"Please continue these kinds of programs at the Museum of Science. The Nanotech program was one of the best professional development experiences I have had in twelve years of teaching" (#WS13); "Create more symposiums like this for life sciences!" (#WS7)*
Revise closing activities	*"The one part I found to be least valuable was the closing segment, where we discussed implementation with other teachers. Given that I don't work with any of these teachers and have a different teaching situation than them, I did not find this to be helpful. More time on content or student activities would have been a better fit for me" (#WS14)*
Take-aways	*"The PowerPoints presented by the museum and other presenters should be made available for participants" (#WS24); "More tangible things for the students" (#WS27).*
Logistics	*"Do a later start (to avoid the horrible traffic) and stay later (to avoid the horrible traffic!) I'd suggest 10-6" (#WS6); " I liked the working lunch to get more of the time" (#WS12)*

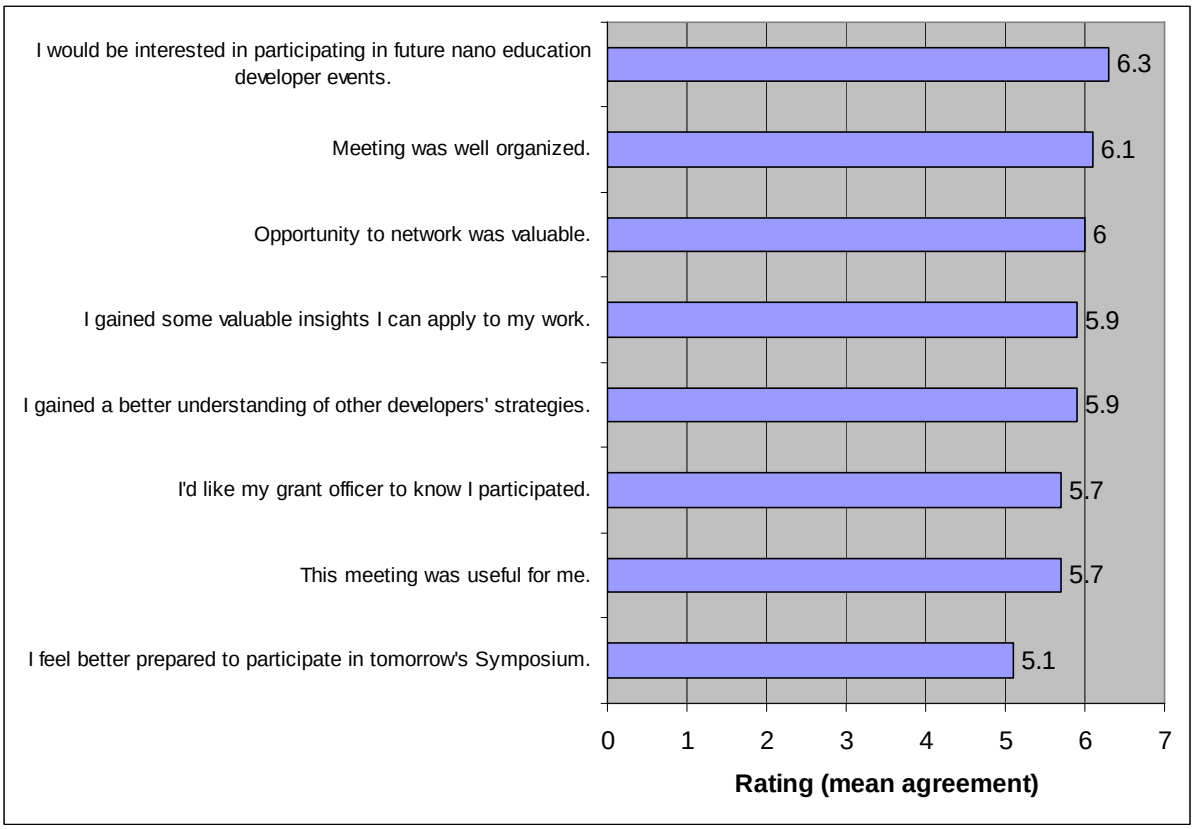
6. DEVELOPERS' DAY SURVEY RESULTS

Of the approximately 40 Developers' Day participants, 21 (52%) completed end-of-day surveys. (Note: Four survey respondents only filled out one side of the survey due to late distribution of forms.) The majority of respondents were attending the Symposium on the following day, but most were not workshop leaders. Overall, participants valued the full day focused on sharing best practices in nano curriculum development. They were most interested in learning about what other developers were doing and wanted even more time to share, discuss and ask questions. They felt that the daylong format should continue and indicated interest in participating in Developers' Day (or other developer events) again.

6.1 Developers felt the day was valuable and would like to participate in other, similar events.

Overall, participants were very positive about their experience and rated all statements 5.1 or higher (see Graph 14). The statement with the lowest rating, "I feel better prepared to participate in tomorrow's Symposium," was likely rated lower because a) only eight attendees were workshop leaders for the following day; and/or b) the day was not largely focused on logistical preparation/orientation for workshop leaders (although this is something workshop leaders indicated as needing to be increased/changed).

GRAPH 14. Developer Day Participant Agreement with Overall Program Description Statements.[17]



6.2 Hearing about what others are doing was most interesting aspect of the day.

When asked what aspect of the day they found most interesting, participant responses fell into four broad categories, the most frequently cited being "learning about what others are doing/what's out there." Other common responses related to seeing specific materials, examples, resources, etc.; discussing how to integrate nano into curriculum; and networking. See Table 15.

[17] Scale ranges from 1 to 7, with 1 representing "Strongly disagree" and 7 represents "Strongly agree."

TABLE 15. Aspect of Developers' Day Participants Found Most Interesting.

Category	Examples of Open-Response Comments
Learning about what others are doing/ what's out there	*"learning about what others were doing" (#DD7); "It provided time to learn about what others are doing" (#DD8); "summaries of tomorrow's presentations/ workshops" (#DD22); "useful to see what other people are up to" (DD20)*
Specific materials, examples, resources	*"hearing examples of curriculum materials" (#DD6); "hands-on activity developments that explain nanoscience concepts" (#DD11); "lesson plans" (#DD12)*
Integrating nano into curriculum discussion	*"the facts surrounding why the education system doesn't change and how we can only make a change or affect our immediate area" (#DD9); "discussions about integrating nano into educational curriculum" (#DD22); "how each program is implemented and interaction with students and teachers and the program's impact" (#DD15)*
Networking	*"networking -- learning about other programs" (#DD21); "meeting others" (#DD17)*

6.3 Networking and ideas/resources were most valuable aspects of the day.

When asked what aspect of the day they found most valuable, participant responses fell into four broad categories: networking; hearing new ideas/different perspectives; receiving helpful resources/tools; gaining specific tips or strategies (e.g., curriculum integration, frameworks, dissemination &/or teaching strategies). See Table 16. These responses echo themes noted (above) in their responses about the day's most interesting aspect.

TABLE 16. Aspect of Developers' Day Participants Found Most Valuable.

Category	Examples of Open-Response Comments
Networking	*"to meet new people doing this work, seeing the development occurring and seeing old 'nano friends'" (#DD5); "networking with other individuals connected in the same interest area" (#DD9); "meeting people in the field and networking" (#DD22)*
Hearing new ideas/different perspectives	*"hearing how other people think about nano curriculum" (#DD2); "different view points" (#DD4); "a few new ideas and better insight into what's going on around the country" (#DD17)*
Receiving helpful resources/tools	*"Web sites/list of useful tools I can use and also ways to increase dissemination methods" (#DD11); "ideas, web resources" (#DD12)*
Gaining specific tips or strategies	*"discussions about developing curriculum and challenges in fitting into k-12 standards" (#DD6); "get ideas for projects/programs" (#DD7); "sense of how to structure activities, their place in framework" (#DD13)*

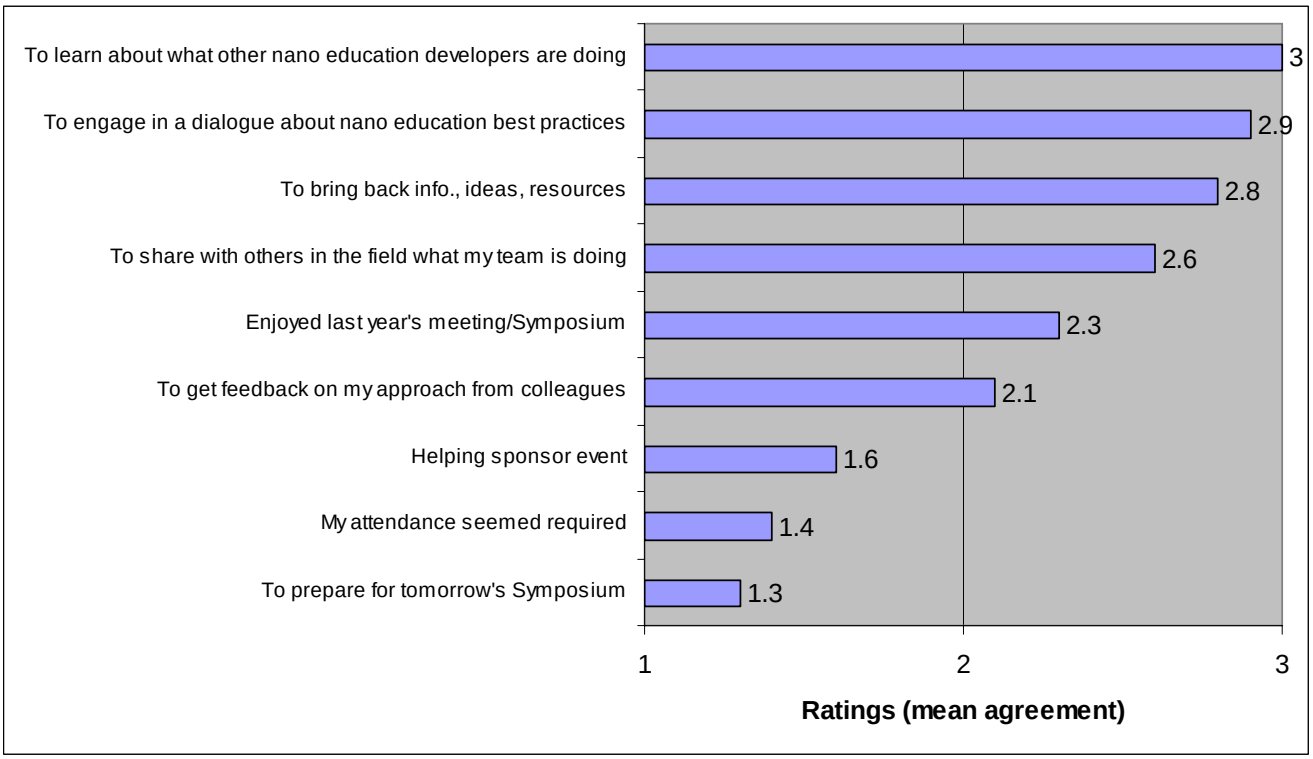
6.4 Participants gained insights around specific implementation formats and approaches.

Survey respondents were asked, **"**Please jot down a few of the insights you gained from today's meeting about the ways in which people are approaching the development of nano education classroom resources." Their comments noted having learned about new formats (games, videos, Web sites, hands-on) for curricula and about the similarities/differences in the approaches employed by other curriculum developers. For some, the event raised questions about whether the work presented at the event had been researched/field-tested or whether it was incorporating existing educational research.

6.5 Learning about what other developers are doing was reason most participants attended.

Participants were asked to rate on a scale of 1-3 (with 1 being "least important" and 3 being "most important") a list of factors that may have influenced their decision to attend Developers' Day (see Graph 15). The top four responses all related to wanting an opportunity to learn from/ share with others in the field. The fact that preparing for the next day's symposium was the lowest rated factor, adds color to the result reported in section 5.1 (above), namely, that while participants rated the statement "I feel better prepared to participate in tomorrow's Symposium" relatively low (compared with other statements), preparation for the Symposium was not their primary reason for attending the event.

GRAPH 15. Developers' Day Participants Reasons for Attending.[18]



[18] Scale ranges from 1 to 3, with 1 representing "Least important" and 3 representing "Most important."

6.6 Participants looking for more teachers to be in attendance.

When asked, "Who else should be invited to Developers' Day?" the most frequently cited request was that more teachers be included to provide perspective on having tried activities in their classrooms or about state curriculum standards. Other suggestions included: faculty mentors in RET program; representative from NSF; and NanoLeap developers from Mid-continent Research for Education and Learning.

6.7 Participants recommended more time for discussion and Q&A to be included.

By far and away the most frequent suggestion survey respondents provided for improvement for any future Developers' Day was to allow for more time for questions, whether after each presentation or in open discussion or in guided dialogue. Or, said another way, they requested that future developer events allow for more participant involvement. Other suggestions included creating a central Web site with links, contact information, and sample materials (see next section); discussing underlying concepts/ideas for an hour or two; and allowing time for small group break-out/collaboration.

6.8 Participants want help staying abreast of efforts in the field.

The final survey question asked, "How could the Museum of Science or the Nanoscale Informal Science Education Network be of further assistance to you in the future?" Nearly all respondents indicated a desire for a central clearinghouse/resource to aggregate all work being done in the field of nano curriculum development. The following comment is illustrative of these requests: "There is still not much communication across the nano-ed community. We need some mechanism to learn what is occurring at various sites and your efforts are greatly appreciated in attempting to do this each year" (DD8). In short, curriculum developers have a hard time keeping up on what their peers are doing and would look to MOS or NISE Network to help them share and access materials and news more effectively (and regularly).

IV. RECOMMENDATIONS

With such consistent outcomes from year to year, many of the prior evaluation recommendations still apply:

- Considering alternate structure (or open structure) for the lunch and concluding activities,
- Providing more time for workshop leaders to see their fellow presenters' workshop, content and/or to participate more generally in the overall Symposium activities,[19]
- Addressing directly teacher challenges for integrating materials into the classroom,
- Addressing the learning needs of teachers as both adult learners and as classroom educators to self-select appropriately into workshops, and
- Creating central Web site to house resources for both teachers and content developers that enable them to keep abreast of ongoing work in the field.

Aside from these repeat recommendations, there was the additional question of what format for the Symposium would be most effective for facilitating educators' dual needs for improving their own knowledge and for bringing classroom activities back to their classrooms. To this end, perhaps the Symposium should reassess its goals vis-à-vis teachers.

- **If curriculum integration is the goal rather than subject-matter teacher knowledge**: If teachers are reporting having obstacles to overcome to implementing nano content in their classrooms, perhaps the Symposium should consider adding a workshop(s) that specifically address those obstacles. For example, a workshop focusing on what State standards could be addressed using nano labs/activities or a workshop that shows how to introduce nano without using sophisticated technology. In this case, outcomes measured and assignment of "value" by participants would be expressly linked to classroom integration potential. Alternatively, workshop leaders could be asked to specifically address this issue during each individual workshop.[20]

- **If teacher subject-matter knowledge is the focus:** The data show that teachers come in with different backgrounds and grade levels, suggesting perhaps separating workshops both by level for the participants (beginners vs. intermediates) and by grade level of students that participants teach (middle vs. high school). In this case, the more important outcomes to measure would be those that relate to the teacher as a free-choice adult learner.

Another means to address this question of format/structure is to simply re-order the day's events to use the morning portions as the introduction/content elements (lectures, presentations, etc.) then have lunch, and then allow the workshops in the afternoon to build upon the base of knowledge established in the morning. The workshops could still remain a mixture of foci on content or curriculum implementation (as long as they were clearly labeled to allow educators to

[19] The addition of the Developer's Day was supposed to provide workshop leaders with exactly this opportunity. The persistence of this request, however, suggests that the Developer's Day as it was implemented did not fully meet this need.

[20] The latter approach was the one pursued during the 2007 Symposium.

choose those best suited for them, based on their reasons for attending and their level of understanding of nano).

V. CONCLUSION

Overall, findings reveal that the Symposium largely achieved its goals: educators and workshop leaders alike left the Symposium feeling as though they had gained something – greater knowledge, networking contacts, and valuable feedback. The follow-up educator survey confirmed this perceived gain in the months after the event. In terms of content, educators found the applications and implications of nanotechnology to be most intriguing. In addition, the expansion of Developers' Day to a three-quarters-day format was valued by the participants.

Of primary importance for future Symposia is addressing educators' need to feel as though they can make informed choices about what workshops to attend, how to tailor the content for their classes, etc.; in short, facilitating their ability to design what they want to learn and take away from the day. Many, though not all, educators are new to the topic of nanoscience and come to learn more about it, focusing less on immediate classroom implementation.

As for workshop leaders and curriculum developers, their primary need and interest is hearing from their peers and from educators, so any opportunities to meet that need even more effectively should be pursued.

APPENDIX A: NANO 2006: A SYMPOSIUM FOR EDUCATORS: REGISTRATION QUESTIONNAIRE FOR EDUCATORS

Please help us tailor this and future symposia to best meet your needs by answering the following questions.

Is this your first time attending a professional development (PD) program at the Museum?

- ☐ yes
- ☐ no

If no, please list other PD program(s) you have attended:

_____
_____
_____
_____

How did you hear about this program? (Check all that apply.)

- ☐ at work
- ☐ club/organization _____
- ☐ email (from _____)
- ☐ flyer (from _____)
- ☐ friend or colleague
- ☐ online message board
- ☐ paper mailing
- ☐ print media (e.g., newspaper, magazine)
- ☐ through my school/college
- ☐ website (url):_____)
- ☐ other:_____

What is your gender?

- ☐ Female
- ☐ Male

What grade level do you teach?

- ☐ 6-8
- ☐ 9-12
- ☐ college/university

Is your school public or private?

- ☐ public
- ☐ private

What subject(s) do you teach? (Check all that apply):

- ☐ biology
- ☐ chemistry
- ☐ computer science
- ☐ engineering
- ☐ general science
- ☐ math
- ☐ physical science
- ☐ physics
- ☐ other: _____

How many years have you taught science/engineering/technology?

_____ years

Did you attend last night's Forum (*Nano Future: Privacy & Security*)?

- ❑ yes
- ❑ no

What is your highest level of education in science and/or engineering?

- ☐ some college courses
- ☐ associate's degree
- ☐ bachelor's degree
- ☐ some graduate coursework
- ☐ graduate degree

In what subject area is your highest level of training?

- ☐ biology
- ☐ chemistry
- ☐ computer science
- ☐ engineering
- ☐ general science
- ☐ math
- ☐ physical science
- ☐ physics
- ☐ other:

_____

How interested are you in nanoscale science and technology? (check one number)

- ☐ 1 Not at all interested
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7 Very interested

How much do you feel you understand basic nanoscale science and technology concepts? (check one number)

- ☐ 1 Low level of understanding
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7 High level of understanding

<u>After today, how likely are you to seek out further opportunities to learn about nanoscience and technology?</u>

- ☐ 1 Not at all likely
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7 Very likely

APPENDIX B: NANO 2006: A SYMPOSIUM FOR EDUCATORS: EDUCATOR SURVEY

Please help us better understand your experience by answering the following questions. Thank you.

1a. Having attended the Symposium, how interested are you now in nanoscale science and technology:

Not at all interested Very interested
1 2 3 4 5 6 7

1b. What aspect(s) of nanoscale science and technology discussed during the Symposium did you find most intriguing?

2a. Having attended the Symposium, how much do you now feel that you understand basic nanoscale science and technology concepts:

Low level of understanding ***High level of understanding***
1 2 3 4 5 6 7

2b. What did you learn during the Symposium that you didn't know before?

3. How would you describe the level of the content presented at the Symposium:

Too basic ***Too advanced*** ***Just right*** ***Not sure***

4a. How much did the following contributed to your learning about nanoscale science(s)?

	Did not contribute						Strongly contributed
a. Keynote address – George Whitesides	1	2	3	4	5	6	7
b. Workshop I: (list title)	1	2	3	4	5	6	7
c. Nanotech Today presentation	1	2	3	4	5	6	7
d. Lunch conversations	1	2	3	4	5	6	7
e Workshop I: (list title)	1	2	3	4	5	6	7
f. Concluding activities	1	2	3	4	5	6	7
g. Symposium Overall	1	2	3	4	5	6	7

4b. Please comment on how any of the above activities could be improved in future Symposia.

5. Please rate from 1 to 3 (with 1 being the most important) your reasons attend the Symposium:

_____ ***Personal interest in nanotechnology***	_____ ***Friend/colleague recommended***
_____ ***Keynote speaker***	_____ ***Principal or supervisor recommended***
_____ ***Networking***	_____ ***To gain practical teaching tips/tools for my class***
_____ ***To improve my teaching skills***	_____ ***To keep up with new developments in science***
_____ ***Other (please list: _____)***	

6a. What are the biggest challenges you foresee, for you and your students, with incorporating material from the workshops into your class(es)?

6b To what extent did this symposium provide you with materials/techniques to help you incorporate nano-science and engineering topics into your classroom?

Not at all						***Very much***
1	***2***	***3***	***4***	***5***	***6***	***7***

6c. How could the Museum further help you incorporate nano-science and engineering topics into your classroom?

7. If offered again, how likely are you to recommend this Symposium to other science & engineering educators?

Not at all likely						***Very likely***
1	***2***	***3***	***4***	***5***	***6***	***7***

8. Having attended the Symposium, how likely are you to seek out further opportunities to learn about nano-science and engineering?

Not at all likely						***Very likely***
1	***2***	***3***	***4***	***5***	***6***	***7***

9. How likely are you to consider applying to participate in a Research Experience for Teachers Summer Program?

Not at all likely						***Very likely***
1	***2***	***3***	***4***	***5***	***6***	***7***

10. How could the Museum further help you learn about nanoscale science and engineering?

APPENDIX C: NANO 2006: PRESENTER/WORKSHOP LEADER SURVEY

Please help us better understand your experience by answering the following questions. Thank you.

1. *Rate your agreement with the following statements:*

	About your workshop overall:	*Strongly disagree*						*Strongly agree*
a.	***My morning workshop went well***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
b.	***My afternoon workshop went well.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
c.	***I could have used more assistance during the workshop.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
d.	***My workshop space was well-suited for the activities I had planned.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
e.	***Museum staff were helpful to me in setting up my space***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
f.	***I would like to offer a workshop again next year.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
g.	***If offered again next year, the Symposium should shorten other activities to provide more time for workshops.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
h.	***I am looking for volunteer teachers to try-out my classroom materials.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
	About your workshop discussions:	*Strongly disagree*						*Strongly agree*
i.	***I gained valuable feedback from the teachers participating in my workshop.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
j.	***I discovered something new about my materials or approach.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
k.	***Based on today's experience, I'll be making some changes to my curricula unit(s).***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
l.	***Based on today's experience, I'll be making some changes to the way I conduct teacher workshops.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
m.	***I will be in further contact with some of the teachers who participated in my workshop.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
	About the Symposium overall:	*Strongly disagree*						*Strongly agree*
n.	***Today's Symposium was well-organized.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
o.	***I enjoyed participating in my workshops.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
p.	***I enjoyed participating in the other Symposium events (i.e. aside from my workshop)***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
q.	***Symposium participants seemed to enjoy the day.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
r.	***The Symposium provided teachers with a good one-day introduction to nano science/ engineering and related classroom activities.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***

Please use this space to comment on any of your above ratings:

2. What was of greatest value to you in participating as a workshop leader in today's Symposium?

3. What do you think was of greatest value to the organization you represent in offering a workshop here today?

4. What insights did you gain today about issues teachers might face when trying to implement your classroom units?

5. Please rate the following on the extent to which you perceive that they contributed to teacher learning about nanoscale science(s)?

	Did not contribute						**Strongly contributed**
a. Keynote address – George Whitesides	1	2	3	4	5	6	7
b. Workshop I (please list title below) Title:	1	2	3	4	5	6	7
c. Nanotech Today presentation	1	2	3	4	5	6	7
d. Lunch conversations	1	2	3	4	5	6	7
e Workshop II (please list title below) Title:	1	2	3	4	5	6	7
f. **Concluding activities**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
g. **Symposium Overall**	**1**	**2**	**3**	**4**	**5**	**6**	**7**

6. What improvements can you suggest for the Symposium if we hold it again next year?

APPENDIX D: NANOTECHNOLOGY EDUCATORS SYMPOSIUM: WORKSHOP EVALUATION FORM

Please help the Museum of Science improve future workshops by providing us with comments.

This is (please check one): ☐ ***Workshop I (morning)*** ☐ ***Workshop II (afternoon)***

Title of workshop (please check one):
☐ ***Molecular Workbench: Nanoscience with Interactive Computer Models***
☐ ***Intro to Nanoscale: Inquiry into Surface Area***
☐ ***Intro to Nanoscale: Manipulating Light in the Nanoworld***
☐ ***NanoSense Curricula Modules: Size Matters and Clear Sunscreen***
☐ ***Societal Implications of Nano***
☐ ***NNIN Classroom Modules: Self-Assembly in Nanotechnology***

1a. How valuable did you find this workshop?

Not at all valuable						***Extremely valuable***
1	***2***	***3***	***4***	***5***	***6***	***7***

1b. What did you value most about this workshop?

2. On a scale of 1 to 7 how much do you feel you learned in this workshop?

Learned nothing						***Learned a great deal***
1	***2***	***3***	***4***	***5***	***6***	***7***

2b. What, if anything, did you learn?

3a. How likely are you to try some of these activities in your classroom?

Not at all likely						***Very likely***
1	***2***	***3***	***4***	***5***	***6***	***7***

3b. Why or why not?

4. How could the workshop have been improved?

APPENDIX E: FOLLOW-UP WEB SURVEY FOR EDUCATORS

Museum of Science

Dear Nanotech Symposium 2006 participant,

Thank you for agreeing to share your thoughts about your Nanotech Symposium experience with us. Your responses will be used to make improvements to the Symposium for next year, so please be as candid as possible (note: your survey responses will be kept confidential and will not be linked to your name. All findings will be reported to the program staff in aggregate.)

As a token of our appreciation for your time completing this survey, we would like to offer you **two passes to the Omni theater** at the museum. Once you complete the survey, you will be prompted on a separate screen to enter your name and mailing address, so that we can send the tickets to you. (Note: this information will be kept separate from your survey responses.)

Thank you, again, for participating in the Symposium and for sharing your thoughts with us. If you have further questions about this survey and how it will be used to improve the Symposium, please contact the Research and Evaluation Department at researcheval@mos.org.

1.) Please rate your level of interest in nanoscale science and technology:

Not at all interested						Very interested
1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

2.) Please rate how much you feel you understand basic nanoscale science concepts:

Understand very little						Understand a lot
1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

3.) Did attending the 2006 Nano Symposium prompt you to . . .
(check all below that apply)

- ☐ discuss nanoscale science and technology topics with other adults (colleagues, friends, family)
- ☐ search for more information about nanoscale science and technology
- ☐ access an Internet Web site related to nanoscale science and technology
- ☐ access the Museum of Science Web site's nanotechnology section
- ☐ purchase a book or other item related to nanoscale science or technology
- ☐ look for nanotechnology products
- ☐ notice nanoscience-related information in mass media venues (e.g., newspaper, TV, radio)
- ☐ write to someone in the field of nanoscale science or technology
- ☐ sign up for a research opportunity in nanoscale science or technology
- ☐ recommend the museum workshop to others
- ☐ discuss nanoscience with your students
- ☐ present nanoscience information to your students

- ☐ do some other activity. Please explain:

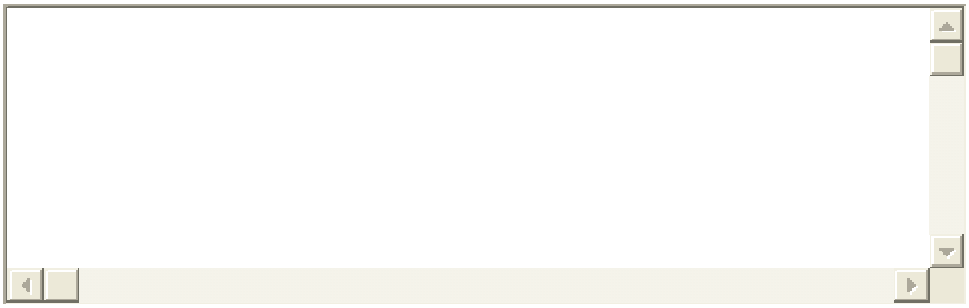
4.) Thinking back on your experience at the Symposium, please rank the following in terms of their value to you (personally and/or professionally) on a scale of 1-7, with 1 being "no value" and 7 being "very high value."

	No value to me						Very high value to me
	1	2	3	4	5	6	7
Time away from the classroom	☐	☐	☐	☐	☐	☐	☐
Time to focus on my own learning/development	☐	☐	☐	☐	☐	☐	☐
Getting a better understanding of nanoscale science & technology	☐	☐	☐	☐	☐	☐	☐
Networking with other science and engineering teachers	☐	☐	☐	☐	☐	☐	☐
Hearing from research leaders in the field	☐	☐	☐	☐	☐	☐	☐
Trying out nano-related hands-on activities I could bring back to the classroom	☐	☐	☐	☐	☐	☐	☐
Finding out where I can get additional nano-related resources	☐	☐	☐	☐	☐	☐	☐
Having discussions with other teachers	☐	☐	☐	☐	☐	☐	☐

5.) Have you incorporated nanoscale science concepts or activities into your classroom yet?

If you *have* incorporated nanoscale science into your classroom curriculum, please describe what you did and how successful or unsuccessful the experience was for you and your students.

If you have *not* incorporated nanoscale science into your classroom curriculum, please describe why you haven't.



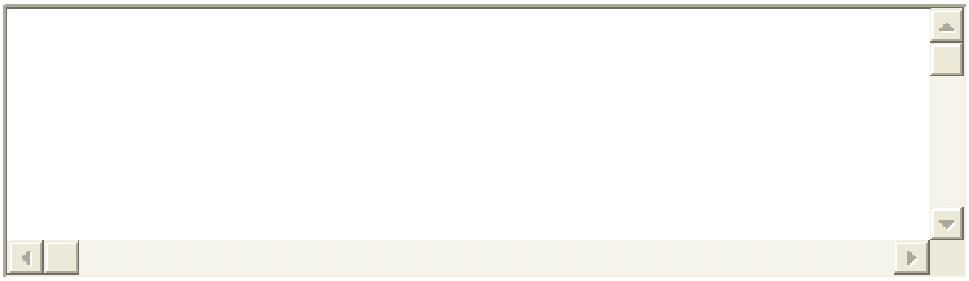
6.) The Symposium included elements to increase your understanding of nanoscience and elements to expose you to nanoscience-related activities to bring back to your classroom.

If you had designed the Symposium to serve your personal and professional needs as of Nov, 2006, where would you have put your emphasis? (Note: please assume that the sessions on classroom activities would be grade appropriate and tied to state standards.)

Choose one option closest to your emphasis:

- ☐ The whole day focused on my own understanding of nanoscience
- ☐ 3/4 of the day focused on my own understanding of nanoscience, 1/4 of the day on nanoscience-related classroom activities
- ☐ Half of the day on my own understanding of nanoscience, half of the day on nanoscience-related classroom activities
- ☐ 3/4 day focused on nanoscience-related classroom activities, 1/4 of the day on my own understanding of nanoscience
- ☐ The whole day focused on nanoscience-related classroom activities

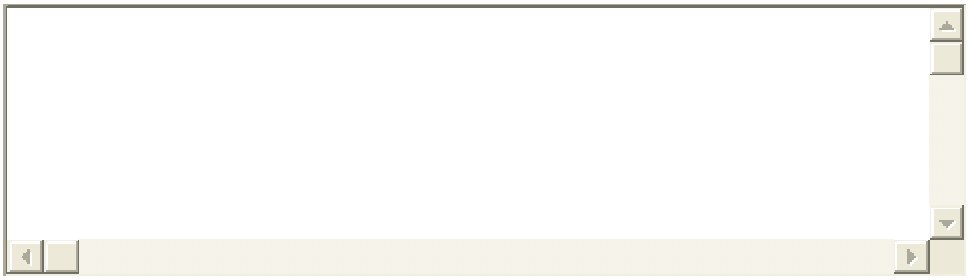
Please explain your answer to question #6:



7.) Given what you recall of the scientists' talks at the Symposium, would you like to have heard more or less nano content in a presentation/lecture format?

- ☐ More presentations by scientists
- ☐ Same amount
- ☐ Fewer presentations by scientists

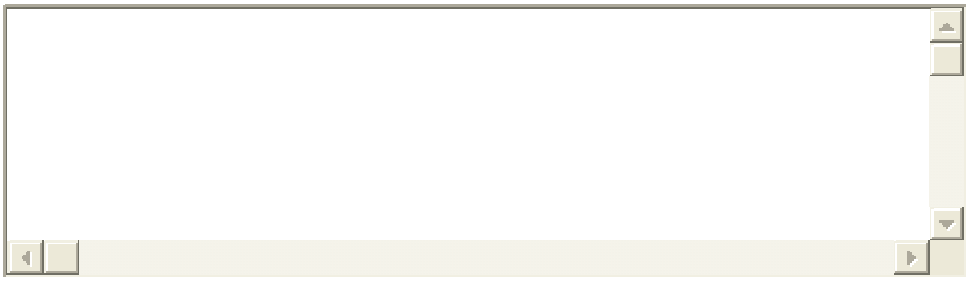
Please comment here if you have further ideas about presenters or the content for presentations:



8.) Would you rather:
(Select one)

- ☐ arrive at 8:00am and have a continental breakfast
- ☐ arrive at 8:30am and not have breakfast provided

9.) Do you have any other suggestions or ideas to share with us?



Thank you for sharing your thoughts with us. If you have further questions about this survey and how it will be used to improve the Symposium, please contact the Research and Evaluation Department at researcheval@mos.org.

When you press "submit" you will be directed to another screen on which you can enter your name and mailing address, so that we can send you your complimentary Omni theater passes.

APPENDIX F: DEVELOPERS' DAY PARTICIPANT SURVEY

2006 NANOTECHNOLOGY EDUCATION DEVELOPERS' DAY:
PARTICIPANT SURVEY

Please help us better understand your experience by answering the following questions. Thank you

1. Rate your agreement with the following statements.

		Strongly disagree						Strongly agree
a.	***Participating in today's meeting gave me a better understanding of the strategies/ approaches of other nano education developers.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
b.	***The opportunity to network with colleagues was valuable.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
c.	***Today's meeting was well-organized.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
d.	***I feel better prepared to participate in tomorrow's Symposium.***	***1 n/a***	***2***	***3***	***4***	***5***	***6***	***7***
e.	***This was a useful meeting for me.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
f.	***I gained some valuable insights I can apply to my work.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***
g.	***I'd like my grant program officer(s) to know that I participated in today's meeting.***	***1 n/a***	***2***	***3***	***4***	***5***	***6***	***7***
h.	***I would be interested in participating in other future nano education developer events.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***

2. What aspect of today's meeting was most interesting to you and why?

3. What was the most valuable thing you gained by participating in today's meeting?

4. How much did you learn about what others are doing to support teaching nanoscience in the classroom:

Nothing A great deal

1 2 3 4 5 6 7

5. Please jot down a few of the insights you gained from today's meeting about the ways in which

6. Please rate the extent to which each of the following was an important factor, if at all, in your decision to attend today's meeting:

		Least important			Most important	
a.	***I am helping to sponsor this event***	***1***	***2***	***3***		***n/a***
b.	***I enjoyed last year's meeting and Symposium.***	***1***	***2***	***3***		***n/a***
c.	***My attendance seemed to be required.***	***1***	***2***	***3***		***n/a***
d.	***To help me prepare for tomorrow's Symposium***	***1***	***2***	***3***		***n/a***
e.	***To get feedback on my approach from my colleagues***	***1***	***2***	***3***		***n/a***
f.	***To share with others in the field what my team is doing***	***1***	***2***	***3***		***n/a***
g.	***To learn about what other nano education developers are doing***	***1***	***2***	***3***		***n/a***
h.	***To engage in a dialogue about nano education best practices***	***1***	***2***	***3***		***n/a***
i.	***To bring back information, ideas, resources, etc. to my institution***	***1***	***2***	***3***		***n/a***
j.	***Other (please list):***	***1***	***2***	***3***		***n/a***

7a. If you attend next year's symposium, would you be willing to attend a pre-Symposium meeting similar to today's meeting? ☐ ***Yes*** ☐ ***No*** *Why/why not?*

7b. Who else should be invited to this pre-Symposium meeting if it is held again next year?

8. Please comment on how this or future meetings for nano educators/developers could be improved.

9. How could the Museum of Science or the Nanoscale Informal Science Education Network be of further assistance to you in the future?

10. Will you be:

*Attending tomorrow's Symposium?	☐ **Yes** ☐ **No**	*Offering a workshop tomorrow?	☐ **Yes** ☐ **No**	*Attending tonight's Forum **(*Nano Future: Privacy & Security*)?** *Why/why not?	☐ **Yes** ☐ **No**

APPENDIX G: SYMPOSIUM MATERIALS AND HANDOUTS

Museum of Science

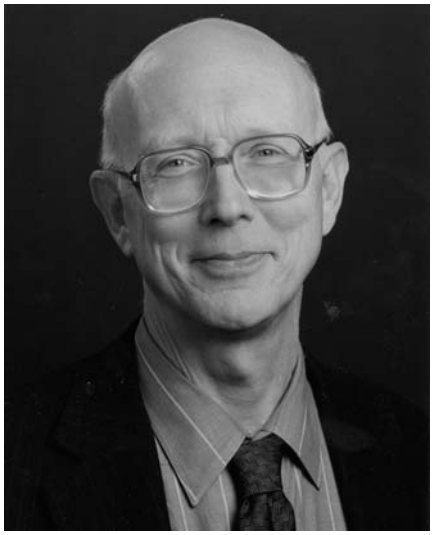
Nanotech 2006: A Symposium for Educators

Boston | Tuesday, November 7, 2006

PROGRAM

Registration and Continental Breakfast Lobby	8:00-8:30 Museum
Seating in Cahners Theater, 2nd floor, Blue Wing	*8:30-8:40*
Welcome: Ioannis Miaoulis, Museum President and Director	8:40-8:50
Keynote Address: Professor George Whitesides	8:50-9:50
Transition to Workshops—Session One *Museum staff guides to various venues…*	*9:50-10:00 Follow*
Workshops: Session One venues	10:00-11:30 Various
Transition to Current Science & Technology Stage *Museum staff guides…*	*11:30-11:40 Follow*
Tim Miller presents *Nanotech Today* Science & Technology Stage, 1st floor, Blue Wing	11:40-12:00 Current
Transition to Skyline Room *Green Wing Elevator or Stairs to 6th floor*	*12:00-12:10*
Lunch with Special Emphasis Gatherings Room, 6th floor	12:10-1:00 Skyline
Transition to Workshops—Session Two *Museum staff guides to various venues…*	*1:00-1:10 Follow*
Workshops: Session Two venues	1:10-2:40 Various
Transition to Skyline Room	*2:40-2:50*
Concluding Activity and Debriefing with Refreshments Raffle Prizes, Parking Stamps, Certificates of Attendance Skyline Room, 6th floor	2:50-4:00

KEYNOTE SPEAKER



George M. Whitesides. Woodford L. and Ann A. Flowers University Professor. Born, 1939, Louisville, KY. A.B., Harvard, 1960. Ph.D., 1964, California Institute of Technology (with J.D. Roberts). Faculty: Massachusetts Institute of Technology, 1963 to 1982; Harvard University, 1982-present. **Awards:** American Chemical Society (ACS) Award in Pure Chemistry (1975). James Flack Norris Award (ACS, New England Section) (1994). Arthur C. Cope Award (ACS) (1995). Defense Advanced Research Projects Agency Award for Significant Technical Achievement (1996). National Medal of Science (1998). Von Hippel Award (Materials Research Society) (2000). Pittsburgh Analytical Chemistry Award (Society for Analytical Chemists of Pittsburgh) (2003). Kyoto Prize (2003). Paracelsus Prize (Swiss Chemical Society) (2004). Ralph and Helen Oesper Award (Cincinnati Section of ACS) (2004). Jacob Heskel Gabbay Award in Biotechnology and Medicine (2004). 2004 Dickson Prize in Science (Carnegie Mellon University) (2005). Dan David Prize (Dan David Foundation) (2005). Emanuel Merck Lecture Prize, (Technische Universität Darmstadt/Merck) (2005). Linus Pauling Medal Award (Portland, Puget Sound and Oregon Sections of ACS) 2005. Welch Award (The Welch Foundation) (2005), Priestley Medal (ACS) (2007).

Memberships and Fellowships. American Academy of Arts and Sciences, National Academy of Sciences, National Academy of Engineering, American Philosophical Society, Royal Netherlands Academy of Arts and Sciences, Institute of Physics, Foreign Fellow of the Indian National Science Academy, and Honorary Fellow of the Royal Society of Chemistry. **Public Service:** National Research Council; National Science Foundation; National Institutes of Health; Department of Defense (DARPA DSRC, 1984- ; Defense Science Board (1992-2002); DTRA Treat Reduction Advisory Committee (1998-). Intelligence Science Board (2003-). **Present research interests include:** physical and organic chemistry, materials science, biophysics, complexity and emergence, surface science, microfluidics, optics, self-assembly, micro- and nanotechnology, science for developing economies, catalysis, origin of life, and cell-surface biochemistry.

Museum of Science

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WORKSHOPS

Each workshop will be offered twice, once in the morning and once in the afternoon.
Symposium participants will be able to attend two of the six workshops.
Spaces are limited; Sign-up is first-come, first-serve.
To sign up, email nano@mos.org listing at least four workshops in order of preference.
Those who do not sign up in advance will be assigned to workshops based on availability.
Links to specific science standards are covered in each workshop.

A. Molecular Workbench: Nanoscience with Interactive Computer Models

Robert Tinker, President, The Concord Consortium

It is difficult to develop an intuitive understanding of nanoscience concepts because the nano-scale world is so unfamiliar: thermal motion is ceaseless, atoms stick, electric fields dominate, and gravity is negligible. A powerful way to understand this world is to experience it through the Molecular Workbench (MW): a free, comprehensive computational model developed with NSF funding. Using MW, students can explore the nano-scale world and investigate the mechanisms behind liquid crystals, self-assembly, protein conformation, and nano-machines. Unlike animations and visualizations, these models let students experiment with models by constructing their own object and changing the fundamental properties of atoms and molecules. (Grades: 9-12 and Middle School)

B. National Center for Learning & Teaching in Nanoscale Science and Engineering

This NSF-funded Center's primary focus is on *learning and teaching through inquiry and design of nanoscale materials and applications.* Center members are developing curricular activities based on the latest laboratory research, using nanoscale concepts to enhance existing science and mathematics courses while providing students with exposure to the cutting-edge technology. Following a combined introduction to the overall approach, participants will split into two classroom unit workshops. ***Choose B1 or B2:***

B1: Introduction to the Nanoscale: Inquiry into Surface Area

Ken Turner, Chemistry Teacher, Schaumburg HS, Schaumburg, IL

As an introduction to the nanoworld, the inquiry-based curricular activities are designed to (1) give students a feel for just how small is the nanoscale, (2) give students practice in communicating nanoscale quantities and relating them to the familiar macroscale, and (3) illustrate the first and foremost property that increases in importance at the nanoscale: surface area. Students are engaged in various hands-on activities to investigate the effects of changing surface area with size/shape of different forms of sugar, polymers, and models. The activities culminate in a card game that further reinforces the foundational knowledge of size, scale, and surface area relationships at the nanoscale. **(**Grades: 7-12)

B2: Manipulating Light in the Nanoworld

Diane Riendeau, Physics Teacher, Deerfield HS, Deerfield, IL

Students explore size-dependent properties of nanoscale materials through their interaction with light. A home-made spectroscope is used to compare light emission from nanoscale light sources in which size determines spectral output (the color of light produced) and from macroscopic light sources, for which size is not a determining factor. The interactions of light with micro and nanoscale structures (such as soap films and bird feathers) also reveal the production of color due to wave interference effects. The activities culminate in students designing their own artificial opals made from nanoscale-sized spheres. **(**Grades: 7-12)

(cont'd next page….)

C. NanoSense Curricula Modules: Size Matters and Clear Sunscreen

Tina Stanford, Educational Researcher, SRI International

NanoSense is an NSF-funded effort to develop 4-5 curricular modules that can be used to introduce nanoscale science into standard high school classes in physical science, integrated science, chemistry, and physics. The first two units, Size Matters (an introduction to nanotechnology) and Clear Sunscreen (dealing with different sized particles involved in blocking UVA and UVB wavelengths) have been pilot tested, revised, and are now freely available at our website: http://www.nanosense.org. Teachers in this workshop will be given an overview of the NanoSense curriculum and of the pedagogical philosophy of teaching an emergent science in the classroom. Copies of the two complete modules will be handed out. Participants will also participate in selected activities that demonstrate 'the science' behind nanotechnology, designed to give hands-on experience demonstrating how properties of the same material can change in going from bulk to nanosized particles. Make your own UV bead bracelet, to keep. (Grades: 9-12)

D. NNIN Classroom Modules: Self-Assembly in Nanotechnology

How do scientists build something so small?

Nancy Healy, NNIN Education Coordinator, Georgia Tech

Diana Palma, Assistant NNIN Education Coordinator, Georgia Tech

The National Nanotechnology Infrastructure Network, an NSF-funded consortium of research institutions, also fosters development of supplementary classroom modules for middle schools and high schools. The unit to be explored in this workshop includes two hands-on inquiry-based activities: *The Fly Prison* introduces students to nanotechnology and uses modeling to demonstrate how researchers build very small devices through molecular self-assembly; *The Water Maze* is a follow-up activity designed to give students the opportunity to demonstrate what they have learned. The activities require no chemicals and use common, inexpensive materials. They are designed for high school students who have an understanding of how atoms and molecules interact. Participants will receive take-away copies of the teacher and student guides and the materials needed to build the models. Participants will also receive an overview of another NNIN classroom module, *Exploring Nanotechnology through Consumer Products.* This unit includes an activity for students to make class presentations on nanotech-based products and the underlying science, and also provides information on education and career opportunities. Teachers will receive the teacher and student guides, a CD of the PowerPoint presentation used in the activity (with teacher notes for each slide), and a resource list for purchasing nano-products used in the unit. (Grades: 9-12)

E. Societal Implications of Nanotechnology *and Materials Science Education Materials from the University of Wisconsin-Madison MRSEC*

Aura Gimm, Department of Biomedical Engineering, Duke University

Ken Gentry, Postdoctoral Associate, University of Wisconsin-Madison MRSEC

The Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces at the University of Wisconsin-Madison is an NSF-funded interdisciplinary center for research on the formation, characterization, and exploitation of materials at the nanoscale. The Interdisciplinary Education Group of the MRSEC brings this research to the public through kits, web resources, demonstrations, activities, workshops, lab development, and journal publications. This workshop will consist of two activities exploring the intersection of advanced research and society. NanoCommunities is a small group activity appropriate for middle school, high school, and college science and engineering students, in which small groups think about the positive and negative impacts that a new nanomaterial might have on a hypothetical community. NanoVenture is a Monopoly-style board game for high school and college students in which players are the ruler of a small country and must manage the emerging science of nanotechnology in order to lead their country to prosperity. (Grades: middle through college)

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SPONSORS and ORGANIZERS

Program Partners

- **Center for High-rate Nanomanufacturing NSEC**
  Northeaster University and University of Massachusetts-Lowell
  http://www.nano.neu.edu

- **Nanoscale Systems and Their Device Applications**
  Harvard University and M.I.T.
  http://www.nsec.harvard.edu

- Nanoscale Informal Science Education Network
  http://www.nisenet.org

- The National Center for Learning and Teaching in Nanoscale Science and Engineering
  http://www.nclt.us

- The National Center for Technological Literacy
  http://www.nctl.org

- National Nanotechnology Infrastructure Network
  http://www.nnin.org

- University of Wisconsin / Madison NSEC, MRSEC, and Institute for Chemical Education
  http://mrsec.wisc.edu/Edetc/

- The Concord Consortium
  http://www.concord.org

- SRI International
  http://www.sri.com

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NANOTECH WEB RESOURCES

Nanoscale Science and Engineering Education

- NanoSense Project, curricula and activities developed by SRI International. www.nanosense.org
- Integrating Nanotechnology into the K-12 Classroom. Ken Bowles, Apopka High School, has a K12 Nanotechnology PowerPoint for teachers, a teaching module, and a Teacher's Guide for Nanotechnology. See http://www.bowlesphysics.com/nano/
- Introduction to NanoScience http://nanonet.rice.edu/intronanosci/
- University of Wisconsin-Madison MRSEC
- http://mrsec.wisc.edu/Edetc/takeout/index.html
- http://mrsec.wisc.edu/Edetc/IPSE/educators/
- http://mrsec.wisc.edu/Edetc/nanolab/index.html
- http://mrsec.wisc.edu/Edetc/cineplex/index.html
- http://mrsec.wisc.edu/Edetc/IPSE/educators (societal implications)
- www.nanooze.org Web science magazine for kids with a focus on nanotechnology.
- www.mainstreetscience.org Website for K12 educators, students, and public. Includes information on teacher and student institutes and internships at Cornell University.
- NanoKids http://nanokids.rice.edu/
- Institute for Soldier Nanotechnologies at MIT http://web.mit.edu/isn
- Teachers can also access a video at this website http://web.mit.edu/isn/aboutisn/isnvideo.html
- The Nanotechnology Group Inc. thenanotechnologygroup.org
- Subject specific math curriculum targeted for grades preK-20, featuring Interactive Virtual Nano Science Classrooms for Global access and Virtual Interactive Nano Science Laboratories (nano-lab) for experiential learning.
- National Nanotechnology Initiative nano.gov
- Museum of Science, Boston. mos.org/nano

Size and Scale

1. Office of Basic Energy Sciences "The Scale Of Things - Nanometers and More" chart at http://www.science.doe.gov/bes/scale_of_things.html
2. Project 2061's Common Themes: Science for All Americans (including nice 1 page discussion of scale) http://www.project2061.org/tools/sfaaol/chap11.htm
3. Molecular Expressions interactive "Powers of 10" applet http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/ and Perspectives lesson at http://micro.magnet.fsu.edu/optics/activities/students/perspectives.html and Virtual Scanning Electron Microscope applet at http://micro.magnet.fsu.edu/primer/java/electronmicroscopy/magnify1/
4. Discovery School's Size and Scale activity. Intended for high school (9-12), specific lesson plan with procedures, questions, rubrics, mappings to standards, suggestions for extension, etc. Includes Word version. http://school.discovery.com/lessonplans/programs/sizeandscale/
5. InVSEE Size and Scale module that (1) identifies key concepts, learning objectives, mapping to standards, (2) shows an introductory video (requires real audio), and then (3) presents a nice long explanation (several pages) of issues of size and scale http://invsee.asu.edu/Modules/modsum/ssSUM.htm
6. How Small am I? Lesson Plan (Nanobiotechnology Center, Cornell University) http://www.pbs.org/newshour/extra/teachers/lessonplans/science/nano.html
7. There's Plenty of Room at the Bottom. Transcript of Richard Feynman's historical talk about the possibilities of moving "downward" into the realm of nanoscale science and technology (talk given in 1959!) http://www.zyvex.com/nanotech/feynman.html
8. Isn't That Spatial? US Geolocial Survey lesson on scale. Although not at the nanoscale, provides another angle at thinking about size and scale http://rockyweb.cr.usgs.gov/public/outreach/articles/isntthatspatial_scale.html
9. Scale and Scaling Across the Science Domains. Recently awarded NSF grant (July 04) to study how students learn the concepts of size and scale in science. Probably too early to be helpful, but there might be some good info in time for our first revision of "Size Matters" http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0411656
10. Powers of Ten website. Just about anything you'd ever want to know about the powers of ten http://www.powersoften.com/edu/index.php
11. Nanoscale Science Education Group at North Carolina State University. Scale and Scaling: What is a nanometer? http://www.ncsu.edu/project/scienceEd/scale.htm
12. How big are things? http://www.vendian.org/howbig/
13. An intro to nanoscience presentation that has a nice example of zooming in to a hand several times to illustrate scale

HTTP://WWW.MATERIALSWORLD.NET/NCLT/DOCS/INTRODUCTION%20TO%20NANO%201-18-05.PDF

General Engineering Education Web Resources

Tufts Center for Engineering Education Outreach
http://www.ceeo.tufts.edu/

Massachusetts Pipeline Initiative - Greater Boston
www.masspipeline-east.neu.edu

Teach Engineering www.teachengineering.org

ASEE Engineering K-12 Center
http://www.engineeringk12.org/

Project Lead the Way www.pltw.org

Infinity Project www.infinity-project.org

National Center for Engineering and Technology Education
http://www.ncete.org/

Center for Engineering Teaching and Learning/
http://depts.washington.edu/celtweb/

National Science Resources Center/Science and Technology for Children Curriculum
www.nsrconline.org

US FIRST robotics and LEGO League competitions www.usfirst.org

Future City Competition/part of Eweek http://www.futurecity.org/

E-Week www.eweek.org

City College's Stuff That Works! Curriculum
http://citytechnology.ccny.cuny.edu

ZOOM Into Engineering http://www.discoverengineering.org/

Engineer Girl! A site by the NAE geared to middle-school girls
www.engineergirl.org