Nanotech 2005:
A Symposium for Educators
Summative Evaluation Report

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Museum of Science, Boston

Nanotech 2005: A Symposium for Educators

This professional development event was held on November 6 and 7, 2005 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, the University of Massachusetts – Lowell, and by the "Science of Nanoscale Systems and their Device Applications" NSF NSEC headquartered at Harvard University.

The opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect those of the sponsoring organizations.

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EXECUTIVE SUMMARY

On November 7, 2005 the Museum of Science hosted its first Nanotech Symposium for Educators, funded by the National Science Foundation and the National Institutes of Health. The Symposium was intended to provide educators from middle schools, high schools and community colleges with an introduction to nanoscale science and engineering, and a toolkit of classroom teaching modules and activities. Six teams of professional curricula developers and educators led workshops, and two notable researchers addressed the participants and workshop leaders.

This report provides a full analysis of the day's events. One of the goals of the report is to provide feedback on steps that the Symposium Team can take to further deepen educators' understanding of nanotechnology and incorporation of materials into the curriculum in future Symposia.

Methods

During the Symposium, we utilized three methods of data collection: a) ethnographic observations of the workshops, performed by members of the Evaluation team, b) surveys administered to workshop leaders and educators, and c) focus group sessions in the format of a debrief session at the end of the day. After the Symposium, we used two methods of data collection to measure long-term impact: a) follow-up educator web surveys six months post-Symposium, and b) follow-up stakeholder and/or workshop leader interviews ten months post-Symposium.

Of the 64 Symposium educators, we received a total of 43 educator surveys (67% response rate). Of the 19 Symposium workshop leaders, fifteen responded to their survey (79% response rate). To measure long term impact, a total of thirteen educator web survey responses were received (of 32 educators who had given permission to be recontacted, or 41%) and four of 5 stakeholder and/or workshop leaders were interviewed (80%).

Results

1. Impact on Educators

- Educators learned about basic nanoscale concepts.
- Educators increased their interest in nanoscale science and technology.
- Educators reported they were more likely to seek out more information on nanotechnology.
- Educators foresaw challenges as to where and how to fit nanotech into their curriculum, given a mandated curriculum and nanotech's interdisciplinary nature. They were unsure as to when to include lessons on nanoscale science and engineering in their classroom schedules. They wondered how much impact nanoscale science and engineering would have in the future.
- Educators felt they had to contend with students' cognitive development to help them comprehend something intangible like nanoscale sizes. Educators saw challenges in presenting such information in an interesting way to engage their students.

- Six months after the Symposium, many educators reported that they had not yet brought up nanotechnology in their classroom and would most likely introduce concepts into future curriculum. Many said that their school might explore incorporating it into the curriculum.
- After the workshop, most educators talked to other adults about the nanotechnology, did some online research, and noticed related news in the media. Their ratings of their understanding of and interest in nanotechnology had dropped slightly; educators' likelihood to seek out learning opportunities related to nanotechnology dropped significantly in the months after attending the Symposium.

2. Impact on Workshop Leaders

- For many workshop leaders and stakeholders, the simple act of preparing and presenting at the Symposium was rewarding in and of itself.
- Workshop leaders felt they gained from professional networking.
- Workshop leaders acquired awareness of social implications of nanotechnology and declared they would bring this aspect into their own classrooms and workshops.
- About 10 months after the Symposium, four interviewed representatives of stakeholder institutions reported feeling that their institution had gained exposure or experience to these types of events.
- Stakeholders and/or workshop leaders had different ideas on how to improve future Symposia, such as through more online resources, better advanced collaboration with workshop leaders, greater diversity and different order of presentations.

3. Strengths of Symposium

- Educators felt the most interesting and valuable parts of the day were researchers' presentations on nanowires, nanomedicine, and the future of nanotechnology. They felt these presentations contributed most to their learning.
- Educators varied in their preferences of workshops. Some preferred content-based workshops to build a foundation of content knowledge, whereas others desired and appreciated receiving classroom and curriculum ideas.
- Workshop leaders reported gaining most from sharing their curricula with educators and hearing educators' questions.

4. Weaknesses of Symposium

- Attendees felt the Symposium's organization could have been stronger, particularly in providing advance notice of events and workshops, having more handouts and having a pre-existing website available.
- Both workshop leaders and educators wanted to attend more workshops. Educators with previous background knowledge of the field desired more advanced offerings; workshop leaders wanted to view their peers' workshops and provide suggestions to one another about their nanotech curriculum.

Recommendations

Based on the findings, it is important that future Symposia follow the below recommendations:

1. Keep researchers and presenters as a feature of the Symposium.

2. Create a website with additional resources for educators to continue learning and to learn more about stakeholder institutions, like the Museum of Science, Center for High-rate Nanomanufacturing (CHN) NSF Nanoscale Science and Engineering Center (NSEC) headquartered at Northeastern University, the University of Massachusetts – Lowell, and the "Science of Nanoscale Systems and their Device Applications" NSF NSEC headquartered at Harvard University.

3. Collaborate with workshop leaders when planning the Symposium.

4. Restructure "Lunch with Researchers/Workshop Leaders" so that researchers and workshop leaders are present at each table and facilitate conversation; or keep as a simple "lunch."

5. Provide future follow-up learning opportunities to educators through lectures, exhibits and news of other relevant professional developments.

6. Provide another meeting time for workshop leaders to share curriculum and ideas or provide videos of the other workshop leaders' presentations.

7. Address the learning needs of advanced or repeat educators with higher level workshops.

8. Have workshop leaders address how to integrate material into the school year, especially given the constraints of a tightly regulated curriculum. Invite educators who have already incorporated nanotechnology into their classrooms to share their experiences with other Symposium attendees.

9. Improve evaluation procedures in order to increase survey response rate and decrease time allocated to the evaluation during the actual event.

The results described in this report demonstrate that the Symposium met many of its original goals. Overall, the Symposium 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. With these understandings in hand, Symposium organizers can continue to move forward to best support the learning and practices of educators, workshop leaders, stakeholders and students.

I. INTRODUCTION

With a growing ability to detect and manipulate matter on the nanoscale level, nanoscale scientists and engineers are developing ways to transform information technology, medicine, manufacturing and energy. 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. Recognizing the need for greater educator awareness and knowledge of these developments, the Museum of Science organized *Nanotech 2005: A Symposium for Educators.* 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.

The Symposium was organized by the Museum of Science staff in collaboration with two National Science Foundation funded Nanoscale Science and Engineering Centers (NSEC): the Center for High-rate Nanomanufacturing (headquartered at Northeastern University, the University of Massachusetts-Lowell, and the University of New Hampshire) and the "Science of Nanoscale Systems and Their Device Applications" NSEC (headquartered at Harvard, M.I.T., University of Santa Barbara and the Museum of Science). These two NSECs provided financial support for the Symposium. The Nanotechnology Center at Boston University also played a role in helping to catalyze and contribute content to the Symposium, and several other NSF-funded nanoscale science and education research centers contributed professional development staff and curricular resources, including: the National Nanotechnology Infrastructure Network (NNIN), SRI International, and the Institute for Chemical Education at the NSEC at the University of Wisconsin-Madison.

Symposium organizers and stakeholders shared an interest in exploring new ways of bridging the gap between current science and engineering education, research in university environments and grades 6-14 curricula and standards. Initially, the Symposium was conceived primarily as an opportunity to provide professional development for K6-14 educators, but lead organizer Carol Lynn Alpert soon realized that there was "as great need for curricula developers and workshop leaders to learn from each other, network, and receive valuable feedback from the attending educators" (Alpert, personal correspondence, May 31, 2006). Consequently, a half-day session for the curricula developers and workshop leaders was added the day prior to the Symposium for Educators.

1.1 Workshop Teams

Three local New England nano education centers sent workshop leaders to the Symposium: a Research Experience for Teachers (RET) team from Northeastern, a grad student/RET pair from Harvard, and a K-12 team from Boston University. These local partners were joined by three national teams: SRI International, which was developing the Nanosense curriculum; and the Institute of Chemical Education at the University of Wisconsin at Madison, which was developing a societal implications curriculum. The Director of Education and Outreach for the National Nanotechnology Infrastructure Network came representing the work of the thirteen NNIN organizations.

The Northeastern team was organized by Clare Duggan. This team showcased a summer RET program and stressed how it can inform and inspire classroom practice.

The Harvard team included Logan McCarty, a graduate student associated with the Harvard NSEC, and Christina Talbot, a New Hampshire teacher who had participated in Harvard's RET program. Together, McCarty and Talbot had developed a classroom lab for exploring the process of nanolithography.

The Boston University team was organized by Professor Bennett Goldberg and Cynthia Brossman and consisted of graduate students in research who were participating in a GK-12 program to expand their teaching skills. This team developed a classroom activity about carbon nanotubes.

Tina Stanford, of SRI International, brought their "Size Matters" nanotech curriculum, under development with NSF funding. Workshop attendees were introduced to a lesson plan from the multi-week curriculum that had been designed to provide an overview in one classroom period.

Andrew Greenberg of the UW Madison Institute for Chemical Education brought a role-playing exercise he is developing to address some of the societal implications of nanotechnology in classroom settings. He teamed up with Professor Ron Sandler, of Northeastern, who gave an overview of the types of societal issues potentially associated with nanotechnology.

Nancy Healy of Georgia Tech and the NNIN and Kathryn Hollar of the Harvard NSEC and the NNIN prepared an overview of nanotech research and brought a kit developed by an NNIN-associated group at Penn State. The kit uses samples of nano-based consumer products to lead students on an inquiry-based investigation of nanomaterials.

1.2 Narrative of the Day's Events

Most educators had learned about the Symposium through other teachers, emails from the Museum of Science or the Museum's annual Educators' Night.[1]

8:00-8:45am	Registration and Continental Breakfast
8:45-9:00am	Welcome and Orientation
9:00-9:45am	Professor Eric Mazur Presents Nanowires
10:00-11:15am	Workshops: Session One
11:30-11:50am	Daniel Davis Presents Nanomedicine
12:00-1:00pm	Lunch with Researchers and Workshop Leaders
1:00-1:50pm	Professor George Whitesides presents Keynote Address
2:00-3:05pm	Workshops: Session Two
3:15-4:00pm	Concluding Activities and Refreshments

The day opened at 8:00am with registration and a light breakfast served outside Cahners Theater. At the registration space, educators read about the six workshops offered and selected two they

[1] Educators' Night was held the prior Thursday evening. It is an event where local K-12 teachers can see what projects and exhibits the Museum is currently offering and how they can plan a field trip.

would attend. Workshops differed in their foci and activities; some presented a high degree of science content; others focused on ways to present the information to students through materials, curriculum and activities; and one focused on research opportunities for educators.

At 8:45am in Cahners Auditorium, lead Symposium organizer Carol Lynn Alpert welcomed attendees and introduced Harvard professor Eric Mazur. Professor Mazur delivered an introductory talk about some of the history and underlying concepts of nanoscale science and engineering and about his recent experiments pulling nanowires at room temperatures. At the conclusion of his presentation, Professor Mazur and Geoff Svacha, one of his graduate students, led a demonstration of the room-temperature nanowire pulling method that his laboratory developed. This live demonstration was projected by video onto the theater screen.

After the lecture, at 10:00am, Museum Public Programs Manager Mike Alexander provided a brief orientation, and Museum volunteers—who were present throughout the entire event as guides—led educators and workshop leaders to their respective workshop rooms. At 11:15am, the volunteers led educators back to the Exhibit Hall to view a 20-minute Current Science & Technology (CS&T) presentation. There, they listened to Daniel Davis, an educator at MOS partially supported by the Harvard NSEC, deliver a live presentation he had developed for general Museum audiences on research in nanomedicine targeted at cancer diagnosis and therapy.

After an hour-long lunch with researchers and workshop leaders in Skyline, the educators returned to Cahners Auditorium for a keynote address by Professor George Whitesides. Professor Whitesides spoke about how nanoscience is providing new insights into our understanding of nature and behavior of matter and the ways in which nanotechnology might impact our lives, economy, culture and national security. Professor Whitesides also answered some audience questions, providing some personal views on education.

At 2:00pm, educators had the opportunity to attend the second workshop they had selected during the registration period. When this second workshop ended at 3:05pm, educators and workshop leaders filled out a two-page evaluation survey and then headed upstairs to the Skyline Room to wrap up the day. In Skyline, Museum staff led six tables of educators and one table of workshop leaders in a debrief session on their general thoughts of the day's events and what aspects they found most and least helpful to their teaching. At 4:00pm, a raffle was held for t-shirts and nano-instructional kits provided by the NNIN.

A nearly complete set of hand-outs that was distributed at the Symposium can be found in Appendix G. This includes biographies of the speakers, full descriptions of the Symposium, resources and website addresses.

In preparation for the Symposium, organizers invited workshop leaders to meet at the Museum of Science on November 6, a day before the event. Logistics were reviewed, workshop leaders were given a tour of the spaces they would be using, and workshop leaders shared what each curriculum development team would present to educators.

1.3 Goals of Participation for Educators, Workshop Leaders, and Stakeholders

In developing this Symposium, organizers set complementary goals for educators, workshop leaders and their respective stakeholder institutions. Goals were written by lead Symposium organizer Carol Lynn Alpert.

Educators

Educators would:

1. Come away feeling they had an increased understanding of nanoscale science and technology (NST);
2. Come away feeling they had an increased interest in NST;
3. Come away feeling they had some useful tools for incorporating ideas about NST into their classrooms;
4. After the Symposium, successfully implement one or more of the ideas gained during the workshop into their classrooms;
5. Know where they could get more information about nanotechnology, about research experience and other professional development opportunities for educators, and about other potentially useful educational materials in this subject area;
6. Feel their time was well spent attending the Symposium;
7. Be willing to recommend this Symposium to other educators; and
8. Offer helpful suggestions to improve the workshop.

Workshop Leaders

Workshop leaders would:

1. Feel the effort had been well worth their time;
2. Feel they had gained something of value through their participation;
3. Feel that the Symposium organizers had planned carefully and were respectful of their needs;
4. Feel their contributions had been appreciated;
5. Consider returning next year;
6. Offer helpful suggestions to improve the Symposium;
7. Feel they had learned useful things from each other; and
8. Were interested in staying in touch with each other and continuing to network on ideas for further collaboration and improvements in practice.

Stakeholders

Stakeholders would:

1. Feel their interests and their funders' interests were served by the event;
2. Feel positively about the way the event was organized and their organization's participation in the event;
3. Would be interested in repeating the Symposium again next year, although perhaps with improvements;
4. Offer helpful suggestions for improving the Symposium.

II. METHODS

This evaluation relied on multiple methods of data collection, each of which focused on capturing different aspects of the event. These methods include the following:

- **Registration data:**

  When educators called to sign up for the Symposium, the Museum's Science Central staff asked a series of questions about registrants' background. Educators were asked for their name, address, what grades and subjects they taught, how they heard about the Symposium, whether this was their first Museum of Science professional development and if not, which previous professional developments they had attended. Since this was a new procedure for Science Central, background information was not consistently collected from all registrants.

- **Surveys:**

  After the second workshop, educators and presenters were asked to fill out a two-page survey that contained both closed and open-ended questions. The purpose of the survey was to gain as much comparable information about the Symposium and from as many attendees as possible. As can be found in Appendix A, the educator survey measured respondents' learning, interest, and likelihood to continue learning about nanoscale science and engineering before and after attending the workshop. Paired t-tests were performed to determine significant differences. The workshop leader survey, found in Appendix B, measured their satisfaction with their participation and what they perceived gaining from the workshop.

- **Ethnographic observation of workshops**:

  A member of the Evaluation team attended each of the six offered workshops. By attending the various workshops, we were able to see the ways workshops varied from one another and better understand the educators' experience. The team took notes on the workshop format, style and flow; on the points of interest for the educators, presenters, and evaluators; and the types of questions teachers asked (see Appendix C for observation sheet). While evaluators rated workshops on multiple scales (e.g., level of engagement, interest, hands-on activities, curriculum, connections to state curriculum standards and organization), these ratings were performed without interrater reliability testing. The purpose of the ratings was less to compare which workshop was most and least successful, and more to see how the workshops differed from each other. Thus, the notes found in Appendix D should be used as background information that supports data collected through the surveys and debrief sessions.

- **Debrief session:**

At the end of the day, Museum of Science staff and one workshop leader led groups of Symposium attendees in a debrief session. Having spent the day at several lectures and workshops, the debrief session was designed for attendees to decompress and share their thoughts with each other. Staff had been given a handout outlining three main strands of thought that should guide these conversations (see Appendix E): what educators felt were the most important things they learned, what they will incorporate into their class, challenges they foresee and what questions they still have. The debriefs were designed to be more educational than evaluative in focus. For this reason, the data collected through this method cannot be extensively analyzed and provide limited insight into the experiences of the educators.

- **Educator follow-up web surveys**:

  In May 2006, six months after attending the Symposium, the 32 educators who had provided their contact information for follow-up interviews were emailed a link to a web survey. 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 educators incorporated nanotechnology into their classroom and in what ways. Findings are limited by the low number of respondents (13 of 32 educators or 41%) and the fact the population was self-selected. Wilcoxon Signed Ranks Tests were performed to measure significant changes in educators' attitudes.

- **Stakeholder follow-up interviews:**

  In July and August 2006, four stakeholders and/or workshop leaders participated in a follow-up interview regarding what their institutions had gained from the Symposium and what they personally gained from the Symposium. Prior to the interview, stakeholders and/or workshop leaders were sent a copy of this summative evaluation report and the executive summary and questions about what they had learned and what aspects surprised or resonated with their experience. Interviewees had been selected by Symposium organizer Carol Lynn Alpert.

III. RESULTS

In this report, the first section presents both educator and workshop leader survey responses together grouped by topic. The second section summarizes important points made during the debrief session.

1. REGISTRATION DATA

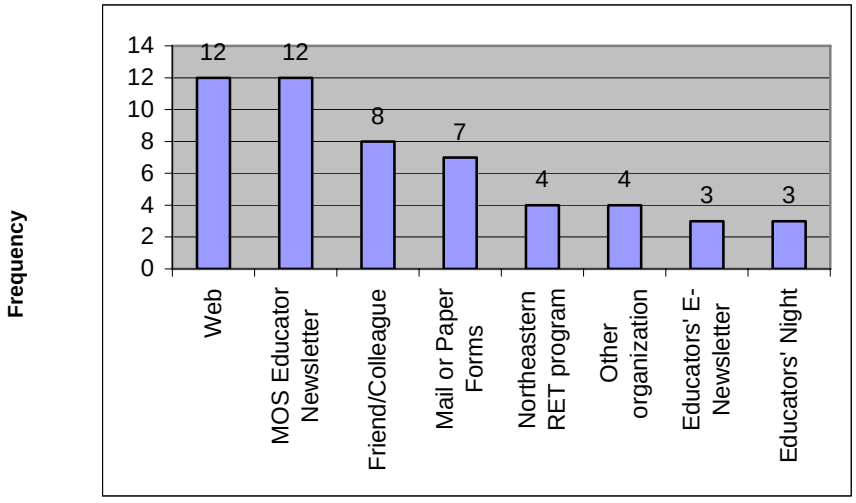
1.1 This was the First MOS Workshop for Many Educators; Many Educators Heard About Symposium through MOS Newslettters

Sixty-four educators registered through the Museum of Science's Science Central telephone line. Most individuals were asked a series of questions about where they teach, what grade levels and subjects they have taught and whether this was their first workshop. However, since this was an experimental registration approach and Science Central was not accustomed to asking many background questions of its callers, this information was not always collected; some individuals were re-contacted to obtain this information.

43 educators (77%) reported that this was their first MOS workshop. For the 13 educators (23%) for whom this was not their first workshop, many did not remember what other MOS workshops they attended; one person mentioned *Strange Matter* and another individual mentioned the *Biotech Symposium*.

Registrants most commonly described finding out about the Symposium through the Museum of Science Educator Newsletter and the Web, including the Museum of Science website (see Figure 1). Friends and colleagues were also cited frequently. Nearly half who had received notice through the mail were from field trip brochures.

FIGURE 1 Most Common Ways Educators Learned about the Symposium



How Educators Found Out About the Symposium (N=53)

2. SURVEY RESULTS

2.1 Workshop Leader Survey Respondents Represented all Six Stakeholder Institutions

Thirteen of the 19 workshop leaders completed surveys immediately following their participation in the Symposium (68%), representing five of the 6 stakeholder groups (83%). In order to obtain the highest response rate and a full representation of all stakeholder institutions immediately following the Symposium, the remaining six presenters were emailed an electronic version of the survey. In the email message accompanying the survey, evaluation staff stressed the confidentiality and importance of the workshop leaders' responses. It should be noted that one individual who returned the e-survey had expressed discomfort of filling out the paper survey while at the Symposium because of this individual's more critical stance and the requirement of placing one's name at the top of the survey. Another individual sent his response back in March 2006. The final workshop leader response rate was 15 of 19 workshop leaders, or 79%.

2.2 Educator Survey Respondents were Largely Male High School Teachers with Graduate-Level Educational Backgrounds

Of the 64 Symposium educators in attendance, we received a total of 43 educator surveys (67% response rate).[2] As seen in Table 1, a large number of the respondents were male, taught high school, and had some graduate level training in the field of science, technology, engineering or math (STEM). Many respondents had also been teaching for many years (Median = 9.5 years) and were currently teaching at local public high schools.

TABLE 1 Demographics of Educator Survey Respondents

	Count	Percentage
GENDER		
Male	24	56%
Female	19	44%
Total	43	100%
AFFILIATION		
Middle School	6	14%
High School	23	54%
Community College	4	9%
University	6	14%
No Response	4	9%
Total	43	100%

	Count	Percentage
LEVEL OF STEM EDUCATION		
Prof. Developments	0	0%
College coursework	7	16%
Associates degree	0	0%
Bachelors degree	8	19%
Graduate coursework	8	19%
Graduate degree	16	37%
No Response	4	9%
Total	43	100%

[2] It should be noted that three additional surveys were filled out by educators, however they had mistakenly received the Workshop Leader Symposium Survey during registration.

YEARS TAUGHT			SUBJECT TRAINING		
Average	11 yrs.		Physics	7	13%
Standard Dev.	11 yrs.		Chemistry	13	25%
Median	9.5 yrs.		Biology	16	30%
Range	3 mo. - 36 yrs.		Physical science	4	8%
No Response	3		Engineering	9	17%
Total Responses/N	43		Technology	7	13%
			Total	53	102%
			Multiple subjects	17	
OTHER			SCHOOL TYPE**		
Contact for interview			Public	34	46%
Yes	33	77%	Private	7	10%
No	4	9%	College or university	7	10%
No response	6	14%	No response	25	34%
Total	43	100%	Total	73	100%
Local/MA					
Yes	38	88%			
No	5	12%			
Total	43	100%			

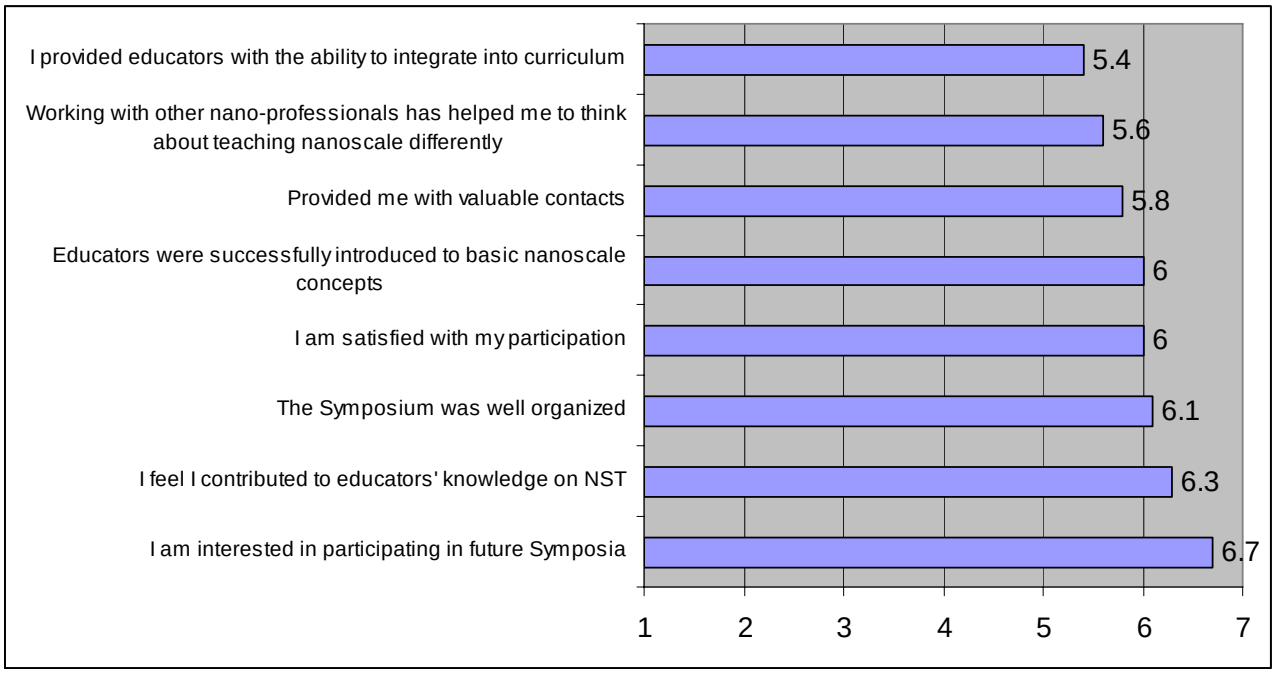
*Percentages do not necessarily add up to 100% because they are rounded or because respondents listed more than one subject **Information about school type was interpreted from the registration list and not the survey, explaining a higher total number of respondents.

2.3 The Symposium was Successful in Many Ways

According to educator and workshop leader survey responses, the Symposium was largely a success in introducing educators to the basic concepts of nanoscale science and technology. On closed ended questions, which ranged on a scale from 1 to 7, less than 5% of educator ratings and 2% of presenter ratings of the day's components dipped below 4.

According to their ratings, workshop leaders were pleased with their participation in the Symposium, felt they gained networking contacts and felt they were able to think about teaching nanoscale science and technology in different ways (See Figure 3). Their average agreement to the positive statements was about 6 out of a scale of 7.

FIGURE 3 Workshop Leader Agreement to Positive Symposium Experience Statements

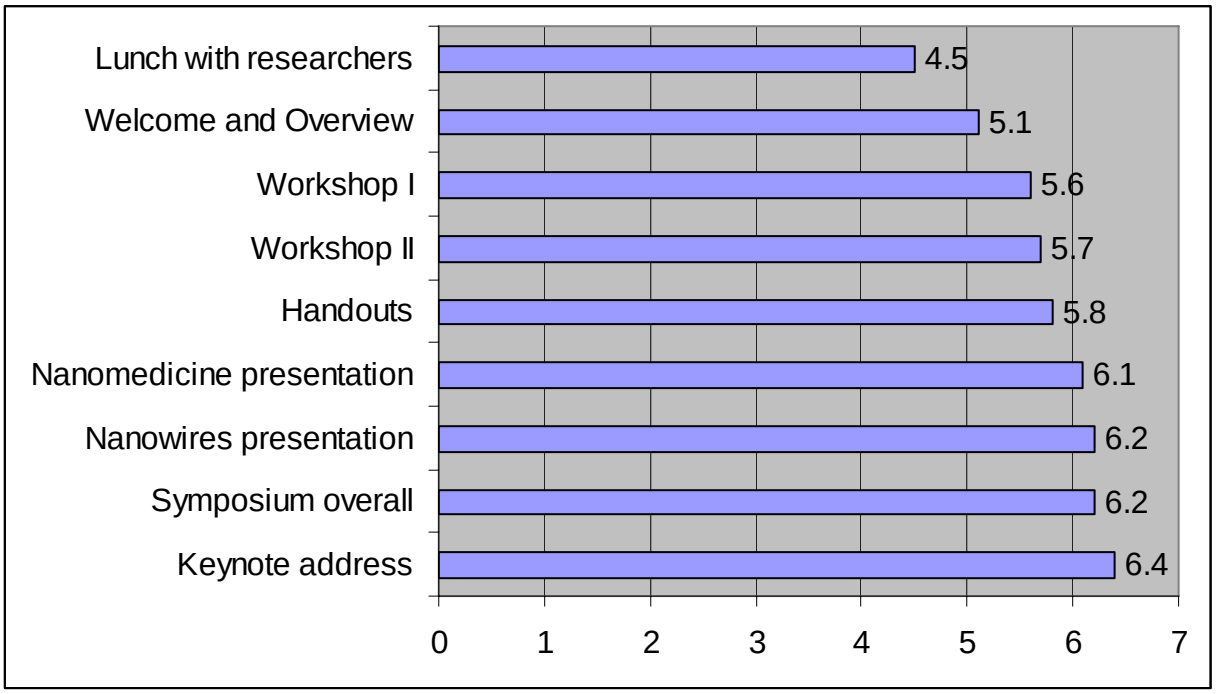


*Scale ranges from 1 to 7, with 1 representing "Strongly disagree" and 7 represents "Strongly agree"

While workshop leaders felt that the Symposium helped give educators the ability to integrate nanoscale concepts into the curriculum, they believed the Symposium was significantly more successful at introducing basic nanoscale concepts to educators ($t_{1, 13}$=3.7, p<.003). In fact, they rated their agreement to the curriculum integration statement the lowest (M=5.4) compared to the rest of the statements (see Figure 3).

Similar to the workshop leaders, educators responded quite positively to questions about the Symposium's components and the components' contribution to educators' learning of basic nanoscale science and engineering concepts (See Figure 4). The keynote address by Professor George Whitesides, Daniel Davis's Nanomedicine presentation and Eric Mazur's Nanowires presentation were perceived as contributing to educators' learning the most. These presentations were also rated nearly equally.

FIGURE 4 Educator Ratings of Symposium Components



*Scale ranges from 1 to 7, with 1 representing "Did not contribute" and 7 represents "Strongly contributes" to learning of nanoscale science and technology

For educators, the second most helpful aspect of the Symposium was the handouts, perhaps because they would allow educators to think about the material in greater depth at home. The workshops were rated third most helpful. No significant correlations were found between educator ratings and years taught or subject taught.

Overall, lunch with researchers and workshop leaders was considered the least helpful aspect in contributing to educators' learning. It was rated 4.5 on a scale of 7. The comparatively low rating is perhaps because very few researchers/workshop leaders were sitting at each table and/or carried on conversation with many educators at their table.

2.5 Speakers, Content and Networking are Most Interesting Aspects of the Day

When answering the open-ended question, "What aspect of the Symposium did you find most intriguing?" both educators and presenters responded that hearing the nanoscale science and engineering field's leaders speak was an interesting experience in and of itself. This matches their ratings of the day's components (see Figure 4). However, as one might expect, most of the Symposium's other interesting aspects differed for educators and workshop leaders. For educators, most of whom were new to the nanoscale science and engineering field, the most intriguing parts of the day were content related. For workshop leaders, on the other hand, it was professional networking.

As shown in Table 2, two of the presentations that educators had rated as contributing most to their learning also happened to be what they had described as the most intriguing aspects of the day. Educators identified Daniel Davis' nanomedicine presentation as being quite fascinating, in particular the possible medical advancements nanotechnology presented. Some educators felt their students would be very interested in this topic. Equally intriguing to educators was George Whitesides' keynote speech and his philosophies on the implications of nanotechnology. Some educators were taken by his comments on how public education placed too much emphasis on covering breadth rather than focusing on teaching for understanding.

TABLE 2 Most Intriguing Aspects of the Symposium to Educators

	N	%	Example Open-Response Comments
1. Nanomedicine/Biomedical applications	16	30%	*"The nanomedicine presentation really interested me and I can't wait to share this technology with my students." (#E15)* *"biology – medicine, especially as an advancement in breast cancer" (#E16)*
1. George Whitesides' Keynote Speech	16	30%	*George Whitesides's "social ideas," (#E29) "world view" (#E28) and "observation that it is no longer an American race for technology but a race of competing countries." (#E31)*
3. Applications and products of nanoscale science	7	13%	*"The products. How it's in our lives already" (#E20)*
4. Social implications	4	8%	*"Related impact on society" (#E24), "The societal and ethical impacts of all emerging technologies are most intriguing and should be discussed with students of all disciplines - allows for informed decision making." (#E36)*
5. General concepts behind nanoscale science	4	8%	*"definition of nanotechnology" (#E36) and "how nanoscale science and engineering extends the fundamental principles of science onto a different scale and results in the observation of new behaviors of matter and light." (#E39)*
6. Nanowires	3	6%	*"Bending light using nanowires - future [of] optic cables" (#E4)*
6. Curriculum on Nanoscale	3	6%	*"The idea that its tenets could be taught at a middle or a high school level -> the idea that lithography/carbon nanotubes are a reasonable discussion." (#E3)*

*The number in parentheses following each quotation corresponds to the survey's unique ID
**It should be noted that this table reflects the major categories that emerged and does not represent other categories with fewer than 3 comments.

As displayed in Table 3, for workshop leaders, the most interesting aspect of the day was having the opportunity to meet other nanoeducators in the field and seeing what other work was being done. Next, workshop leaders enjoyed hearing the field's leaders speak, and in particular seeing how Professor Whitesides and Professor Mazur addressed educators. Workshop leaders also liked being able to hear educators' questions and working with them in preparation for the Symposium. For two additional individuals, the planning process for the Symposium was most useful. These workshop leaders were new to nanotechnology curriculum and professional development and felt preparing for the Symposium helped them to develop new methods and skills.

TABLE 3 Most Interesting Aspect of Symposium Experience to Workshop Leaders

	N	%	Example Open-Response Comments
1. Networking/Sharing with other nano-curriculum developers	5	33%	*"The networking with others associated with the nano-movement and just the opportunity to share what we learned in the RET program." (#W3) "hearing about different perspectives, ways of incorporating nanoscience into classroom" (#W105)*
2. Presentations	4	27%	*'I loved the Mazur talk in the morning. Great demos with ways I can show things to my class!" (#W107)*
3. Working with teachers	4	27%	*"I also enjoyed the teachers' questions which will help enhance the unit." (#W13)*
4. Planning	2	13%	*"Planning the Symposium with RET teachers" (#W106)*

2.6 Workshop Leaders and Educators Show Significant Gains in Learning from Symposium

At the end of the Symposium, attendees retrospectively compared what they gained (e.g., likelihood to seek out nanoscale science and technology learning opportunities, and their understanding of and interest in nanoscale science and technology) before and after attending the Symposium. As a result of attending this Symposium, both presenters and workshop leaders reported a gain in learning. As displayed in Figure 5, after attending the Symposium, educators retrospectively reported a significant increase in interest towards nanoscale ($t_{1,43}$=6.5, p<.000), understanding of nanoscale science and engineering ($t_{1,43}$=11.7, p<.000), and a greater likelihood of seeking out new opportunities for learning ($t_{1,42}$=6.0, p<.000).

Figure 6 shows that workshop leaders retrospectively exhibited similar gains. After the Symposium, workshop leaders felt more familiar with educators' perceptions of teaching nanoscale science and engineering in the classroom ($t_{1,12}$=4.4, p<.001) and with the range of classroom teaching techniques ($t_{1,13}$=3.7, p<.003).

FIGURE 5 Educator Gains in Learning from Attending the Symposium

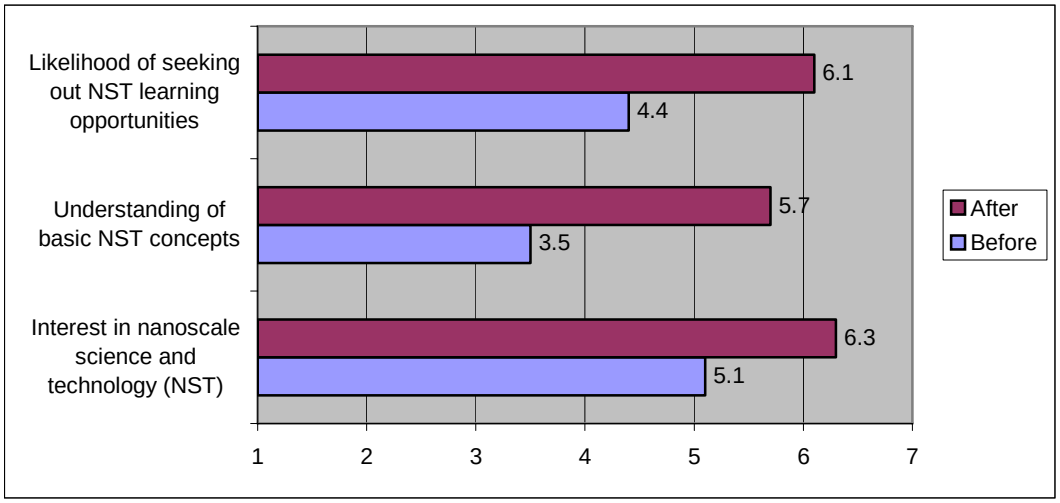
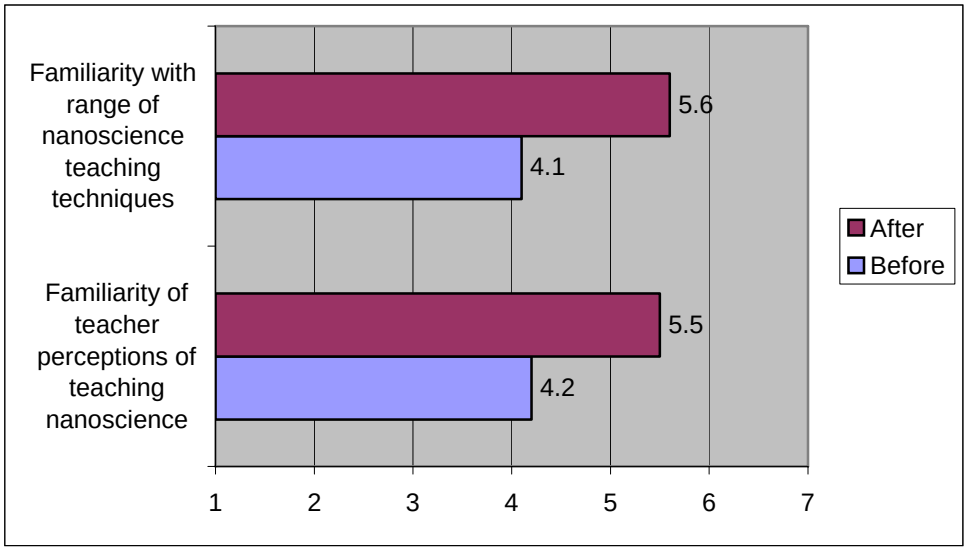


FIGURE 6 Workshop Leader Gains in Learning from Attending the Symposium



When educators were asked what they had learned that they hadn't known before, educators most frequently reported the applications of nanotechnology (see Table 4). Many educators expressed surprise because its applications, like CDs and nano-socks, are already all around us and furthermore, they are tangible, innovative and relevant to our lifestyles. Educators frequently reported that "everything" was new to them. Many educators also wrote that they learned specific concepts of nanoscale science and engineering. Many responses mirrored what educators had found most intriguing.

TABLE 4 What Educators Learned that They Didn't Know Before

	N	%	Example Open-Response Comments
1. Current uses and applications (non-medical)	17	34%	*"That it was already around us" (#E9)* *"Nanowipes, all of the real-world applications" (#E17)*
2. Nanomedicine	11	22%	*"Its potential in medicine" (#E37)* *"medical implications such as identify[ing] and removing cancer (lymph no[d]es) with quantum dots, shells, etc.," (#E41)*
3. General concepts of nanoscale science and engineering / Learned a lot	9	18%	*"More than just size – the concept that physical (chemical) properties actually change," (#E38) "A lot. Little exposure to sciences prior to seminar" (#E24)*
4. Quantum mechanics	3	6%	*"quantum mechanics implications" (#E43), "that the nanoscale operates in both classical and quantum models of mechanics" (#E13)*
4. Photolithography	3	6%	*"light interactions" (#E6), "photo lithography" (#E9)*
4. Social Implications	3	6%	*"Future implications" (#E8), "Its amazing applications and implications in our society" (#E15)*
7. Existence of Nano Job Field	2	4%	*"It's impact on future jobs" (#E27), "That it most likely is revolutionary science and workers are needed in this area." (#E26)*
7. Nanowires	2	4%	*"Nanowires presentation and the 'pulling' of the fibers" (#E31),*

No significant correlations were found between educators' ratings of their own learning or the Symposium's components with the number of years they have spent teaching, the subject of their highest level of training, or whether they taught in a public or private school. This may reflect how new nanoscale science and technology is to the public regardless of educators' background.

Because we did not necessarily expect them to learn new content knowledge from the Symposium, workshop leaders were asked what they felt was the most valuable thing they had gained from this Symposium experience. Like educators, workshop leaders' responses resembled aspects that they had reported to be most interesting in the Symposium experience, such as networking and working with other educators and professionals in preparation for the Symposium (see Table 5). For some individuals, gaining experience in leading a workshop was perceived as being one of the most valuable aspects. One might expect this to be the case for RET teachers and graduate students. One respondent thought that participation in this Symposium was so important that involvement should be more widespread: "The direct participation by faculty and graduate students in the workshops is a requirement, in my opinion, if we are really going to change the way we educate students and the public around these issues" (#W115). The new consideration of societal implications seemed to be one important aspect some workshop leaders realized was important to teach and discuss with their peers.

TABLE 5 Most Valuable Aspect of Symposium to Workshop Leaders

	N	%	Example Open-Response Comments
1. Networking with other curriculum developers	5	30%	*"Networking experience." (#W108) "Contacts" (W#111)*
2. Working with teachers, researchers, Museum of Science in preparation and at Symposium	4	24%	*"An opportunity to interact with teachers about nanoscale education" (#W110), "being part of other teachers, researchers and scientists" (#W104)*
3. Gaining experience in leading workshops	4	24%	*"Participating as a presenter" (#W106), "Clearly it was a personal thrill for me to have an opportunity to present at the Museum of Science" (#W104)*
4. Dissemination of curriculum	2	12%	*"A sense of progress on disseminating our summer work" (#W104), "Sharing and new ideas" (#W113)*
5. Learning about societal implications	2	12%	*"Will incorporate lesson on Societal Implications into current program for students and teachers" (#W114)*

2.7 There are Time, Curriculum and Conceptual Challenges to Incorporating Nanoscale in the Classroom

Organizers knew that with nanoscale science and technology being a new field and the Symposium only being a one-day introductory event, educators would undoubtedly face many challenges leaving the Symposium. What challenges did educators foresee for themselves in incorporating nanoscale into their classroom? What did the workshop leaders' perceive as challenges for educators? Symposium organizers hoped to uncover any discrepancies and identify areas in which the MOS could help provide support to educators.

For the most part, both educators and workshop leaders reported many of the same challenges in implementing nanoscale into the curriculum (see Tables 7 and 8). These challenges were not having enough time or resources to integrate nanotechnology into the curriculum and educators' lack of content understanding. This alignment might highlight the strength of the workshop leaders, who were in tune with the educators and understood the perceived challenges set before them.

Two aspects, however, were not predicted by workshop leaders: finding a way to make students interested in learning about the nanoscale subject and contending with their students' difficulty in understanding something "invisible." Educators wrote that it is conceptually difficult for students to grasp, particularly for middle school students. One educator wrote she would not attempt to teach it because her students would not be developmentally ready.

TABLE 6 Biggest Challenges Educators Foresee in Integrating Nanoscale into Classroom

	N	%	Example Open-Response Comments
1. Time	11	25%	*"TIME (isn't that always the kicker)" (#E13), "Finding time to prepare for a lesson or two involving nanoscience" (#E18)*
2. Cost/Resources	10	23%	*"Possible costs" (#E32), "Equipment and demo material to bring to light the scope and potential of this emerging technology" (#E31)*
3. Curriculum constraints/Fitting into the curriculum	8	19%	*"Having mandated curriculum makes it difficult to fit in new material… Integrating with existing concepts effectively." (#E41)*
3. Size/Students not developmentally ready	8	19%	*"Students have a tough time w/ concepts that are not concrete" (#E17)*
5. Own lack of knowledge	3	16%	*"I foresee my incomplete understanding as a barrier in attempting to introduce the material into my class. I need to know more, before I feel confident to extend concepts to my students" (#E16)*
5. Developing student interest	3	16%	*"keeping abreast of newest nano advances and presenting them in an interesting format" (#E34)*

TABLE 7 Biggest Challenges Workshop Leaders Foresee Educators Having in Integrating Nanoscale into Classroom

	N	%	Example Open-Response Comments
1. Fitting into curriculum	5	29%	*"It is such a diverse field and I believe teachers are unsure where it fits in the classroom" (#W113)*
2. Time/space with standards	4	23%	*"Overcoming conflicts with covering the minimum DOE learning standards will continue to be an issue for teachers of 9-10 grade students." (#W104)*
3. Educator understanding	3	18%	*"In general, increasing their comfort level with novel ideas" (#W110) ""Having so many technical questions" (#W107)*
3. Resources	3	18%	*"perhaps not having the materials" (#W110) "money – additional materials/labs etc." (#W114)*
5. Sharing information	2	12%	*« The communication with others » (#W105) « Those attending the symposium need to share their information with others in order for the power of the symposium to have maximum impact. How can we insure that it happens ? » (#W104)*

2.8 Suggested Improvements to Symposium are Related to Having More Hands-on Activities and Hand-outs, and Better Organization

When asked to suggest improvements for future Symposia, some educators instead chose to say what they enjoyed. For example, one person commented on how the breakdown between sitting and being active was perfect. However, the majority of educators still had suggestions on how to

improve future Symposia and most commonly suggested having more hands-on activities and hand-outs (see Table 8). While most workshops had at least one hands-on activity, there seemed to be a perception that there could be even more activities that were even more hands-on, such as laboratories. There could even be hands-on activities during the lectures.

TABLE 8 Educators' Suggested Improvements to the Symposium

	N	%	Example Open-Response Comments
1. More hands-on activities	7	35%	*"More hands-on during Whitesides lecture or a demonstration." (#E34)*
2. Hand outs	6	30%	*"[I wanted to find out about] what products and where to get them" (#E17)* *"More handouts with take away activities to highlight topics." (#E35)*
3. Logistics	4	13%	*"Lunch was a little long but otherwise everything else was awesome" (#E44)*
4. Attend more workshops	3	10%	*"Everything was great. I just wish I could have attended more of the workshops, but then I would <u>not</u> have wanted them to be shorter." (#E13)*

Since educators faced challenges in not having enough money, time or resources to plan demos in class, one person wrote about the resources an internet website could provide to teachers if it provided demonstrations online: "so we can show them in class. You have money, we don't" (#E44). Or, the Museum should have a "traveling nano exhibit or demos to bring out to the classrooms [since] the school doesn't really have time or money to bring students in" (#E35).

Educators who responded to this question also wanted opportunities for follow-up, through "workshops, seminars, [or] volunteer opportunities that would help me to understand the concepts better" (#E16) or "lectures, TV shows, possible other workshops" (#E18). An open lecture series, for example, would be an appropriate opportunity for expanding teachers' content knowledge.

In order to provide continued additional help to them, a few educators suggested:

- more workshops should be held, with some presenting information at more advanced levels
- a website should be created with demonstrations and "links to relevant sites"
- an exhibit and field trip program should be created
- educators should have greater access to nano curriculum
- greater access should be provided to contacting researchers directly

According to workshop leaders, future Symposia should have better organization and provide workshop leaders with as much information as possible prior to the event (see Table 9). Many of the workshop leaders would have liked more advance notice of the agenda and the background of their workshop's participants so they could tailor their session. Furthermore, workshop leaders wanted to attend other workshops. Some workshop leaders also expressed a desire to be involved in the planning process, perhaps because they had much experience working with educators already and planning similar types of events.

To provide continued support to educators, workshop leaders believed the Museum of Science could further nanotechnology education through more symposiums, outreach programs and websites for educators to easily access. One person even thought we could expand the Symposium to have more people, "there is capacity to entertain a crowd of at least 200."

TABLE 9 Workshop Leaders' Suggested Improvements to the Symposium

	N	%	Example Open-Response Comments
1. Organization	6	46%	*"Giving information to presenters before on who would be in each workshop." (#W106)* *"Better organization - Sunday afternoon meeting seemed somewhat disorganized."(#W111)* *"Involve lead teachers and other presenters in the design of the day… Next time please make sure you add affiliations to name tags and prepare an attendee list to facilitate networking after these meetings." (#W114)*
2. Attend other workshops	3	23%	*"designing the workshops so that presenters could also attend their colleagues' workshops"(#W112)* *"Have lead teachers present only only once – give them the opportunity to attend other sessions. Have lead teachers provide written feedback to each other." (#W114)*
3. Contact information	2	15%	*"I would have liked to make my contact information more public" (#W110) "Provide list of contact names/emails" (#W107)*
3. Feedback	2	15%	*"I would also like to have some feedback from MoS about the reaction to the symposium from all parties" (#W104), "Have lead teachers provide written feedback to each other." (#W114)*

3. DEBRIEF SESSION RESULTS

This section presents the experiences of four of the 8 debrief tables from the notes each presenter kept. Due to the informal nature of the debrief sessions , the focus on education rather than evaluation, and the different facilitators and experiences attendees at each table had, the findings from table to table differ quite significantly. Overall, we see that many of the findings reflect the survey responses, although they are represented differently at each table.

3.1 Table A: Critical Educators who Sought a Foundation in Knowledge about Nanotech from the Symposium

This table was comprised of all males. All but one of the educators were high school instructors and had many years of teaching experience. They were also very critical. Most of their discussion focused on how this Symposium was really an introduction to the subject and that they would not even consider incorporating the subject into their classroom; they needed to gain further background knowledge first. As a result, when comparing the different workshops, the educators strongly felt that the content based workshops were most important to their learning. The "carbon nanotubes workshop [was] excellent. [It] combined information with suggested activities. [It] had a scholarly approach" which they were looking for. In fact, they wanted to learn even more facts at the Symposium "like more specifics/theories [and] ideas" and receive a "compilation of [web]sites" to do more background information research. This table described other workshops, like *Introduction to Nanoscience*, as "fluff." They discounted another workshop for not being clear or having hard, definite answers to their questions.

One challenge this group foresaw to incorporating nanoscale science and technology into their curriculum was the interdisciplinary nature of the subject. They asked, "Can one teacher cover it all? It's across subjects." Another topic that arose was gaining their students' interest. One educator expressed surprise that curriculum had not been "tapping cars" as this was a topic many youth are interested in.

3.2 Table B: Educators Raised Many Questions, Particularly about the Challenges in Teaching Nanotechnology

At this table, many members were very engaged in the debrief – so engaged, in fact, that some members even stayed after the Symposium had officially ended to finish answering the session leader's questions.

Members at this table recognized the value of the Symposium and asked many good questions about what they had learned. Table members expressed surprise at the biology and medical applications. They were also taken by the interdisciplinary nature of the subject and the natural "cohesion of programs – [how they] all fit together under theme." Yet this very interdisciplinary nature of nanoscale science and engineering also presented some challenges for the educators: in what class do you teach it? How do you prioritize information? How do you convey scale?

"Where will funding/training come from?" Educators also wondered about the direction and relative importance of this technology. "Where is it headed?" the table asked. "How soon will it impact us? What does the timeline look like?" Notably, the table applied nanoscale science and engineering to Professor Whitesides' philosophical commentary: "Whitesides said we should be teaching less better – is [nanotech] to be included or omitted?"

Organization also arose as an issue in the debrief session. Table members would have preferred more advance notice of workshops and advance notice in general. One person preferred that it not be held "at the end of the term or Veterans' Day week." People felt it was difficult to get an overview with just two workshops. However, members of this table felt that advertising in ACS Nucleus was a smart move and appreciated the hands-on materials provided at the Symposium.

3.3 Table C: Educators Stress the Importance of Hand-outs and Hands-on Activities

In part due to a lack of oversight, this one table had no facilitator. Instead, one of the teachers there served as a makeshift scribe and facilitator and wrote their reflections on the day. This group broke up their discussion in terms of a "kudos," "deltas" and "next steps" section on their large notepad. From their comments, it is apparent that handouts were really important for their own learning and to bring into the classroom. Under the kudos section, they applauded the Symposium for its price, some of the take-home lesson plans and the "excellent speaker choice." However, they wanted to attend more sessions, "more nanotoys" and "more lab based activities/workshops." For next steps, they requested an "e-community/message board for continuing support/advice" and "field trip connections / possibilities."

3.4 Table D: Workshop Leaders Felt Greater Organization Needed

This table consisted of workshop leaders only. The workshop leaders' comments echoed many of the workshop leader survey findings. They felt that the "sessions flowed well, [and there were] no technical snags." There were many benefits of "meeting other people involved in science education who are from different academic backgrounds" and gaining "experience in presenting for own personal growth – learning from others." However, compared to Table B and C, this group focused largely on ways the Symposium could be improved. Their general feeling was that, "A lot of stuff came together at the last minute. [It] went well, but [there was] anxiety feeding up to it."

Before attending the Symposium, workshop leaders felt they should be more informed. "Have mini-presenters be aware of what the large lectures will cover" and tell them about workshop attendees: "Where are they from? What level they teach? Have more information… before to tailor workshops."

These workshop leaders felt that certain logistics of the Symposium should have been different, such as the ordering and size of workshops. "George Whitesides – would have been ideal to be

the first talk. [He provided a] good overview. [He] gave better context to the afternoon sessions. Dan [should have been] earlier in the morning [to] give context of full thing."

Furthermore, at the end of the Symposium, they felt there should be a way to find out about workshops they didn't attend: "Having a single website where we could all post stuff, follow-up and learn about sessions you couldn't attend." One member was concerned about how to further support attendees' learning: "How much does it all get shared once you get back? Is this just a one time thing? I would like to connect."

3.5 Debrief Session in Review

Across the four tables, many of the same comments from the educator and workshop leader survey responses appeared. In certain groups, certain issues—like organization, content knowledge learned, and classroom application—were stressed more than others. Likewise, certain groups were more positively oriented than others.

Part of the differences could be explained by the range in educator learning preferences and reasons for coming. At one table, there was strong dislike of their *Social Implications* workshop due to the presentation style and moderation whereas members of another table declared it their favorite of the day's workshops. Or, certain individuals would voice disliking the small size of workshops and another person would applaud its intimacy. Furthermore, some educators craved having hand-outs and being given a curriculum to use in their classrooms while other educators stated they were there to build a foundation of understanding.

For those who wanted to take away a curriculum, several *Size Matters* attendees highlighted the curriculum as a great way to implement nanoscale in the classroom. One table was so taken by these comments that they rushed up to the *Size Matters* professional curriculum developer during the debrief session to request booklets.

The main suggestion that emerged from the debriefs was to create a website full of content from the day's workshops, complete with handouts educators could obtain from workshops that they did not attend. Another common suggestion that arose throughout the debriefings and in the survey results was having better planning and organization beforehand. Both educators and workshop leaders wanted more advance notice, particularly in terms of workshop availabilities, grade level the workshops were geared towards, and content information or curriculum foci. Workshop leaders also felt advance notice of their workshop attendees would have helped guide their foci.

Perceived challenges included prioritizing what information to teach, being able to effectively teach the concept of scale, and contending with the subject's interdisciplinary nature.

4. EDUCATOR FOLLOW-UP SURVEYS

In May 2006, the 32 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 13 educators responded (41%).

4.1 Educators Talked about and Noticed Nanotechnology after Participating in the Symposium

After attending the Symposium, most educators reported:

- discussing nanotechnology with other adults (10 of 13 respondents)
- searching for more information online (9 of 13 respondents),
- noticing related news in the mass media (8 of 13 respondents).
- accessing the nanotechnology website for more information (7 of 13 respondents)
- recommending the Symposium to others (6 of 13 respondents)
- noticing nano-products (6 of 13 respondents)
- and visiting the Museum of Science website for more information (6 of 13 respondents).

To a lesser degree, a few of the respondents wrote to someone in the nanotechnology field (3 of 13 respondents), signed up for a related research opportunity or bought a book (2 of 13 respondents each), and one person kept in touch with a Symposium participant or leader.

4.2 Six Months After Attending, Educators Experienced Significant Drop in Likelihood to Seek out Additional Learning Opportunities

In the original survey educators filled out at the Symposium, a question asked them to rate their interest level in, understanding of, and likelihood to seek out opportunities to learn about nanoscale science and engineering before and after attending the Symposium. While the majority of attendees indicated a gain in all three areas as a result of attending the Symposium, six months later when asked to fill out the same questions, their ratings had decreased for all three measures. Educators' likelihood to seek out additional learning opportunities on nanoscale science and engineering had fallen significantly (Wilcoxon, p=.034). In other words, after some time passed, educators felt they had gained something from the workshop, but it was not as large as they had reported immediately after attending the workshop. It is possible that in their original ratings, educators were excited and with time, this sense of discovery faded. Of course, the findings have limited applicability because there were only 11 comparable responses (comparisons were possible either because these educators provided their names on their surveys or because we matched up demographics).

In answering how the Symposium changed educator perspectives on nanoscale science and engineering, two themes arose: that nanotechnology is everywhere already ("how prevalent nanoscale technology already is in our world," #F2) and that it will eventually impact the science curriculum ("things are changing rapidly and our curriculums are very stagnant," #F13). One educator wrote that she would be participating in nanotechnology-related research this summer at MIT and was very excited.

Educators most frequently reported remembering the nanomedicine presentation, confirming the saliency of applications that have a direct impact on people's lives. Slightly less frequently mentioned were Professor Whitesides' keynote address and individual workshops.

4.3 Educators Intend to Incorporate Nanoscale Science and Engineering in the Classroom, but Still Have Questions on How to Do So

When asked if they had incorporated nanoscale science and technology concepts into their classroom, there was a range of responses. Two educators responded that they had (2 of 10) through a "webquest" assignment (#F6) and with a short unit which "was well received by the students. We also had some positive feedback from parents" (#F1). Three educators felt nanoscale science, engineering and technology (NSET) did not fit into their curriculum well, so one educator passed the information on to "the chemistry classes" (#F13) and another educator brought it up in class "in incidental ways, in teachable moments" (#F6). Four educators said they were planning to do so either after MCAS, the next year. Only one educator said there was no time in his curriculum: "We've discussed it, but the CT Frameworks has generated a curriculum w/ not even a nanosecond to spare to explore something as important as this" (#F3).

Many educators still had the same questions about how to teach this topic to their students. They wanted "some ideas of how to integrate [NSET] into all areas of science" (#F14) and one educator suggested having "applets that could fit into biology, chemistry, physics, physical science, math, business and career development… in a manner that is consistent with state frameworks" (#F11). One educator wanted to know how to "dumb it down" (#F4) Other educators wanted ways to "keep up to date without reading technical papers" (#F1) and to know "what is currently 'happening' in the field? Who is doing interesting work? What are some new or innovative applications? What are some current failures in nanotech?" (#F6).

While a third of respondents said they didn't know if their school was interested in incorporating the topic into the classroom (4 of 11 respondents), another third of educators said their school might explore it (4 of 11 respondents). Two educators responded that their school was very interested in incorporating it and one educator said that his school wasn't interested due to a full curriculum without a "nanosecond to spare" (#F3).

Recommendations on how the Symposium could have better supported educators echoed those listed in the initial survey responses. Educators wanted more science and technology content, like "more labs and real life applications" (#F10) and "more information on the 'technology' aspect." One educator emphasized " I want to learn about it, about the science… I need background information and that is what I would like to gather when there are experts around" (#F6). One educator wanted attendees to share NSET curricula and methods for introducing NSET into their classroom: "Maybe put together a [listserv] for participants to share their experiences back at school so that there is a quick and easy way to share experiences" (#F2). Another educator suggested inviting people with authority over the state frameworks, the "powers that be, i.e. the state Department of Education science people, to witness this" (#F4).

5. FOLLOW-UP WORKSHOP LEADER & STAKEHOLDER INTERVIEWS

In July and August 2006, four stakeholders and/or workshop leaders participated in a follow-up interview regarding what their institutions had gained from the Symposium and what they had personally gained from the Symposium. Interviewees had been selected by Symposium organizer Carol Lynn Alpert. Three of the interviewees had read this report's executive summary and one interviewee had read this entire summative evaluation. Two of the interviewees had participated in the Symposium minimally while one helped with the planning and other helped with planning in addition to serving as a workshop leader.

5.1 Workshop Leaders and Stakeholders Reported Gains from the Symposium

Interviews revealed that all individuals felt positively about the Symposium: "We basically were happy with it" (#P2). Three of the interviewees mentioned being taken by educators' interest during and motivation for attending the Symposium: "it's also very nice to see teachers [who] are excited about this topic, so it's a motivator for us as researchers and educational outreach professionals that research we're doing is exciting to teachers and their students" (P3).

Two of the stakeholders and/or workshop leaders described gaining experience as an institution and personally in running a workshop:

> *Well we gained experience in doing this type of symposium in this topic. We learned who had relevant knowledge and information to share with teachers; we learned about what the teachers' issues and interests were with it. We learned… what worked and what didn't with the format (#P4).*

One interviewee described how their institution was able to get "good exposure for the research we're doing here" (#P3). Another interviewee described how lessons were learned for next year's Symposium (#P2). On a personal level, only the individual who served as a workshop leader reported gaining something substantive, such as presentation experience.

More than anything, the summative evaluation report confirmed the stakeholders and/or workshop leaders' ideas, which is not surprising given these individuals deal with these challenges on a regular basis in their professional life.

5.2 Each Stakeholder and/or Workshop Leader had Different Opinions on How to Improve Symposium

Each stakeholder and/or workshop leader had different ideas about how to improve the Symposium, which were in part informed by their previous thoughts on the topic:

- *"What would help would be people who know science and help people work out either a sort of module you could use in the classroom… Getting graduate students can be interesting...*

One comment [educators] made [in the report] that would be effective like EBay… putting modules or demos or news or new development shows that are prepared for the public [online]" (P1)

- *"Teachers in general wanted hands-on; [they] agreed with me. Collaborating with the workshop leaders [doing] a better job" (P2)*

- *"Follow-up online… I'm just not totally clear of all the things out of their suggestions and analysis would result in further activity. This at least raised the teachers' awareness" (P4)*

In addition, some interviewees mentioned wanting greater diversity of educators present as well as possibly exploring presenting nanotechnology as an interdisciplinary topic that can be integrated into all types of science classes.

V. CONCLUSION

Overall, findings reveal that the Symposium largely achieved its goals. From the high ratings to the survey scale questions, we have learned that the educators and workshop leaders alike left the Symposium feeling as though they had gained something –greater knowledge, interest and avenues to pursue further information, and networking contacts. The follow-up educator survey and stakeholder/workshop leader interviews confirmed this perceived gain months from the event. As one educator responded to the survey and follow-up, "The point was to introduce a concept that is not normally covered in the current classroom and see if teachers can respond to the impetus. The Symposium accomplished that task" (#F10). From the perspectives of the attendees, the focus of the Symposium seemed to be on personal learning rather than professional learning for immediate application in the classroom. As many of the debrief and follow-up web surveys indicated, before teaching nanoscale science and engineering to their students, educators wanted to understand the technology themselves and become more familiar with the underlying concepts.

The true strengths of the workshops were researchers' presentations on what nanoscale science and technology is and what the relevant issues are. Both educators and workshop leaders reported the weight Professor Mazur, Professor Whitesides and Daniel Davis' presentations had in contributing to their learning and interest. Notably, all three lectures consistently presented new content information and provided context on the technology's importance. For workshop leaders, many of whom are in the business of leading such workshops, it was also a treat for them to see how such noted researchers interacted with the educators.

In terms of content, educators found the applications and social implications of the technology most intriguing. In fact, two of the 14 workshop leaders said they would definitely bring the social implications aspect up with their students/teachers. Educators were also quite fascinated with the future of nanomedicine. The great interest in these three aspects of nanoscale science and engineering corresponds with previous research findings that people are most interested in areas of science that have a direct impact on their lives– typically through health and the environment (Chin, 2005; Flagg, 2005; Storksdieck, Jones, Falk & Alpert, 2002).

With workshop leaders feeling the Symposium was least successful in providing educators an ability to integrate nanoscale into the curriculum, the major question was whether any educators would actually teach nanoscale that year. From the follow-up web surveys, we found that two educators actually implemented lesson plans into their curricula, but most other educators either thought they would in the future or did not find the topic relevant to their own subject matter. Six months after attending the Symposium, educators were still interested in the topic and had many of the same questions about how to integrate it into their classes and how to stay knowledgeable of developments in the field.

As with any event, there were strengths alongside weaknesses. What emerges from both the educator and the workshop leaders' comments is the fundamental importance of feeling informed,

about knowing all relevant information about the Symposium beforehand. In part, it is a matter of comfort and feeling as though one can make informed choices within the Symposium – like what workshop to go to, how to tailor the workshop for attendees and in effect, designing what one would learn from that day. While the website claimed it would provide more information about the workshops and told educators to come back later (see http://www.mos.org/doc/1894), it was never updated. Ideally, the website should not only have had descriptions of workshops, but have an online sign-up. Recommendations for the website are made below.

As the results revealed, there was still room for many other improvements like providing more handouts from other workshops and being able to attend more workshops and more advanced workshops. We also discovered educators' viewpoint – that because this was such a new topic to educators, many just wanted to come and learn about it and focus less on immediately teaching it. This might weigh workshops that focus on teaching content knowledge as opposed to nano-related curricula more heavily. Many wondered how they would help their students overcome the conceptual underpinnings of size—a faceless concept—and how to present the information in an interesting and engaging fashion. Educators also wondered how they would fit the topic into the curriculum given time and space restrictions with the state standards and how to fit it across the disciplines. Other educators wanted to know how stay up to date on developments in nanoscale science and engineering.

For workshop leaders, the issue was consistently about organization. For example, *Carbon Nanotubes* workshop leaders collected their own evaluation surveys. One person did not rate their *Carbon Nanotubes* workshop for that reason, stating that he had already turned in their evaluation. In addition, part of the original goal was to support workshop leaders' learning of what other organizations were doing. Their learning would have been better supported had they attended their colleague's workshops which would allow for discussion and feedback. It might also help create a discussion of best practices in nano-curriculum and in how to enhance their own professional development workshops. Another suggestion was having greater involvement in the planning process.

In effect, all of the suggestions could be executed through advanced planning which is quite understandable given that this was the first "experimental" Symposium and one to learn many lessons from. It appears that some of the educators seem open to attending the Museum's next workshop or future related programming if offered. Thus, future Symposia have to take into consideration designing a Symposium that might include repeat attendees.

Recommendations

From the findings emerges a clear set of recommendations for future Symposia:

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1. Keep researchers and presenters as a key feature of the Symposium.

With attendees valuing the researchers and nanomedicine presentations highly, it is important to keep these sources of content knowledge for educators. Future Symposia might start out with

such presentations and lectures to set context followed by lunch and then two to three workshops; for some attendees who enjoyed the mixture of speaking and listening, there might be opportunity to discuss thoughts between sessions and try hands-on activities. The workshops would remain a mixture of foci on content or curriculum, allowing the educators to choose based on their reasons for attending the Symposium and required knowledge basis. Future Symposia might also directly address educators concerns about their students' lack of developmental readiness to take on the concept of size and engaging ways to present NSET to students.

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2. Create a website with additional resources for educators to continue learning and to learn more about stakeholders.

The website should exist throughout the year as a means of planning, learning and support for educators. Before Symposia, educators could find out information on each workshop and sign up for individual workshops. (Incidentally, information could also be collected on the demographics of each workshop's anticipated attendees.) Furthermore, the website might even have handouts and PowerPoint presentations before the next Symposium occurs for individuals who like to prepare for the event beforehand, and for others to view after the event. Links and contact information should be provided for the Symposium's sponsors and stakeholders; furthermore, links should be provided to the Museum of Science's CS&T section on nanotechnology and other nanotechnology websites. The website might even provide an online forum for attendees who have questions afterwards – whether about content, implementation or logistics –to extend learning and support. Additionally, it should advertise future events, such as the nanotechnology forums the Museum of Science will be hosting in 2006.

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3. Collaborate with workshop leaders when planning the Symposium.

As the workshop leaders, too, have years of experience in leading professional developments, they could provide valuable insight in Symposium logistics and planning. Collaboration with workshop leaders would not only change the nature of their experience, but help design the Symposia so it further supports the workshop leaders' growth.

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4. Restructure lunch with researchers so that researchers and workshop leaders are present at each table and facilitate conversation.

The lunch needs to have a guided conversation with the "experts," as the MOS Energy Forum successfully did, in which the workshop leaders can have the opportunity to ask the educators questions and vice versa. With a guided conversation, ideas can be stimulated around teaching nanoscale science and engineering. Alternatively, this component could just be a standard lunch that allows for informal conversations between attendees.

5. Provide follow-up learning opportunities to educators through lectures, exhibits and news of other relevant professional developments.

As nanotechnology is an emerging field, educators used the Symposium as a platform for building knowledge and to learn ways a unit might be incorporated into their physics, chemistry or technology class. However, one of the educators' perceived challenges was battling their own lack of understanding. By providing related, interesting lectures on the weekend, forum programs, Friday evenings at the Museum and/or on the web, or developing a comprehensive exhibit, the Museum could provide opportunities for educators to extend their own learning and their students' knowledge on the topic. This is especially important given that many educators are not planning on teaching nanoscale science and engineering for a while.

6. Provide another meeting time for workshop leaders to share curriculum and ideas.

Because the Sunday workshop leader session was largely spent reviewing logistics, workshop leaders might benefit from having more time together as a group. Perhaps if a meeting was set for a different weekend day and for a longer period of time, workshop leaders could even run through their presentation, discuss issues or problems that are relevant to them, and give one another suggestions. Such collaboration would benefit the Symposium overall.

7. Address the learning needs of advanced or repeat educators with higher level workshops.

Consider designing workshops designed for educators who are coming to the Symposium with a higher level of knowledge on nanoscale science and engineering or those who are returning to the Symposium to continue their learning. These workshops might be advertised as being designed for individuals with prior knowledge of specific concepts in nanoscale science and engineering.

8. Have workshop leaders address how to integrate material into the school year, especially given the constraints of a tightly regulated curriculum.

Since so many educators brought up time, cost and curriculum constraints as the main obstacles they foresaw in integrating nanoscale into the curriculum, workshops should directly address these challenges. Perhaps workshop leaders might present or feature educators' real experiences in trying to fit nanoscale science and technology into their curriculum, when, for how long and how it fared.

9. Adjust evaluations based on methods that worked well and remove aspects that were less successful.

Because there was no time to pilot test the instruments beforehand, the Evaluation team can learn lessons about what data collection methods that worked well and those that did not. Next year, surveys should not request personal information like names and contact information on the same sheet of paper; names should be optional and contact information placed on a detachable sheet stapled to the survey. In addition, since the debrief session tended to reiterate many of the survey findings, it is an unnecessary component for evaluation. Finally, next year Science Central should be better equipped and experienced to collect registration data.

There are some limitations to the findings that we must consider. With the same categories of responses reappearing across survey questions and in open-ended questions (e.g., nanomedicine, Professor Whitesides' presentation), it is possible that these were the most salient, interesting and important aspects and learnings attendees took away from the Symposium. Alternatively, the earlier survey questions, which list these elements, may have prompted or brought to mind these same elements to mind. These categories—which often included the presentations—might also appear most often because all attendees saw the same presentations, unlike the individual workshops.

The results demonstrate that the Symposium met many of its original goals. Overall, the Symposium is a valuable experience for educators in raising awareness of an emerging field and in creating much learning. While educators feel it is important that they are aware of and understand nanoscale science and technology at a basic level, incorporating the topic into their curriculum faces challenges with restrictive statewide standards, limited resources, the seemingly interdisciplinary nature of nanotechnology, and their basic understanding. In recognizing these challenges, Symposium organizers can move forward to best help educators, workshop leaders, stakeholders in future Symposia and in providing follow-up opportunities to continue educators' learning of nanoscale science and technology.

V. REFERENCES

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APPENDIX A Nanotechnology Educator Symposium: Educator Survey

Please help us better understand your experience by answering the following questions. Your answers will remain confidential and unassociated from your personal information. Thank you!

Name:_____ **School:** _____ **Gender: M F**

1. Which of the following workshops did you attend today?

☐ Intro to Nano through Products ☐ Carbon Nanotubes ☐ Research & Teaching
☐ Size Matters: Intro to Nano ☐ Soft Lithography ☐ Societal Implications of Nano

2a. How much did the following contribute to your learning about nanoscale science(s)?

	Did not contribute						Strongly contributed
a. Welcome and Overview	1	2	3	4	5	6	7
b. Nanowires presentation	1	2	3	4	5	6	7
c. Workshop I (list):	1	2	3	4	5	6	7
d. Workshop II (list):	1	2	3	4	5	6	7
e. Nanomedicine presentation	1	2	3	4	5	6	7
f. Lunch with Researchers	1	2	3	4	5	6	7
g. Keynote address – G. Whitesides	1	2	3	4	5	6	7
h. Handouts	1	2	3	4	5	6	7
i. Symposium Overall	1	2	3	4	5	6	7

2b. Please comment on how any of the above activities could be improved in future Symposia.

3a. How interested were you in nanoscale science and technology:

	Not at all interested					Very interested	
BEFORE attending the Symposium?	1	2	3	4	5	6	7
AFTER attending the Symposium?	1	2	3	4	5	6	7

3b. What aspect of nanoscale science and technology discussed during the symposium did you find most intriguing?

4a. How much did you feel you understood basic nanoscale science and technology concepts:

	Understood nothing						Understood a lot
BEFORE attending the Symposium?	1	2	3	4	5	6	7
AFTER attending the Symposium?	1	2	3	4	5	6	7

(OVER➔)

4b. What did you learn about nanoscale science and technology that you didn't know before?

5. What are the biggest challenges you foresee, for you and your students, in incorporating material from the workshops into your class?

6. If offered again, how likely are you to recommend this Symposium to other educators?

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

7a. How likely were you to seek out opportunities to learn about nano-science and engineering?

	Not at all likely					**Very likely**
BEFORE attending the Symposium?	1	2	3	4	5	6	7
AFTER attending the Symposium?	1	2	3	4	5	6	7

7b. How could the Museum further help you learn about nanoscale science and engineering?

8. How many years have you taught science/engineering/technology? _____

9a. Check off your highest level of education in science and/or engineering:

- ❑ Professional developments in science/engineering
- ❑ College coursework in science/engineering
- ❑ Associates degree in science/engineering
- ❑ Bachelors degree in science/engineering
- ❑ Graduate-level coursework in science/engineering
- ❑ Graduate degree in science/engineering
- ❑ Other: _____

9b. In what area of science is your highest level of training?

- ❑ Physics
- ❑ Chemistry
- ❑ Biology
- ❑ Physical science
- ❑ Engineering
- ❑ Technology
- ❑ Other: _____

10. Could we have your permission to call you in a few months to get more thoughts and feedback? Our conversation would last only 10 to 15 minutes. c

☐ No ☐ Yes -> If yes, what is your preferred contact method(s)?

☐ Home phone:_____
☐ Work phone: _____
☐ Cell phone: _____
☐ Email: _____

APPENDIX B Nanotechnology Educator Symposium: Presenter/Workshop Leader Survey
Please help us better understand your experience by answering the following questions. Your answers will remain confidential and unassociated from your personal information. Thank you!

Name: _____ Gender: M F

1. Rate your agreement to the following statements.

		Strongly disagree						Strongly agree
a.	The Symposium was successful in introducing basic nanoscale concepts to educators.	1	2	3	4	5	6	7
b.	The Symposium was successful in providing educators the ability to integrate nanoscale to the curriculum.	1	2	3	4	5	6	7
c.	The Symposium was well organized.	1	2	3	4	5	6	7
d.	I feel I contributed to educators' knowledge on nanoscale science and technology.	1	2	3	4	5	6	7
e.	I am satisfied with my participation in the Symposium.	1	2	3	4	5	6	7
f.	This Symposium has provided me with valuable networking contacts.	1	2	3	4	5	6	7
g.	Working with other nanoscale professionals has helped me think about teaching nanoscale in different ways.	1	2	3	4	5	6	7
h.	I would be interested in participating in future Symposia.	1	2	3	4	5	6	7

2. What aspect of your Symposium experience (with teachers, presenters, workshop leaders, Museum staff, etc.) was most interesting to you? In what ways?

3. What was the most valuable thing you gained during this Symposium experience?

Rate your agreement with the following statements:

4. How familiar were you with teachers' perceptions of teaching nanoscience in the classroom:

	Not at all familiar						Very familiar
a. BEFORE attending the event?	1	2	3	4	5	6	7
b. AFTER attending the event?	1	2	3	4	5	6	7

(OVER➔)

5. How familiar were you with the range nanoscience classroom teaching techniques:

	Not at all familiar						Very familiar
a. BEFORE attending the event?	1	2	3	4	5	6	7
b. AFTER attending the event?	1	2	3	4	5	6	7

6. After attending the Symposium, what are the biggest challenges you foresee educators having in integrating nanoscale science and engineering into their classroom?

7. Please comment on how future Symposia could be improved.

8. How could the Museum further help you inform educators about nanoscale science and engineering?

9. Could we have your permission to call you in a few months to get more thoughts and feedback? Our conversation would last only 10 to 15 minutes. Any personal information you provide will not be associated with your responses.

☐ Yes ☐ No

If yes, what is your preferred contact method(s)?

☐ Home phone:_____

☐ Work phone: _____

☐ Cell phone: _____

☐ Email: _____

APPENDIX C Nanotechnology Educators Symposium Focused Workshop Observations

November 7, 2005

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Workshop Title:
Time:

MoS staff present:
Number of Educators present (& demographics, notes):

As the workshop progresses, describe the following types of information in the space below. Note anything else you find interesting, unusual or noteworthy:

- basic format (Q&A, lecture, open discussion, activities, etc.)
- style of workshop leaders
- flow

- turning points
- points of interest to you, educators, presenters
- questions teachers asked

RECAP:
What was the mood/group dynamics of the workshop?

What were the basic points the workshop covers?

- **nanoscale content**
- **teaching**
- **overall**

Workshop Debrief Sheet:

On a scale from 1 to 10, where 1 represents a low level/amount, and 10 represents a high amount/level, rate the workshop on the following criteria:
If you are unsure, write a question mark and write notes.

Criteria	**Scale from 1 to 10**
EDUCATORS' GENERAL EXPERIENCE	
Level of educators' engagement/interest level	
Level of discussion among educators/workshop leaders	
Level of question asking	
Level of educators' perceived comfort	
Level of confusion	
Level of perceived learning	
WORKSHOP CONTENT	
Amount of hands-on activities	
Depth of hands-on activities contributing to nanoscale knowledge	
Amount of connections made to state curriculum framework	
Amount of nanoscale science and technology information presented	
Amount of curriculum presented explicitly	
Amount of sponsor promotion/recruitment	
Amount of time spent listening to workshop leaders	
WORKSHOP ADMINISTRATION	
Level of workshop's organization/flow	
Workshop's time management	

Breakdown of Workshop by %:
Hands On Activities: _____
Teacher Discussion: _____
Direct instruction: _____
Teacher questioning: _____
Other (list): _____
_____
100%
Overall practicality (1-10):
Overall Quality of Program to Increasing Teacher Understanding (1-10):

APPENDIX D Evaluation Team Workshop Summaries and Reviews

Introduction to Nanotechnology through Consumer Products

This workshop was based on a summer camp program that the stakeholders run in presenting nanotechnology through everyday consumer products. The presentation was based on a PowerPoint with basic information about what nanotechnology is, conceptualizing how big a nanometer is and good websites. Pairs of educators were given a product (e.g., CD, bacteria-eating socks, tennis balls and photo paper), a description of it, and asked to briefly give a presentation to the group. Unlike other workshops, only one "extension activity" handout was given.

Evaluation: The workshop had a moderate-low amount of perceived educator learning, but provided easily accessible products and examples educators could use in their classroom. While the workshop was well organized and time management was good, the hands-on activities and curriculum activities were lacking, no connections were made to the state curriculum. A moderate-low level of information of nanoscale science was presented. The overall practicality was rated a 4 and overall quality of the program to increasing teacher understanding was rated a 3.

Size Matters: Introduction to Nanoscience

Size Matters presented a curriculum unit to teachers, giving each teacher a hefty book of lessons to take home. Teachers participated in one hands-on activity illustrating nanoscale principles on measurement. The workshop leader took teachers through the book and different types of activities they could do, as well as a one-day activity curriculum. Some material about nanoscale instruments, common teacher questions, teaching to standards, and principles the curriculum emphasizes were touched upon.

Evaluation: Teachers asked many questions about how to use the unit and engagement was high as this course had great perceived practicality. While level of learning more about nanoscale concepts was not very high and the workshop leader ran out of time, with teachers seeming to want to ask more questions, the workshop presented much curriculum and had a moderate amount of teacher discussion and question asking. This workshop had an overall practicality rating of 10 and an overall quality of program to increasing teacher understanding rating of 7.

Stronger than Steel: Carbon Nanotubes

Students from Boston University presented applications for nanotubes in the science areas of chemistry, physics and biology, giving some technical background information. Among topics presented were an overview of carbon including its history, an activity to make a carbon using paper, and information on nanotubes and medicine and nanotubes as filters to see the spectrum. In each presentation, students offered one demonstration or participation based activity.

Evaluation: The presentation was highly engaging and educators asked questions about specific science components and information on new product development and cost factors. There was a high level of nanoscale science and technology information presented and a moderate-low amount of discussion among educators and workshop leaders and no hands-on activities. Instead, much time was spent listening to workshop leaders. This workshop had a

practicality rating of 9 and the overall quality of this program contribution to teachers' increased understanding was rated an 8.

Soft Lithography: Modeling Nanoscale Manufacturing Processes

In Soft Lithography, the workshop primarily focused on the activity lab. A brief introduction was given beforehand of lithography, what it was and its history. Rubbery, solid stamps were given out. Course and lab outlines were also presented to provide a connection to the classroom.

Evaluation: There was a great deal of hands-on activity in this lab but a weak amount of nanoscale science and technology was presented. Educators' perceived learning was moderate as was the depth of the hands-on activity. Overall, this program received a practicality rating of 8.

Research Experiences for Teachers: Strengthening Classroom Practice

This workshop was only offered in the morning session. Its main points were to give teachers an idea of what it was like to spend a summer in a nanoscale research lab. The workshop gave two activities educators could do in the classroom to teach about nanoscale science and technology, the logistics of being part of a program (e.g., where it takes place, when, how much you get paid, etc.). There was a brainstorming session of professional development needs, which was unclear as to how it benefited teachers.

Evaluation: It appeared that teachers were moderately engaged in the workshop and learned a moderate amount of information. There was a great deal of sponsor promotion and recruitment. The organization and time management was rather poor. No connections were made to the state standards. There was an overall moderate level of practicality to the workshop (e.g., rated a "5") and a "5" for overall quality of the program to increasing teacher understanding.

Societal Implications of Nanotechnology

This workshop was structured with a conversation at the beginning that was designed to be an example of the type of conversation educators could have with their students. The basic points of this workshop were that every technology impacts our society on many different ways, such as the way we teach, the way we learn, our health, environment, military and many other ways. Currently, the public does not know much about nanotechnology. The "experts" feel nanotechnology is a revolution and nanotechnology's impacts are vast, numerous, endless and unknown.

Evaluation: The afternoon session was observed and there was a high level of discussion among teachers as well as teacher questioning. There was a high level of perceived comfort and interest among educators, moderate amount of perceived learning and curriculum presented, and no hands-on activities or connections made to the state frameworks. A great deal of time was spent listening to workshop leaders as well. This workshop was rated a "7" in terms of practicality to teachers and a "5" in overall increasing teacher understanding.

APPENDIX E Debriefing Session Protocol and Questions

At the end of the symposium, educators will participate in concluding activities where they can reflect on the experiences of the day. This debriefing sessions (which will take place in Skyline) will serve three purposes: (1) to provide the educators with a forum for sharing their perspectives of the day with one another, (2) to raise the educator's awareness of their own learning, and (3) to create an opportunity for the Museum of Science Research and Evaluation department to capture what the educators felt were the most beneficial aspects of the symposium.

The format and structure of the debriefing session will be as follows:

- Carol Lynn Alpert will inform the educators at the beginning of the day that there will be "concluding activities and refreshments" at the end of the day;
- Following the second workshop, educators will be directed to go to Skyline to participate in the concluding activities;
- Once most of the educators are settled in Skyline and have refreshments in hand, Carol Lynn Alpert will introduce the purpose and structure of the debriefing session to the symposium participants (highlighting the opportunity for information sharing and reflection);
- Each discussion group should have ten educators plus a few stakeholders or presenters. One table should be designated for college/ community college professionals only;
- A Museum of Science staff person will lead a 15 to 20 minute discussion at each table, asking the questions listed below, and recording the participants' responses on the large pads of paper and easels provided. The person who is facilitating the discussion should use the provided questions as a guide, but should feel free to ask additional or alternative questions if the educators move the discussion into a certain direction (these questions, however, should also be recorded on the easel so that we know what the question was the prompted the different responses recorded). If time permits, an educator from each table can report back what the whole group has discussed.
- Staff at each table should point out a sign-up sheet for an email nanoscale science and engineering news list.

During the discussions, the facilitators should try to focus the discussion on the following:

- What the educators feel were the most valuable aspects of the symposium;
- How the symposium may affect the educators' classroom instruction, if at all; and
- What the Museum can do to further help educators learn about nanoscale science and technology.

Specific questions to be asked during the debriefing could include the following:

- [Warm up question] So, how are you feeling about how things went today?
- What were the most important things you learned? [Probe: From your workshops?]
- What, if anything, from today do you think you could incorporate into your class? [Probe: What? When?]
- What challenges do you think you and your students will have with the nanoscale materials?
- What questions do you still have about nanoscale science and technology? [Probe: What still confuses you?]

APPENDIX F FOLLOW UP WEB SURVEY

Nanotech 2005: A Symposium for Educators Follow-Up Survey

1 of 2

Now that several months have passed since you attended the 2005 Nanotech Symposium for Educators, we'd like to hear your thoughts. Please answer this brief survey. Your responses will shape our planning for the 2006 Nanotech Symposium for Educators.

1. Name

(optional)

2. School you teach at:

(optional)

3. How interested are you in nanoscale science and technology?

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

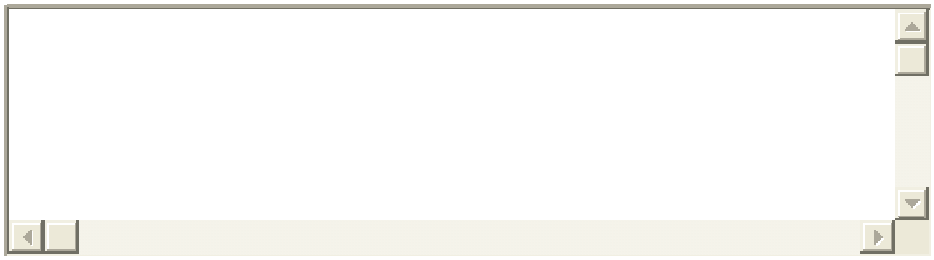
4. How much do you feel you understand basic nanoscale science and technology concepts?

Understood nothing						Understood a lot
1	2	3	4	5	6	7
○	○	○	○	○	○	○

5. How likely are you to seek out additional opportunities to learn about nanoscale science and engineering?

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

6. What has been for you the Symposium's most memorable event or activity?

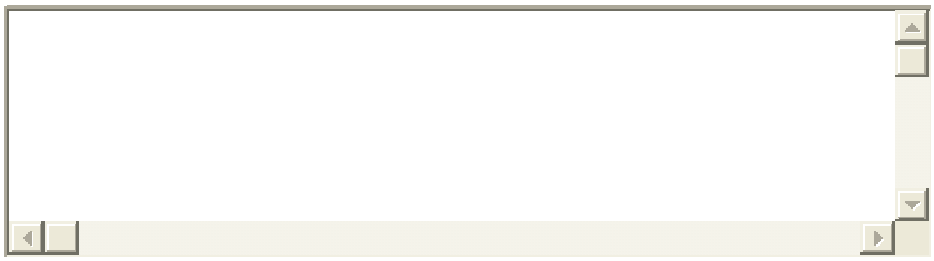


7. Did attending the workshop prompt you to...

(Check all that apply)

- ☐ Discuss nanoscale science and technology topics with other adults
- ☐ Search for more information about nanoscale science and technology
- ☐ Visit the Museum of Science website to look for more information
- ☐ Access an Internet website related to nanoscale science and technology
- ☐ Purchase a book or other item related to nanoscale science or technology
- ☐ Notice nanotechnology products
- ☐ Notice related information in mass media venues like newspaper, radio, TV
- ☐ Write to someone in the field of nanoscale science or technology
- ☐ Keep in touch with other participants/presenters you met at the Symposium
- ☐ Sign up for a research opportunity in nanoscale science or technology
- ☐ Recommend the Symposium to others
- ☐ Review/re-read Symposium handouts, materials, or notes

8. Have you incorporated nanoscale science and technology concepts into your classroom yet? If so, describe what you did and how successful the experience was for you and for your students. If not, describe why you haven't.



9. If you did incorporate nanoscale into your curriculum, which Symposium materials did you use?

- ☐ Activities/curriculum learned during Symposium workshops
- ☐ Handouts from Symposium presentations
- ☐ Notes I took from the Symposium
- ☐ Activities/curriculum produced by others (not from Symposium)
- ☐ None, I developed my own
- ☐ Other:

10. How has your school responded to the idea of incorporating nanoscale science and technology in the classroom?

- ☐ Uninterested in incorporating it into the classroom
- ☐ Might explore incorporating it into the classroom
- ☐ Very interested in incorporating it into the classroom
- ☐ Don't know
- ☐ Other:

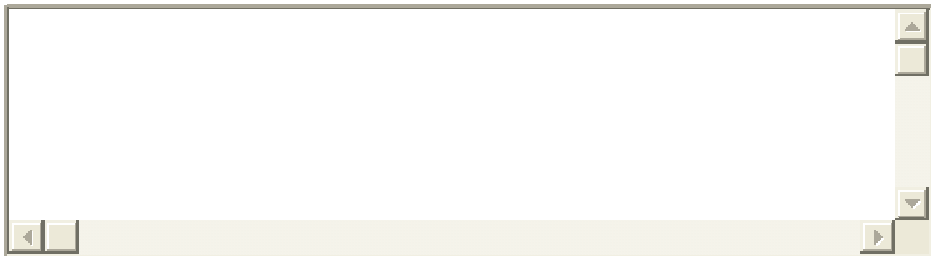
11. How, if at all, has attending the workshop changed your behaviors or perspective on nanoscale science and engineering?

(What are the one or two take-away messages that have stayed with you since you attended the Symposium?)

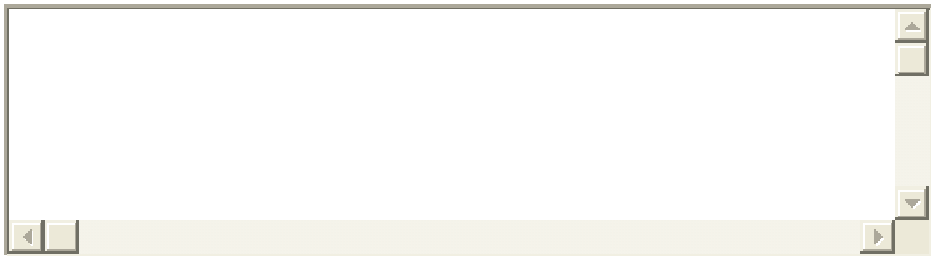
12. At the next Symposium, do you think we should add a workshop on careers in nanoscale sciences and engineering and invite guidance countselors to this event?

- ☐ Yes
- ☐ No

13. In retrospect, what could the Symposium have done differently to better support you?



14. What questions or thoughts have you had about nanoscale science and technology since attending the Symposium?



2 of 2

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

16. Check off your highest level of education in science and/or engineering:

- Professional development in science/engineering
- College coursework in science/engineering
- Associates degree in science/engineering
- Bachelors degree in science/engineering
- Graduate-level coursework in science/engineering
- Graduate degree in science/engineering

Other:

17. In what area of science is your highest level of training?

☐ Physics ☐ Engineering ☐ Chemistry ☐ Technology ☐ Biology ☐ Physical science

☐ Other:

APPENDIX G SYMPOSIUM MATERIALS

NANOTECH 2005: A SYMPOSIUM FOR EDUCATORS
Museum of Science, Boston
November 7, 2005
PROGRAM

Registration and Continental Breakfast 8:00 – 8:45
Museum Lobby and 2nd Floor, Blue Wing

Welcome and Orientation 8:45 – 9:00
Cahners Theater, 2nd Floor, Blue Wing

Professor Eric Mazur Presents Nanowires 9:00 - 9:45
Cahners Theater, 2nd Floor, Blue Wing

Transition to Workshops – Session One 9:45 – 10:00
Follow Museum staff guides

Workshops: Session One 10:00 – 11:15
Various venues

Transition to Current Science & Technology Stage 11:15 – 11:30
Follow Museum staff guides

Daniel Davis Presents Nanomedicine 11:30 – 11:50
Current Science & Technology Stage, 1st Floor, Blue Wing

Transition to Skyline Room 11:50 – 12:00 noon
Green Wing Elevator or Stairs to 6th Floor

Lunch with Researchers and Workshop Leaders 12:00 - 12:50
Skyline Room, 6th floor

Transition to Cahners Theater 12:50 – 1:00

Professor George Whitesides presents Keynote Address 1:00 – 1:50
Cahners Theater, 2nd Floor, Blue Wing

Transition to Workshops - Session Two 1:50 – 2:00
Follow Museum staff guides

Workshops: Session Two 2:00 – 3:05

Concluding Activities and Refreshments 3:15 – 4:00
Parking Stamps, PDP Certificates, Wrap-Up
Skyline Room, 6th Floor

NANOTECH 2005: A SYMPOSIUM FOR EDUCATORS
Museum of Science, Boston - November 7, 2005

SPONSORS

Nanoscale Science and Engineering Centers, supported by NSF

- **Center for High-Rate Nanomanufacturing (CHN)** nano.neu.edu
  Northeastern University, University of Massachusetts-Lowell, University of New Hampshire
- **Nanoscale Systems and Their Device Applications** nsec.harvard.edu
  Harvard University, M.I.T., UC/Santa Barbara, and Museum of Science

ADDITIONAL PROGRAM PARTNERS

- Nanoscale Informal Science Education Network
- Boston University Center for Nanoscience and Nanobiotechnology **nanoscience.bu.edu**
- National Nanotechnology Infrastructure Network **nnin.org**
- National Institutes of Health, National Center for Research Resources SEPA
- **University of Wisconsin / Madison NSEC, MRSEC, and Institute for Chemical Education**
- **SRI International** sri.com

WORKSHOP LEADERS

Societal Implications of Nanotechnology
Andrew Greenberg, University of Wisconsin/Madison; and Ron Sandler, Northeastern University

Introduction to Nanotechnology through Consumer Products
Nancy Healy, Georgia Tech and NNIN; and Kathryn Hollar, Harvard University

Size Matters: Introduction to Nanoscience
Tina Stanford, SRI International

Soft Lithography: Modeling Nanoscale Fabrication in the Lab
Christina Talbot, Harvard University RET Program; and Logan McCarty, Harvard University

Stronger than Steel: Carbon Nanotubes
Timothy Gay, Jessica Kaufman, and Marc McGuigan, Boston University GK-12, with Bennett Goldberg and Cynthia Brossman of Boston University

Research Experiences for Teachers: Strengthening Classroom Practice
Benadette Manning, Jim Megyesy, Gail Roach, Erica Wilson, CHN RET, with Claire Duggan, Carol Barry, Jacqueline Isaacs, Center for High-Rate Nanomanufacturing, Northeastern and UMass/Lowell

PRESENTERS
Daniel Davis, MoS; Jacqueline Isaacs, NEU; Eric Mazur, Geoff Svacha, George Whitesides, Harvard

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FURTHER PROFESSIONAL DEVELOPMENT OPPORTUNITIES FOR EDUCATORS

University of Wisconsin-Madison Nanoscale Science and Engineering Center
Summer Teacher Fellowships

The University of Wisconsin-Madison NSEC is seeking two motivated science teachers to join our education and outreach staff for six weeks during Summer 2006 as teacher fellows. The selected fellows will work closely with education and outreach staff and faculty in Institute for Chemical Education developing nanoscience related educational materials for the K-12 classroom and the general public. The fellows will also provide valuable feed back on existing and future education and outreach projects. Fellowships include a $5000 stipend. If you are interested in applying for a fellowship please contact Dr. Andrew Greenberg (greenberg@chem.psu.edu).

Harvard University Research Experience for Teachers
email: hollar(at)deas.harvard.edu (see separate hand-out)

Research Experiences for Teachers at Northeastern University
www.ret.neu.edu

Northeastern University GK12 Program
www.gk12.neu.edu

Nanotechnology Academy for High School Teachers of Advanced Science
http://scs.rice.edu/scs/Nanotechnology_Academy.asp

Stanford Center for Professional Development Nanoscience Program
http://scpd.stanford.edu/scpd/courses/ProEd/nano_online/default.asp

Virtual SEM XL30 Electron Microscope for Middle School Educators

A new program at Lehigh University which trains teachers how to "drive" the XL30 electron microscope, (SEM) so that they may then obtain the free software that allows them to run it remotely from their classrooms. A Virtual Nano Lab online designed for middle school. http://lehigh.edu/~inimagin and http://lehigh.edu/nano

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WEB RESOURCES FOR EDUCATORS and STUDENTS

Nanoscale Science and Engineering Education

1. NanoSense Project, curricula and activities developed by SRI International. www.nanosense.org
2. 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/
3. Introduction to NanoScience http://nanonet.rice.edu/intronanosci/
4. 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)
5. www.nanooze.org Web science magazine for kids with a focus on nanotechnology.
6. www.mainstreetscience.org Website for K12 educators, students, and public. Includes information on teacher and student institutes and internships at Cornell University.
7. NanoKids http://nanokids.rice.edu/
8. 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
9. 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.

10. National Nanotechnology Initiative nano.gov

11. Museum of Science, Boston. mos.org/nano

Size and Scale (list provided by SRI, Int.)

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

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Morning Research Talk


Eric Mazur (Photo: Armand Dionne 2002)

Eric Mazur holds a triple appointment as Harvard College Professor, Gordon McKay Professor of Applied Physics, and Professor of Physics at Harvard University. An internationally recognized scientist and researcher, he leads a vigorous research program in optical physics and supervises one of the largest research groups in the Physics Department at Harvard University.

After obtaining a Ph.D. degree in experimental physics at the University of Leiden in the Netherlands, Dr. Mazur came to Harvard University in 1982. In 1984 he joined the faculty and obtained tenure six years later. Dr. Mazur has made important contributions to spectroscopy, light scattering, and studies of electronic and structural events in solids that occur on the femtosecond time scale.

In 1988 he was awarded a Presidential Young Investigator Award. He is a Fellow of the American Physical Society and has been named APS Centennial Lecturer during the Society's centennial year. Dr. Mazur has held appointments as Visiting Professor or Distinguished Lecturer at the University of Leuven in Belgium, National Taiwan University in Taiwan, Carnegie Mellon University, and Hong Kong University.

In addition to his work in optical physics, Dr. Mazur is interested in education, science policy, outreach, and the public perception of science. He believes that better science education for all -- not just science majors -- is vital for continued scientific progress. To this end, Dr. Mazur devotes part of his research group's effort to education research and finding verifiable ways to improve science education. In 1990 he began developing Peer Instruction a method for teaching large lecture classes interactively. Dr. Mazur's teaching method has developed a large following, both nationally and internationally, and has been adopted across many science disciplines.