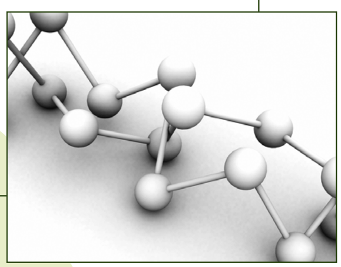

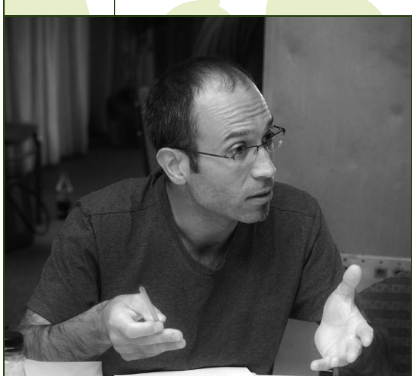

NISE Network
Public Forums Manual

This manual was prepared with funding from the National Science Foundation under Cooperative Agreement #0532536 (CFDA #47.076). Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Foundation.

Edited by Brad Herring
© 2007 Museum of Life and Science, Durham, North Carolina.
For the Nanoscale Informal Science Education Network

Acknowledgments: This manual would not have been possible without the writing, editing and guidance of the NISE Network Forums Team. Specific appreciation is given to the following individuals: Dave Chittenden, Sue Koch, Karen Pollard and Sabrina Sutliff-Gross, Science Museum of Minnesota; Larry Bell, Christine Reich, Elizabeth Kunz Kollmann and Barbara Costa, Museum of Science, Boston; Marilyn Johnson and Amanda Thomas, Oregon Museum of Science and Industry; Troy Livingston, Museum of Life and Science, Durham; and Veronica Garcia-Luis and Erin Wilson, Exploratorium. Gratitude is also expressed to Emily Maletz for providing her expertise with the design and layout of this manual and to the National Science Foundation for funding the NISE Network.

We encourage you to copy, adapt, or distribute this manual and/or the text and images contained in it for educational, non-profit purposes. The elements of this manual are available for download in common electronic formats from **nisenet.org***, and are contained on the CD that accompanies the 2008 NanoDays kits. When making copies or excerpts, please use the copyright credit above. If adapting the contents, please cite the manual as a source.*

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0. INTRODUCTION: THE NISE NETWORK

The Nanoscale Informal Science Education Network (NISE Net) is a national infrastructure comprised of science museums and university-based research centers collaborating to foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology through establishment of a network that links science museums and other informal science education organizations with nanoscale science and engineering research organizations. It is funded by a five-year cooperative agreement between the National Science Foundation and the Museum of Science – Boston and its core partners: the Exploratorium and the Science Museum of Minnesota. Other subawardees have included: Oregon Museum of Science and Industry, Museum of Life and Science – Durham, New York Hall of Science, Sciencenter in Ithaca, Fort Worth Museum of Science and History, Cornell University, University of Wisconsin – Madison, the Materials Research Society, the Association of Science-Technology Centers, Inverness Research Associates, and Multimedia Research.

The goals for the NISE Net are to:

1. Engage the public with nanoscale science, engineering and technology through exhibits, programs, media, forums and other kinds of informal educational products;

2. Build a professional network of relationships, alliances, and professional development opportunities between museums and the research community;

   and

3. Generate essential new knowledge for learning about nanoscale science and engineering.

One of the primary goals is to engage the museum going public and other partner stakeholder groups by helping to bring nanoscale exhibits, programs, and media to as many informal science education venues as possible, with a specific target of 100 venues over the course of the grant. The NISE Net plans to reach this goal by building a network of relationships between informal science education organizations, nanoscience researchers, and professional associations that can work together to accomplish more than any single institution could do on their own.

I. NANO PUBLIC FORUMS OVERVIEW

One focus of NISE Net's activity is the creation of nanoscale science, engineering and technology public forums that offer participants the opportunity to engage in thoughtful conversations about important issues regarding the potential societal, environmental and ethical implications of nanotechnology. They provide a vehicle for people of diverse views and backgrounds to deliberate on difficult issues and to seek a more comprehensive understanding of the topic.

The overall charge to the NISE Net Forums Team is to develop, test, and disseminate program models aimed at engaging adults and teenagers with informal educational experiences that incorporate discussion, dialogue, and deliberation around societal implications of nanoscale science, engineering and technology. The purpose of this manual is to provide information on how to engage members of the public in thoughtful conversations about important issues in nanotechnology.

The Forums Team (Figure 1) collectively has presented more than 30 forum programs and developed two program models (with different formats and topics) that have been tested at all five institutions, as well as a number of other forum program models implemented at only one or two sites. Going forward, the Forums Team plans to develop one more program model and to create dissemination packages for all three developed and tested programs. These program packages will be made available on **nisenet.org** along with information about other program models.

In addition to creating additional program models and distilling and posting the relevant knowledge about producing forum programs, work will be done in the remaining three years of the grant to expand the number of institutions with experience in presenting such programs.

Figure 1. Museum Collaborators in NISE Net's Forums Team

MUSEUM	STAFF	CONTACT
Exploratorium	Veronica Garcia-Luis	veronica@exploratorium.edu
Museum of Science	Larry Bell	lbell@mos.org
Museum of Life and Science	Brad Herring	bradh@ncmls.org
Science Museum of Minnesota	Dave Chittenden	davec@smm.org
Oregon Museum of Science and Industry	Amanda Thomas	athomas@omsi.org
EVALUATION COORDINATOR		
Museum of Science	Christine Reich	creich@mos.org

II. NANOSCALE SCIENCE AND TECHNOLOGY PUBLIC FORUMS

While nanoscale science, engineering, and technology promise advances in medicine, materials science, electrical engineering, energy production, chemical engineering, and many other fields, the very properties that make such advances possible raise concerns about unknown risks and societal, ethical, and environmental implications. These include the potential toxicity and environmental impact of engineered nanoparticles, or the potential implications of human enhancement or the violation of privacy afforded by new computing and sensor technologies. We believe that open public deliberation about these and other, still-emerging issues will help the public steer a midway course between blind scientific boosterism and wholesale rejection of new technologies.

Science centers internationally are exploring new models for engaging adults and older youth in dialogue and deliberation on issues related to the societal, ethical and environmental implications of technology. This democratization of public policy deliberation is a strategy for stimulating learning by both scientists and the public and for revitalizing the role of science museums in the life of the nation. These efforts lay the groundwork for an exciting new role for science centers as a bridge between scientists and the public.

In the first two years of the NISE Net's operation, five science museums have worked together to research, develop, and test a variety of program models aimed at engaging adults and older youth with in-depth informal educational experiences that incorporate dialogue and deliberation around societal implications of nanoscale science, engineering, and technology. The Forums Team is developing materials and expertise to share with the broader science museum community to build capacity in the field to further engage the public in this kind of programming.

FORUM GOALS

Overarching Goal: To provide experiences where adults and teenagers from a broad range of backgrounds can engage in discussion, dialogue, and deliberation by:

- Enhancing the participants' understanding of nanoscale science, technology and engineering and its potential impact on the participants' lives, society, and the environment.

- Strengthening the public's and scientists' acceptance of, and familiarity with, diverse points of view related to nanoscale science, technology, and engineering.

- Engaging participants in discussions and dialogues where they consider the positive and negative impacts of existing or potential nanotechnologies.
- Increasing the participants' confidence in participating in public discourse about nanotechnologies and/or the value they find in engaging in such activities.
- Attracting and engaging adult audiences in in-depth learning experiences.
- Increasing informal science educators' knowledge, skill, and interest in developing and conducting programs that engage the public in discussion, dialogue, and deliberation about societal and environmental issues raised by nanotechnology and other new and emerging technologies.

FORUM BENEFITS

NISE Net forums:

- Provide a new kind of experience for museum visitors beyond a traditional lecture + Q&A format.
- Are interactive "minds-on" experiences.
- Provide opportunities for visitors to meet new people and enjoy thoughtful, meaningful conversations.
- Enable participants to hear others' points of view and values.
- Enrich participants' critical thinking on issues.
- Offer participants the ability to meet scientists and interact with them on a personal level.
- Provide an important step toward defining a new role for the museum in the community, as a neutral place to hold conversations on controversial or unresolved topics.
- Are a relatively easy, inexpensive, and modifiable format.
- Are good vehicles for encouraging thinking about societal, ethical and environmental implications issues.
- Offer a quicker turnaround time from start to finish than exhibits.

- Provide a means for participants to get directly involved with people who have a variety of expertise, beyond those making presentations.

- Enable those in industry/research to gain insight on public attitudes toward their work.

- Build social capital with scientists and community.

III. PLANNING A PUBLIC FORUM

Public forums offer participants the opportunity to engage in thought-provoking conversations about important issues surrounding nanotechnologies and their potential societal, ethical and environmental implications. NISE Net forums are different from traditional museum lecture programs in that they set the stage for visitors to play a more prominent role in the program. Through small group discussions, forums provide a vehicle for people of diverse views and backgrounds to deliberate on difficult issues and to seek a better understanding of the issues. Our public forums are typically geared toward adult and teen audiences but may be adapted to fit your institution's needs.

The NISE Net is currently developing workshops that will be designed to build capacity in the field to engage the public in this kind of programming. At each forum workshop, participants will have the opportunity to experience a public forum and learn firsthand how the programs are implemented. For more information on when these workshops are taking place and to register, please visit **nisenet.org.**

GETTING YOUR INSTITUTION ON BOARD

Some museums/institutions may wish to host a forum at their institution as a means to achieve their mission of bringing current science to their visitors or or as a new way to engage adult audiences. If this sounds like your institution, you might want to consider a forum on nanoscale science and technology. The forums we've developed as a part of the NISE Network:

- focus on a hot current science topic,

- are easy to conduct,

- are relatively inexpensive,

- connect scientists with the public, and

- connect participants with one another in enjoyable, meaningful ways.

The societal and ethical questions raised in our forums level the playing field between scientists and the public and make for very interesting, lively discussions. Participants routinely report that they value the expert presentations and the small group discussions most. We've evaluated these experiences for two years across the five partner museums and 92% of the participants who were surveyed agreed that they enjoyed the experience. In addition, 90% of surveyed participants agreed that they felt more informed about nanotechnology as a result of the forum, and 96% of surveyed participants agreed that they felt comfortable expressing their opinions—all worthy goals for any program designed to reach adults and get them more involved in the life of your science center.

WHO TYPICALLY ATTENDS A FORUM?

Over the past year, the NISE Net Forums Team has collected information about who is attending the forums and, as a result, the institutions have found patterns among those who attend. The statistics detailed below describe the average audience that we have seen at our forums. In order to calculate these statistics, percentages for each forum were gathered and averaged in order to describe a "typical" audience. However, the data do not take into account everyone who has attended our forums because sometimes participants did not fill out surveys, sometimes survey questions were changed or removed, and other times no surveys were collected. Surveys collected from 19 forums from 2006 through 2007 are included in this data set.

The data indicate that on average, a forum audience is usually split close to 50-50 between men (51%) and women (49%). Almost half (43%) of the participants are between the ages of 35 and 54 (Figure 2), and the vast majority (82%) are white (Figure 3). Most of the participants (97%) report that they do not have a permanent or temporary disability.

Figure 2. Distribution of Participant Ages (on Average per Forum)

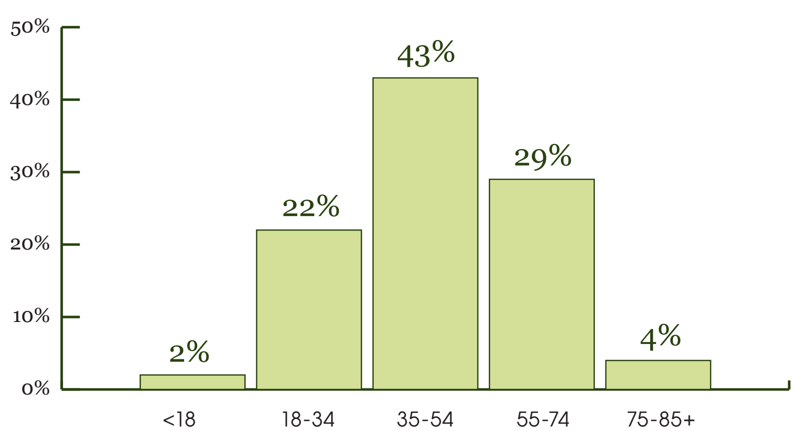
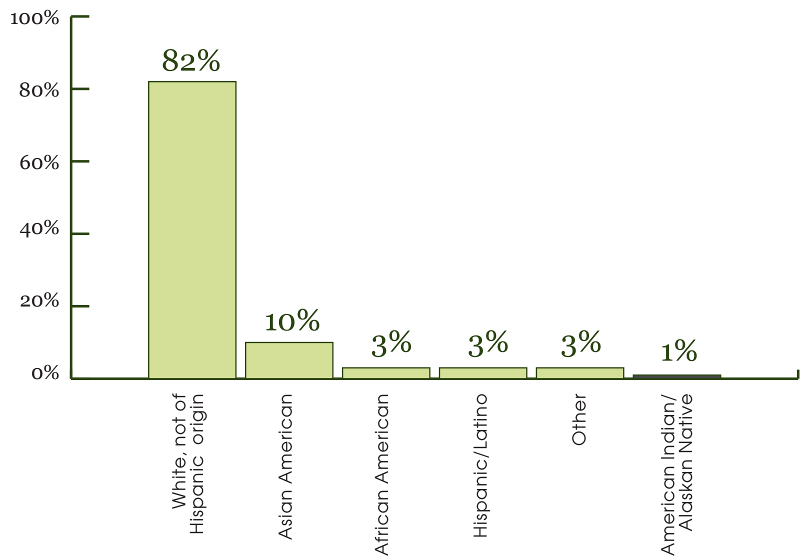


Figure 3. Distribution of Participant Race/Ethnicities (on Average per Forum)



In addition to collecting demographic information, the Forums Team also asked participants about their familiarity with our institutions and the reasons they attended. On average, about half of the participants (44%) reported that they had visited the museum hosting their forum program in the prior three months, and well over half (66%) had been to the museum in the last year (Figure 4). Their recent museum visits are at least partially explained by the fact that on average almost half of the forum participants (42%) are museum members (Figure 5). We have also found that for each forum, many of the participants are teachers/educators (19%) or science researchers/students (19%) (Figure 5). Additionally, most of the participants (52%) came because they are personally interested in nanotechnology (Figure 5).

Figure 4. Last Visit to Museum (on Average per Forum)

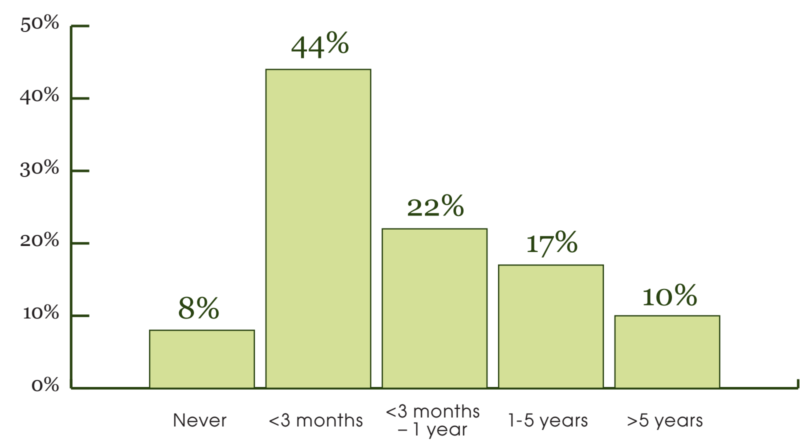
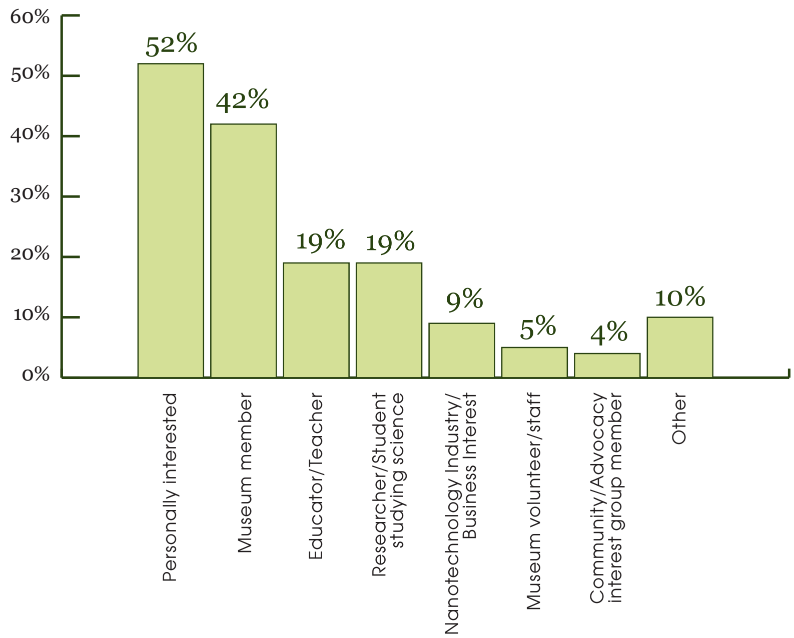


Figure 5. How Participants Related to the Forum Topic (on Average per Forum)
Note: Participants could check more than one answer.



Though this information describes our "typical" audience in 2006 and 2007, it may not necessarily reflect the audiences that you will see at your institution's forums. Most of the 19 forums included in this data set have been held onsite at our museums and were predominantly marketed to people who are museum members or on a museum email list. However, we found that when we changed our marketing or the location of our forums, our audiences also changed. One forum conducted by the Science Museum of Minnesota was held at a nature center with the center's volunteers. This led to an audience that was older than ones we saw at our museums. Additionally, these participants had not been to the museum as recently as the average audience described above. Another forum held at the Museum of Science was marketed to people with disabilities and as a result more deaf and visually disabled participants attended than we have seen at any previous forum. Finally, the demographics of a forum that the Museum of Life and Science held at North Carolina Central University, a historically black college, were more racially and ethnically diverse. What we can conclude from our data is that the makeup of your forum audience is likely to mirror your museum audience unless you work with community partners whose audience differs from yours.

STRUCTURE OF A FORUM

The following example is a generic model of a forum agenda. Each NISE Net Forums Package will include an agenda relevant to that particular forum.

I. Welcome/Introduction

- Have the moderator of the forum provide a welcome to the museum/institution as well as provide an introduction to the format of the forum.
- Introduction to the NISE Net and your role with the network.
- Introduce speaker(s) – obtain presenter biographies beforehand to use for introducing each presenter.

II. Speaker(s)/Experts(s) Present Topic(s)

- Typically one speaker/expert gives an introduction to nanoscale science (20 minutes max) and another speaker/expert discusses societal, ethical and environmental implications aspects (20 minutes max). Presenter talking points can be found in the *Background Information for Presenters* section (page 14).

III. Q&A

- Take approximately 5 minutes after the speaker(s) for the participants to ask any clarifying questions.

IV. Group Deliberation

- Have the moderator go over the ground rules for group discussion. These rules can be found in the *Ground Rules* section (page 20).
- Each forum package found on **nisenet.org** will include the scenarios for that particular forum. Have groups sit around their table and discuss the questions and scenarios to serve as ways of facilitating the discussion. The discussion time will vary depending on the number of scenarios discussed and the number of questions for each scenario.
- Ask the speaker(s) to circulate throughout the room and from table to table to answer questions that members of the breakout groups might have. Encourage the speaker(s) to sit down and spend a few minutes at each table.

V. Individual or Group Reflection/Report-Out

- There are various ways to have the groups report-out on what they discussed. You may wish to have each table create a statement based on their discussion and report to the whole group or ask volunteers to stand up and share with everyone what they discussed. Encourage the participants to keep their table's report-out brief. Questions aimed at facilitating this part of the discussion can be found in the *Ending a Forum* section (page 25).

VI. Post-forum Evaluation (refer to the *Forum Evaluation* section on page 26)

BACKGROUND INFORMATION FOR PRESENTERS

The following is a brief list of basic nanoscale science talking points intended to help presenters think about the kind of information they should include in their presentations. For information regarding societal and ethical implications of new and emerging nanotechnologies, please see the article *Nanotechnology & Society: Ideas for Education and Public Engagement* located in the appendix section.

Figure 6. Nanotechnology Basics

NANOTECHNOLOGY BASICS

- Nanoscale science is an emerging area of scientific research that encompasses many areas of study, including chemistry, biology, engineering, physics, and medicine.
- Nanotechnology will enable new advances in fields such as medicine, computing, and consumer products, and will likely have an effect on much of everyday life.
- Nanotechnology has to do with very small things, smaller than you can see with an ordinary microscope.
- A nanometer is very small, a billionth of a meter or 10^{-9} (for example, approximately 80,000 nanometers = width of human hair).
- Materials can have different characteristics at the nano scale (for example, gold particles change color the smaller they become).
- Along with the new benefits of nanotechnology may come risks that are currently unknown to our health, environment, and society.

MATERIALS

Forum:

Photo Release Form: Prior to the start of the forum, have the participants sign a release form if you plan on taking pictures for later use. Note those who do not wish to have their picture taken and let your photographer know who they are. Most institutions require that some kind of photo release form be signed in order for you to circulate photos from your event. Whether or not this is a formal policy in your institution, you should always ask for permission before photographing participants, especially children. Getting signed releases gives you the flexibility to use your photos in newsletters, reports, and other settings. A sample form can be found in the **Appendix** (although you should check to see if your institution has a different form you should use).

Forum Materials/Scenarios: These are topic-specific and included with a description for each forum package. These materials can be downloaded from **nisenet.org.** Feel free to modify or revise the materials to suit your needs and/or audience.

Room:

Name tags for participants

Chairs arranged in groups of approx 4-10, preferably around round tables (if available)

Tablecloths

Resource table

Registration table

Pre-registered participant list

Refreshments/Water*

Table for drinks and snacks*

Speaker Setup and AV Needs:

Podium

Microphone/Speakers

Projector/Computer

Speaker honorarium*

Evaluation:

NISE Net evaluation forms*

Pencils

*Optional items

ADVANCE PREPARATIONS

The following table represents an estimate of staff time to prepare and host a forum at your museum/institution.

Figure 7. Time Estimates to Prepare and Host a Forum

Staff Time Prior to Forum	Hours
Securing and prepping experts	19
Marketing	10
Pre-registration and communication with participants	6.5
Event planning (assumes museum has tables, projectors)	3
Document preparation (handouts, evaluations)	4
Staff Time at Forum	
Moderator for forum	5
Additional staff	6
Total	**53.5**

The following is a brief checklist for each section listed in the above table.

Securing and prepping experts: Locate potential speakers from local universities, colleges, or research organizations based on their expertise and familiarity with the topic. It is recommended that you take the opportunity to meet with them to introduce yourself and the forum format before inviting them to speak. It is also a very good idea to make time to hear them speak to determine their comfort level and ability to address a public audience. Feel free to share with them any NISE Net materials related to the forum (included with each forum package), and don't hesitate to ask to see their presentation beforehand to see if it fits with the forum topic and scenarios. You should also advise them who the audience will be and offer assistance in tailoring their presentation accordingly. Make sure to let them know that this is not a traditional lecture with Q&A, that we seek more participatory dialogue. They need to be aware that participants really enjoy it when the experts engage in their discussions on the societal, ethical and environmental implication issues. Lastly, share the nanotechnology basics (page 14), and the societal and ethical implications and forum scenarios (included with each forum package) for the presenters to review, if appropriate.

Marketing: Attendance will vary depending on how extensively the forum is publicized. The following methods are just a few ways to advertise your event. Please feel free to contact any of the mentioned NISE Net partners for language or marketing materials that they have found to work best.

- Museum webpage/newsletter
- Museum member email listserv
- On-site marketing
- Local media outlets (newspapers, TV, community papers)
- Craigslist (www.craigslist.com)
- Community calendars
- Posters
- Area universities and colleges
- Local businesses/organizations
- Local research centers
- Local Sigma Xi chapter
- Other email listservs
- Local Materials Research Society chapter

How have different marketing methods worked for the NISE Net forums?
The NISE Net forum partners have marketed their programs through a number of sources with mixed success. The following table shows the success of various marketing methods used by the team during 2006 through the summer of 2007. The table indicates that the most successful marketing methods were partner organizations (working with the institution to present the forum or having the forum in their space) and museum web sources (such as an email from the museum or a message on the museum website). It is our hypothesis that these sources were successful because the people solicited were hearing about the event directly from the forum source or location, and were either already interested in science content, familiar with the institutions, or knowledgeable about their programming.

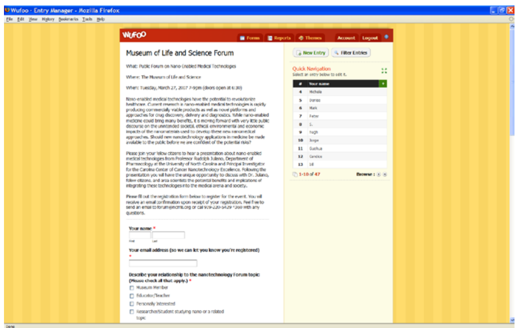
Less successful marketing sources were word of mouth (such as friends and families, places of work, and clubs/organizations), outside internet or email sources (such as Craigslist and emails from outside groups), and other outside sources (such as fliers and newspapers). It is our hypothesis that these sources did not work as well because the people solicited were not necessarily interested in the forum content or familiar with the institutions conducting the forums. Another source that did not attract as many attending registrants to the forums was museum mailings. We hypothesize that this marketing method did not work as well as the other methods because it alerted potential participants too far ahead of the event.

It seems critical to market to people within a month of the event and to remind people that they are registered a day or two before the event.

Figure 8. NISE Net Marketing Methods Used for Previous Forums

On average, what was the way attendee registrants heard about each of the forums?			
	Mean % per forum when asked	**Marketing source**	**Our hypothesis for why the marketing source worked or not**
Partner Group	49%	Science Pub, Nature Center Letter of Invitation, or Staff	People solicited were already interested in science, familiar with the program, or at the forum location.
Museum Internet/Email	32%	Museum website, Museum email	People solicited were already familiar with the museums and their programming, and interested in science.
Other	9%	Other	--
Word of Mouth	7%	Friend/Family, Work, Club/Organization, College/University	Hard to control this source unless directly contacting the sources. Also, clubs, colleges, and workplaces solicited were not necessarily familiar with the museums or looking to participate in museum programs.
Outside Internet/Email	4%	Craigslist, Another Website, Online Message Board, Non-Museum Email	People solicited were not necessarily familiar with the museums or looking to participate in museum programs.
Museum Mailing	1%	Museum Paper Mailing	This source was not often used, potentially skewing the data. Also, it is possible the source did not work well because information was distributed too far ahead of the events.
Other Outside Source	1%	Paper Flier, Print Media	People solicited were not necessarily familiar with the museums or looking to participate in museum programs.

Pre-registration and communication with participants: There are several websites that allow you to manage a registration list. Two options that have been explored through NISE Net forums are **www.wufoo.com** and **www.surveymonkey.com**. Having participants pre-register using an online survey resource will allow you the opportunity to poll them prior to the event to obtain needed pre-forum information such as their email addresses; relationship to the forum; museum, community or business affiliation; how they heard about the forum; and any accommodations for people with disabilities. (Refer to the **Registration Survey** found in the Forms and Surveys section.) This will allow you to keep track of who comes to the forum, learn a little bit about them, and make changes to your setup based on participants with disabilities (i.e. ASL interpreters). It is highly recommended that you send out an event reminder a few days prior to the forum.



Event planning: Secure the location for your event well in advance to ensure availability. If your museum/institution does not have tables you may wish to rent them from an outside company. Round tables are preferable for the small group discussion part of the forum. Place chairs around each table and then place any necessary documents (pre- and post-evaluations, scenarios, background information sheets, etc.) at each table for the participants. Providing refreshments for the participants is optional. You may wish to place water at each seat or locate it near the back of the room for those who want it. If any registered guests require additional accommodations please note what they are and make any arrangements possible to accommodate them.

Document preparation: **Nisenet.org** will provide all necessary documents (evaluations, scenarios, background information, etc.) for each forum package. Download and print off all necessary materials prior to the forum and place the necessary documents at each table. It may be useful to color-code documents so they are easier to track and reference throughout the forum.

Moderator for forum: Prior to the forum the moderator should gather the speakers' CVs and other related information and synthesize them into a brief speaker introduction. The moderator should also become familiar with the forum format and topic prior to event. During the forum the moderator should introduce the event, give the group discussion instructions and facilitate the report-out section. The moderator should also run the question and answer segment after the speakers have presented.

Additional staff: Additional staff may be needed to market the event, help set up the room with the tables and chairs, print off forum documents and place them at each table, register participants as they arrive, and facilitate breakout groups.

Additional preparations: Read the materials for each forum to become familiar with the forum. If you have never participated in or moderated a forum, you may wish to attend one of the NISE Net's regional forum workshops or pilot a forum with your museum/institution staff or volunteers. For more information on upcoming workshops visit **nisenet.org** and click on the **Community Calendar**.

SETUP

About an hour and a half prior to the event, have the registration/check-in table, photo release form and the pre-registered participant list ready. Set up and check the AV equipment (if needed) an hour before the event to make sure it is functioning properly. Have the tables and chairs set up with evaluation forms and any necessary forum materials at each seat.

The moderator should reserve time to review notes for introducing the forum, introducing the speaker(s), providing forum ground rules for the participants (unless facilitator will do so at each table), and guiding the flow of the event.

SMALL GROUP FACILITATION*

One way to help ensure high-quality public discourse is through the use of facilitators at each table during the small group discussion. A facilitator is defined as someone who guides a group through a discussion to achieve a stated goal. Use this section to guide you through the role and duties of a small group facilitator for forums.

It may be best to meet with your facilitators/note takers prior to the forum to inform them of their roles and to share the following information with them. Some potential facilitators and note takers may include staff from your museum/institution or students from your local college or university.

Ground Rules

If you choose to have facilitators present at each table you may wish to have them explain the ground rules to their table. This gives the group members an opportunity to state what is important to them in a discussion, and increases the likelihood that the rules will be followed.

If there is not enough time to have the group define ground rules, some good general rules to follow are (you might put these on a tent card at each table):

- Be respectful of others' opinions
- No interruptions
- Give everyone a chance to speak
- All ideas are OK

Roles

At each NISE Net forum you may find it useful to have note takers accompany the small group facilitators at each table.

Role of a Facilitator
(1 per table)

- Guide the group through the agenda and manage time
- Remain neutral
- Use active listening to encourage each member to participate fully
- Allow all voices to be heard and none to monopolize
- Keep group energy positive and focused

Role of the Recorder/Note Taker
(1 per table if possible, facilitator can take notes if necessary)

- Listen for and write down key words or phrases
- Only need to write down 2-5 words per idea (doesn't need to be verbatim)
- Make sure ideas of every participant are written down
- Write legibly
- Don't be afraid to misspell
- Alternate colors to separate ideas
- Number and identify note pages

Role of the Expert(s)/Presenter(s)

- Roam around the room and stop at various tables to interact with forum participants, try to sit with each group if possible
- Answer technical questions as they arise
- Play devil's advocate (if needed)

*This section features materials adapted from Oregon Museum of Science and Industry staff trainings by Sheri Wantland, Clean Water Services, Hillsboro, Oregon.

FACILITATOR DUTIES

Guide the group through the agenda and manage time

Identify the discussion goals at the beginning of the time, suggest appropriate time intervals if necessary (i.e. "We have 30 minutes to come to a conclusion, so let's discuss options for 20 minutes, then recap and write down our suggestions for the last 10 minutes."). Watch the clock and give the group a 5-minute warning.

Remain neutral

One of the many roles of the facilitator is to be neutral about the content of the discussion. Facilitators should keep their opinions about what is being discussed to themselves. They should refrain from influencing the process to get the outcome they prefer. If there is not an expert/presenter available and the group has specific technical questions about an aspect of nanotechnology about which the facilitator has special knowledge, they may give unbiased scientific information.

Ways to maintain neutrality:

1. Treat All Equally – Acknowledge all contributions similarly. Avoid saying "good idea" to some participants and not to all.

2. Stay on Topic – When the group goes off topic, tell them. Check to see if the group agrees with you, and then ask the group what, if anything, they want to do about it.

3. Avoid Alignment – Watch your comments to avoid giving any member of the group the impression that you have a closer relationship or more agreement with any group members.

4. Involve Participants – Focus on engaging participation, rather than evaluating the quality of the ideas being generated.

5. Stand Strong – In the face of conflict within the group, remain neutral and avoid judging any person or idea in conflict. Participants need to know that you are listening and not taking sides.

Use active listening to encourage each member to participate fully:

The facilitator should become a more effective communicator by showing that they are listening and understanding the facts and feelings others convey. This is especially important when dealing with people who don't know the facilitator and have no reason to trust or believe them.

The basic conversational skills of active listening are outlined below, with sample comments. Active listeners encourage the speaker, restate what is said, reflect on the feelings, and summarize.

- Encourage the speaker. Convey interest, keep the person talking. Don't agree or disagree. Use noncommittal words with a positive tone of voice.

  I see. Uh-huh. That's interesting.

- Restate what has been said. Show you are listening and understand. Restate the other's basic ideas; emphasize the facts.

  If I understand, your idea is… In other words, your preference is…

- Reflect on the feelings expressed. Show you are listening and understand their feelings. Restate the other's feelings.

  You feel that… You were upset by…

- Summarize what was said. List important ideas and facts; review progress; establish a basis for further discussion. Restate, reflect, and summarize major ideas and feelings.

  Your key ideas are… If I understand, you feel this way about…

Let group know that all ideas are OK.

- Pay attention to who is speaking in the group, and who is not. Don't let one person dominate the discussion.
- If someone looks like they want to say something but can't get a word in, ask them (by name if possible) if they have something to add.
- If there are several people not participating, ask, "Is there anyone who would like to comment who we haven't heard from yet?"

Keep group energy positive and focused

There are any number of ways for a discussion to go off track, and lots of ways to get it back. Use any and all of these if necessary:

- State the goal of the discussion at the beginning, remind group members of the goal.
- Remind group members of ground rules (don't interrupt, be respectful, etc.).
- Write down all ideas. When people see their ideas written down and acknowledged, they are less likely to revisit those same ideas.

- If ideas not directly related to achieving the goal come up, create a "parking lot" or separate list on paper to record and acknowledge those ideas. Then move on.

- As facilitator, remain neutral. Ask open-ended questions to encourage discussion, such as: "What led you to that conclusion?" and "What did you find noteworthy about the presentation?"

- Be sensitive to the cultural background of all participants.

- Use body language. By standing up or walking around the group, the facilitator can help refocus the group. This is useful if the discussion becomes heated, when the group is off topic, or if one person is dominating the conversation. With the facilitator getting up and/or moving around, the participants will sense a shift and pay attention to their own actions.

Below are some tips to manage difficult people in discussion groups and meetings. Some of these tips go beyond skills that you will need for NISE Net forums, but they may be useful in other settings as well.

Know-it-all: Avoid arguing. Ask if others agree or need more information to feel comfortable with the facts. Take them aside and ask them to let others have input. Recognize genuine expertise and use it.

Whisperer: Establish ground rules against side conversations. Ask them to share comments with the whole group.

Argumentative or whiner: Turn negative comments into positive statements. Establish ground rules for making positive contributions to the group. Ask what is bothering them. Move on without focusing on their negative energy.

Latecomer: Start without them. Avoid rewarding the behavior, don't start over. During a break, summarize what they missed.

Detailer: Give them committee work and extra research. Thank them for the extra attention to detail.

Backstabber: Confront one-on-one. Ask what is causing the behavior. Remind them of the ground rules for positive contributions.

Hidden agenda: Poll the group to clarify their objective. Review the agenda and ask for additional items at the beginning of each meeting.

IV. ENDING A FORUM

Before ending a forum you may wish to have individuals or a member of each small group report-out to the whole group some of the key points they discussed during the deliberation. The forum moderator may wish to enhance the report-out session by asking some of the following generic questions. The moderator should remain impartial and encourage other participants to respond to the comments from each report-out. Additional follow-up statements may be provided with each specific forum.

- What are some of the key points made in your group's discussion?
- How did you or your group's thinking change as a result of the forum?
- How has your thinking about other people's views changed as a result of this forum?
- How has your perspective changed as a result of what you heard in this forum?
- How has this issue affected you personally?
- Were there any questions raised in the scenarios that made people uncomfortable?
- Did anything that you learned or that someone said during the discussion surprise you?
- Did anything in particular impact your point of view or change the way you feel about nanotechnology?
- Is there anything now that you would want more information about?

V. CLEANUP

Taking down the AV equipment, bidding guests and speakers farewell, and cleaning up the space can take up to an hour. Satisfied speakers and participants tend to linger and continue to discuss the topic. This is to be expected with a forum. It is helpful to have someone cleaning up while at least one other person plays genial host.

VI. FORUM EVALUATION GUIDE

INTRODUCTION

The following instruments and protocols closely match the data collection instruments used by the NISE Net Forums Team to conduct a formative evaluation of our forum programs. These tools are used for formative evaluation, so that information can be gathered to make informed changes to a program, not for summative evaluation.

The data collection instruments are being provided so that you have the instruments necessary to be able to conduct your own basic formative evaluation of any forum program that you present at your institution. The guide includes instruments that allow you to understand the perceptions of various program stakeholders including the participants, the program staff, the speakers, and the facilitators through collection of information from all of these groups. By understanding the perceptions of each of these groups, you can change your forum program to better serve these stakeholders. However, it is not necessary to collect information through all these data collection instruments in order to make informed changes. You may choose which audience(s) you want to pay attention to—whether it be the participants, speakers, program staff, or facilitators—and use just the instruments that give you information about that group. In addition, you may modify any of the data collection instruments by adding or removing questions in order to fit the needs of your individual institution.

Key questions that can be answered through this formative evaluation include the following:

- What aspects of the program appear to contribute to the program's ability to achieve its goals and/or are valued by the stakeholders and should therefore be included in future presentations of the forum?

- How can the programmatic model be refined so that it better achieves the goals and objectives? Particular elements of the programmatic model that can be examined include:

a. The content of the expert presentations

b. The discussion scenarios

c. The overall agenda and flow of the event

d. The question and answer period

e. The participant report-out

- How can the program be improved so that it better meets the needs of the key program stakeholders (including adult learners, program staff, and presenters)?

DATA COLLECTION METHODS

Multiple data collection methods can be employed to create a detailed account of the forum. The most common source of information about an event is often the participants, but the data collection instruments described below allow you to gather information from the program staff, speakers, and small group facilitators as well. Forms of possible data collection include registration surveys, participant surveys, discussion debriefs, observation notes, event debriefs, and speaker follow-ups. Any or all of these data collection instruments can be used based on the needs of your institution. However, in most cases, at least a participant survey is collected in order to have some indication of the participants' perspectives. The data collection instruments are split here to indicate whether they provide information about the participants, speakers, or program staff.

Participant Instruments

Registration Survey: The registration survey will primarily serve as a registration tool for the program staff so that they know who is coming to the forum. However, this tool can also be used to learn more about the participants. Questions can be added in order to learn how participants are hearing about the forum (through what marketing methods) and whether the participants have any specific accommodation needs.

Participant Survey: This method will focus on capturing information about the forum participants. Survey questions address participants' demographics, interests, and backgrounds. In addition, the participants can be asked for recommendations about how to improve the program, what they learned, and what they valued about the program. This will help you to learn what participants thought about their experience, what they valued, and what changes they recommend.

Participant and Program Staff Instruments

Observation Notes: Notes can be taken on the dialogue that takes place between the participants and speakers/moderators. This information will help you learn more about the perspectives of the participants, speakers, and moderator. This will help you to understand the interests, confusion, and/or concerns of these stakeholders so that these things can be taken into consideration during future presentations of the forum.

Discussion Debrief: Observers, either small group discussion facilitators or program staff, can complete a debrief form at the end of the small group discussion to summarize the content of the discussion for one of the small groups. This instrument will help you learn about the participants' views of the small group discussion as seen through the eyes of staff. It will help you to understand the content of the participants' discussions as well as any concerns or confusion they had about the scenarios.

Program Staff Instrument

Event Debrief: In the days following the forum, program staff can be asked to provide information in order to create a record of the forum event. Staff can be asked about their thoughts on the success of the forum, how they felt about their preparation for the event, their thoughts on the structure and format of the forum, what changes they would recommend for future implementations of the program. This can help you to understand the effective components of the event, as well as the parts that need to be changed.

Speaker Instrument

Speaker Follow-up: In the days or weeks following the forum, speakers can be contacted and asked to fill out a survey. The survey will ask the speakers what value they found in participating, how the institution helped them prepare for the forum, and how the institution could have better helped him or her prepare for the forum. This can help you to understand what about your speaker preparations worked well and what changes can be made to improve the process.

FORMS AND SURVEYS

REGISTRATION SURVEY

Use these questions on the forum online registration survey so that there is a record of who is coming and what their needs are. You can also ask what marketing methods attracted people to the forum. Questions can be added or removed as needed.

1. Registrant name:

2. Registrant email address: (We will only use your email address to confirm your registration.)

3. How did you hear about this program? (Please check all that apply.)
    - ❑ From the institution's website
    - ❑ From Craigslist
    - ❑ From another website
    - ❑ From an institution email
    - ❑ From a non-institution email
    - ❑ From a paper mailing
    - ❑ Through a club/organization
    - ❑ Through a friend/family member
    - ❑ Through my work
    - ❑ Through my college/university
    - ❑ From print media (newspapers, magazines, etc.)
    - ❑ Other:

4. If you are registering other individuals, please enter their name(s) and email address(es). We will send a separate confirmation email to them within a few days. Without providing this information, other individuals will not be registered.

5. Do you have any specific accommodation requests?

6. Would you like to be notified by email about future museum events?
    - ❑ Yes
    - ❑ No

PARTICIPANT FEEDBACK SURVEY

Help us improve future programs by providing us with feedback.

Gender:

❍ Male

❍ Female

Age:

❍ < 18

❍ 25-34

❍ 35-44

❍ 45-54

❍ 55-64

❍ 65-74

❍ 75-84

❍ 85+

Race/Ethnicity:

(Check all that apply)

❍ African American

❍ American Indian/Alaskan Native

❍ Asian American

❍ Hispanic/Latino

❍ White, not of Hispanic origin

❍ Other: ___________________________

Last visit to this institution:

❍ Never

❍ Within the last 3 months

❍ 3 - 6 months ago

❍ 6 months to 1 year ago

❍ 1 - 2 years ago

❍ 2 - 5 years ago

❍ 5 - 10 years ago

❍ More than 10 years ago

❍ Not sure

Describe your relationship to the nanotechnology forum topic: (Check all that apply)

❍ Institution member

❍ Educator/Teacher

❍ Researcher/Student studying science

❍ Personally interested

❍ Institution volunteer/Staff member

❍ Researcher/Student studying nano or a related topic

❍ Community/Advocacy interest group

❍ Other: ____

Do you have any of the following temporary or permanent disabilities? (Check all that apply)

❍ No, I do not have a temporary or permanent disability

❍ Mobility

❍ Visual

❍ Learning

❍ Cognitive

❍ Auditory

❍ Other: ____________________________________

Please rate your agreement with the following statements about this event:

	Strongly Disagree	Disagree	Agree	Strongly Agree
I enjoyed the experience.	❍	❍	❍	❍
The experience matched my expectations.	❍	❍	❍	❍
I felt comfortable voicing my opinions.	❍	❍	❍	❍
I feel more informed about nanotechnology.	❍	❍	❍	❍
We weighed the pros and cons of nanotechnology during our discussion.	❍	❍	❍	❍

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What did you value most about this experience?

What, if anything, did you learn from this forum that you didn't know before?

How could we improve the next forum?

OBSERVATION NOTES

Use this instrument to record the dialogue of the presenters and participants during the forum. In the first cell, write the questions and comments the participants make to the moderator or speakers. In the second cell, record any questions or comments that you hear participants make to each other. In the last cell, write down questions and comments made by the speakers or moderator and directed at the participants.

Questions/Comments from Participants to Moderators/Speakers:

continued on reverse...

Questions/Comments between Participants:

Questions/Comments from Moderators/Speakers to Participants:

DISCUSSION DEBRIEF FORM

Have each facilitator or program staff answer the following questions about the small group discussion they facilitated/observed after the discussion is completed.

1. How do you feel the discussion went?
(Probe: What were some good things that happened? What were some bad things that happened? Did you feel that everyone got a chance to talk?)

2. What were the major issues discussed by the group you facilitated?
(Probe: What pros of nanotechnology were discussed? What cons of nanotechnology were discussed? Overall, do you feel that the discussion was more pro or con nanotechnology?)

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3. What questions/confusion arose about the discussion scenarios?

4. Did the group seem more interested in one of the scenarios more than others?

5. How, if at all, did the group incorporate the presentation into the discussion?

EVENT DEBRIEF

Use the questions below to create a record of the forum for your institution and debrief the program team on the forum outcomes. Use the form to review what happened at the event and what changes could be made to improve future presentations of the forum.

Forum date:	Forum time:
Forum name:	Forum location:
Number of participants:	Room setup:
Primary programmatic contact:	
People interviewed for debrief:	

- Overall, how do you think the event went?
    - In your view, what were some indicators of success in the forum?
    - What would you do differently next time?

- How do you feel about your event preparation?
    - What preparation methods would you use again/recommend to others?
    - What would you change about your event preparation for the next forum?

- How do you feel about the different forum segments?
  - Speaker Presentations
    - Who were the speakers?
    - What was the content of their presentations?
    - How do you feel about the presentations?
    - Would you use the speaker(s) again at another forum?
  - Small Group Discussion
    - How do you feel the small group discussion went?
    - What changes would you make to improve the small group discussion?
  - How do you feel about other segments of the forum?
    - What other parts of the forum agenda do you like?
    - What changes would you make to other parts of the forum agenda to make them better?
- How do you feel about the timing of the forum agenda?
  - What changes would you make to the lengths of the different forum segments?

SPEAKER FOLLOW-UP

Pose these questions to speakers after the forum in order to have a record of their participation and to learn what about your preparation worked well and not so well for the speaker. Questions can be added and removed as needed.

1. What is your name, professional background, and contact information?

2. Why did you feel it was important to participate in the forum?

3. What did you find to be the most valuable aspect of participating in the forum?

4. What did we do to help you prepare to present at the Nanotechnology Forum?

5. What should we do differently in the future to better prepare speakers for the forum?

6. Do you have any other suggestions?

APPENDIX

FORUM PARTICIPANT QUESTIONS

The following questions have been crafted based on the questions of participants, but they have been modified in order to cover more broadly the content participants found interesting. Examples of actual questions from participants can be seen below the evaluator-written questions. These questions are being provided to give you an idea of the questions and concerns that you can expect to hear from participants at your own forum.

General Nanotechnology Questions

1. How are the properties of nanoparticles different from the properties of other particles?

Example Participant Questions

- Is the chemistry (of nanotechnology) related to surface chemistry?
- Have properties of both quantum physics and classical mechanics been observed in nanotechnology substances?

2. How far along are we in being able to manufacture products at the nanoscale?

Example Participant Questions

- I was wondering what the current feeling is on nanofabrication – is that getting to be more feasible?
- Is nanotech ready to be cost-effective and go to the market?

3. How will we control the proliferation of nanoparticles?

Example Participant Questions

- What is the deal with "grey goo"? Is it possible? How will we control it?
- Can you address how far along we are in understanding the patterns building up to macro, and controlling it?

4. What are the risks associated with using nanotechnology?

Example Participant Questions

- Does toxicity of nanoparticles depend on just size or just chemical makeup or both?
- How do we find out what's safe? Without the advantage of 20 years?

5. How does waste from nanotechnology products impact the environment?

Example Participant Questions

- If we are going to be concerned about the environment, what do we need to be concerned about?
- How do the sizes of current pollutants compare to the sizes of nanoparticles?

6. What societal and ethical issues will be a part of the nanotechnology debate?

Example Participant Questions

- What are the privacy issues raised by nanotech in the near term?
- Are the religious nuts going to get involved in this like with stem cell research?

7. How will access to nanotechnology products differ between those who are rich and those who are poor?

Example Participant Questions

- What are the stratification ramifications outside the US? Will (disadvantaged peoples) have access?
- What are the potential effects of nanotechnology to the third world? Will they make bigger leaps (relatively) than first world nations?

8. Who funds nanotechnology research, and who is receiving the funding?

Example Participant Questions

- What percentage of nano-research funding is from private sources and what percentage is from government sources?
- How does the budget for research into nanotechnology implications compare to the same research in previous fields like genetically modified foods?

9. What nanotechnology applications are currently available or will be available in the near future?

Example Participant Questions

- What products already exist? Are we using them already?
- What is the timeline for this revolution? Reasons: i) technical; ii) political?

10. How will nanotechnology products impact our current energy needs?

Example Participant Questions

- How will nanotechnology be applied to our long-term energy issues (supply, cost, global warming)?
- What are the energy costs of expanding the nanotechnology industry?

11. What does the public need to know in order to be citizens informed about nanotechnology?

Example Participant Questions

- How would you introduce nanotechnology to middle- and high-school students?
- What will be the "issue" that makes the general public interested in nanotechnology? Is there a way to be proactive rather than reactive in our national awareness to this technology?

DEFINITIONS OF DEBATE, DELIBERATION, DIALOGUE AND DISCUSSION

These definitions are quotes excerpted from those provided in "The Magic of Dialogue: Transforming Conflict into Cooperation" by Daniel Yankelovich (Yankelovich, 1999).

Debate: The purpose of debate is to win an argument, to vanquish an opponent. Attributes of a debate include:

- assuming that there is a right answer and you have it;
- combative: participants attempt to prove the other side wrong;
- winning;
- listening to find flaws and make counterarguments;
- defending assumptions as truth;
- critiquing the other side's position;
- defending one's own views against those of others.

Deliberation: A form of thought and reflection that can take place in any kind of conversation.

Dialogue: Dialogue is a discussion that exhibits three features: equality and the absence of coercive influences; listening with empathy; bringing assumptions into the open. Additional attributes include:

- assuming that many people have pieces of the answer and that together they can craft a solution;
- collaboration: participants work together toward common understanding;
- exploring common ground;
- listening to understand, find meaning, and agreement;
- revealing assumptions for reevaluation;
- admitting that others' thinking can improve on one's own.

Discussion: A conversation between a group of people (this is a rough summary of what Yankelovich says) that does not exhibit the three features associated with dialogue.

This section's featured materials adapted from:

Yankelovich, D. (1999). The Magic of Dialogue. New York, NY: Touchstone.

MEDIA CONSENT AND RELEASE

I, ____, hereby authorize __________the (Institution)__________ to photograph, audiotape, and/or videotape me and grant __________the (Institution)__________ the right to use my photograph, audio recording, video recording, or any reproduction or modification thereof (the "Photograph," "Audio," and/or "Video"), in any manner or medium throughout the world an unlimited number of times in perpetuity for non-profit educational purposes.

I understand that I will not receive any monetary compensation for the permissions I am granting herein. I hereby waive any right of inspection of approval of the uses to which the __________the (Institution)__________ may put the Photograph, Audio, and/or Video. I acknowledge __________the (Institution)__________ will rely on this permission and hereby release and discharge __________the (Institution)__________ from any and all claims and demands arising out of or in connection with the Photograph, Audio, and/or Video, or the exercise of the permissions granted here, including any and all claims for libel, invasion of privacy or emotional distress.

I understand that I cannot withdraw my consent after I sign this form and that this consent and release is binding on me and my heirs, legal representatives and assigns.

YES	NO	(please check)
_____	_____	I grant permission for Photographs to be collected and used by __________the (Institution)__________
_____	_____	I grant permission for Audio be collected and used by __________the (Institution)__________
_____	_____	I grant permission for Video to be collected and used by __________the (Institution)__________

Date: ______________________ Signature: ____

Address: ____

____

____

Telephone Number: ____

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If the individual named above is under 18 years of age, please complete the following:
I am the parent or legal guardian of the individual named above, and I hereby sign this Media Consent and Release on behalf of such individual in accordance with the statements above.

Date: ________________________ Signature: ____

Address: ____

____

____

Telephone Number: ____

The Center for
Nanotechnology in Society
ARIZONA STATE UNIVERSITY

Nanotechnology & Society:

Ideas for Education and Public Engagement

Clark Miller, David Guston, Daniel Barben, Jameson Wetmore, Cynthia Selin and Erik Fisher

September 7, 2007

Center for Nanotechnology in Society at Arizona State University

CNS-ASU and its research, education and outreach activities are supported by the National Science Foundation under cooperative agreement #0531194. Any opinions, findings and conclusions are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Table of Contents

Nanotechnology is poised to be one of the most significant scientific and industrial transformations of the 21st century. With nanotechnology, scientists are acquiring abilities to understand and manipulate materials at the scale of atoms and molecules. In the process, they are creating the potential for people to see the world, act in it, and change it, in fundamentally new ways. These abilities may even transform the foundations of society. While many of today's applications of nanotechnology are mundane, tomorrow's applications may seem miraculous. Just as they have with electricity, automobiles, and computers, people will use nanotechnology to change their lives, their work, their habits, their notions of fun and play, and so much more.

We believe it is essential, therefore, for society to deliberate about a nanotechnology-enabled society, especially now, as nanotechnology is being developed. Today, many are already making choices that will underpin our future, collective nanotechnological lives. What kind of society will we build, as a society, using nanotechnology? Whose ideas and choices will guide the design of nanotechnologies—consumers, corporations, regulators, or citizens—especially when those technologies impact the day-to-day lives of millions? Toward what ends will those ideas and choices be directed? To whose benefit, and whose detriment?

Such questions are not easy to answer. The answers are often complex, and just as often controversial. We see the exploration of these questions as an opportunity for people to think more clearly and deeply about how societies may change through their choices about nanotechnologies. The themes we discuss below are meant to stimulate further conversation about the ways that human lives and technological change are caught up in one another.

We hope that these ideas will help motivate people to take an active role in shaping the future of nanotechnology—and thus the future of society. The ideas contained here are meant as a starting point. We hope that they will help formal and informal science education projects to meaningfully address the societal dimensions and implications of nanotechnology. We welcome requests for further information, and we would welcome the opportunity to discuss these ideas further with anyone who is considering their use in an educational project or initiative.

1. People make nanotechnologies

> *Technology often seems to force changes on society and even, at times, to drive history itself. This impression is false. No technologies, including nanotechnologies, are independent of the choices that people make about how to design, create, buy, use, critique, regulate, or reject them. Individually and collectively, people shape technologies at all stages of innovation—whether they have technical training or not. Scientists and engineers are, of course, crucial to the process, but entrepreneurs, investors, consumers, lawyers, activists, and ordinary citizens are all part of the social forces that contribute to technological change. Thus, each of us has opportunities to make choices about technologies with greater care and forethought.*

It is obvious that people make nanotechnologies. Yet, we often talk about technologies as if people have little or no control over them. We say that a new technology brings about social change or that it "impacts" society. But attributing to technology the ability to force social change is mistaken. People are in control of all aspects of the production, distribution, operation, and use of new technologies (and, as we will see below, they have considerable choices about how to shape those technologies). Many people do change their lives when new technologies become available, as when people decided to buy cell phones and carry them with them everywhere, but these are still conscious or sometimes unconscious choices. Or, sometimes, people can be forced to change their lives when someone else decides to use a technology in a new way: for example, when day laborers were put out of their jobs because farmers decided to buy tractors to work their fields instead. So, when people say that technology causes social change, we should instead look behind the appearances for the choices people are making that are bringing about that change.

People make choices at all stages in technological development. A technology may be technically feasible, but unless someone makes a persuasive case for its development, it may never see the light of day. Even inventions that are technically and economically feasible—and socially desirable—may lose out in the competition to acquire scarce funding, laboratory space, and other resources necessary for research and development. Even if a particular idea captures the attention of researchers, funding agencies, or investors, it is rare that that idea represents the only possible technical approach. Rather, creative technological problem-solving is both enabled and constrained by social relationships, product timelines, technical imaginations, regulations, and markets—all of which are themselves the products of human activities.

In the case of nanotechnology, individuals such as Eric Drexler and Mihail Roco spent years promoting their visions of the field to politicians who ultimately agreed to provide financial support. But their respective visions for the future of nanotechnologies were very different from one another. At least for the time being, scientific and policy communities have selected Roco's vision over Drexler's as the one worthy of billions of dollars of government investment. As a result, nanotechnology research is taking one path toward the future, with few or no public resources committed to the other.

Other players have also contributed to what nanotechnology means today, its rate of development, and what types of nanotechnologies will become available in society. Business leaders have lobbied for nanotechnology and invested significantly in nanotechnologies of relevance to their forms. Non-governmental organizations (NGOs) like Greenpeace and the ETC group have also highlighted potential risks of nanotechnologies. Their efforts have helped persuade Congress to increase funding for research on the environmental and health implications of nanotechnology. A group of influential scientists, policy makers, business leaders, and NGOs called ICON has pushed for international standards for the safe handling of nanomaterials. The Meridian Institute, another NGO, has pushed for funding nanotechnology research that might help alleviate global poverty.

Government agencies in the US and elsewhere are making decisions about whether nanotechnologies will require new regulatory frameworks, or whether existing regulation will prove sufficient. As they make decisions, agencies like the Environmental Protection Agency and the Food and Drug Administration will help shape the kinds of nanotechnology-enabled products that reach the market. Similarly, American consumers have already begun to lend market resonance to nanotechnologies by quickly adopting such relatively mundane “nano-enabled” products as clothing, athletic equipment, electronics, and health care—as well as the *iPod nano*, a product that isn’t really nanotechnology but helps brand “nano” as cool (to consumers) and profitable (for businesses).

Decisions about nanotechnologies matter immensely. These choices involve personal and professional values, social and institutional structures, policies and regulations, consumer needs and wants, and public hopes and fears. They also involve trade-offs among these values, institutions, and beliefs. These choices, however, will ultimately help determine what nanotechnology will mean, what applications it may yield, how people will use these applications, and how society will reshape itself around their use.

2. People live with, in, and through technologies

> *Technologies provide important influences on how people choose to live. They shape what people are able to see and do. They enable people to act in certain ways and foreclose other possibilities. They shape our relationships and facilitate communication and transportation. We modify behavior to take advantage of or avoid them or to ensure their continued operation. For example, we structure our foreign and military policies to help secure supplies of petroleum, which not only fuel the large technological systems of transportation and energy production that are the core of our economy, but also provide critical raw materials for products such as plastics and pharmaceuticals.*

Although it is certainly true that people make nanotechnologies, technologies are also key parts of the ways we live. Technologies do not force us to live in certain kinds of ways, but neither are they just tools. The availability of technologies makes some kinds of lifestyles easier and others much more difficult. Even as we remember that people choose to design, construct, use, or resist technologies, we also acknowledge that people make these choices because technologies can become important parts of their lives as status symbols and elements of day-to-day work and life. Often, our social values, behaviors, and interactions depend on or are focused on technologies.

A good example of living with, in, and through technologies is communication. An essential feature of all human relationships and institutions, communication is also fundamentally shaped by the technological systems that we have designed. Businesses – and many of the rest of us—place high value on face-to-face communication, which is partly why many people travel on airplanes. Telephones are an enormous technological system, but until very recently, they only allowed voice communication from one place to another. Today, we are inviting a range of different technologies that enable people to communicate in new and different ways, each with its own unique characteristics and possibilities. Cell phones, unlike their older cousins, are person-to-person and can be used in many more places—to the demise of many pay phones and even some people's land lines. An email is not a perfume-scented love letter. A blog is not a personal diary. Each is a novel form of communication that is facilitating new forms of social organization at times and in places that would not have been possible with earlier technologies.

Technologies also become part of the moral fabric of life as we shape our expectations around them. Cell phones are a good example. For example, many parents give their children cell phones in order to be able to reach them in an emergency. This capability has become so important that, when schools recently tried to ban cell phones, on the request of teachers whose classrooms were being disrupted by text messaging, parents objected. They feared for their children's safety in the event of violence or disaster, and they wanted their children to always have their cell phones with them.

There is also the question of where and when it is acceptable to use cell phones. Many states are discussing laws that would prohibit the use of cell phones when driving. Many restaurants and libraries have signs discouraging the use of cell phones, as do many businesses near their cashiers. All testify to growing moral questions about the inappropriate use of cell phones in a manner that disrupts others.

Along similar lines, the failure to answer the phone has also acquired greater social relevance with new cell phones. Parents whose children don't answer the phone experience greater concern that something might be wrong, while business employees may not be able to truly go on vacation, since their cell phone (or wireless computer) allows them to remain in contact with their employer. All in all, "being out of touch" has acquired new meaning as a result of new technologies.

Technologies can even become so important that people's lives become dependent on them. The residents of New Orleans built a city that depended on the continued functioning of technological systems that kept water out. When those technologies failed, a disaster occurred. On a smaller scale, we depend on working cell phones, cars, and alarm clocks every day. We rely so deeply on the functioning of a number of technological systems that we don't even notice—until they no longer work.

How will we incorporate nanotechnologies into our lives? This is probably the central question that is at stake in deliberations about nanotechnology-in-society. What is clear is that the choices we make, both collectively and individually, will have significant implications for our lives in the future.

3. Technological and social change are closely interconnected

> *When people make choices to build and buy new technologies, and then they subsequently alter their values, behavior, and relationships around those new technologies, the result is a close connection between changes in society and changes in technological systems. New technologies offer us new ways to see*

> *the world and new ways to act. In turn, these innovations prompt questions about the adequacy and appropriateness of existing values, behaviors, relationships, and institutions. In asking, wrestling with, and answering these questions, people change society in and around new technologies.*

One corollary of the fact that people live with and through technologies is that social and technological changes are closely coupled. Throughout history, changes in technologies have gone hand-in-hand with changes in the broad organization of society. Today, for example, workers in factories pursue lives and work that would have been unimaginable before the invention of the modern manufacturing technologies. Societies have also changed dramatically with the introduction of the automobile into widespread use, and again with the adoption of the personal computer and the Internet. In each case, as people have designed, tested, marketed, and bought new technologies, they have also made novel choices about how and where to live their lives, bringing widespread and sometimes dramatic social change. Today, for example, only 2% of the US population lives on farms, a tiny fraction of those who lived on farms only 100 years ago.

How does this kind of large-scale social change happen? Let's take an example. In the early 1980s, a new method of reproduction called in vitro fertilization was developed in which doctors extracted eggs and sperm and fertilized them in the laboratory instead of in the body. Perhaps this might simply have gone the way of other novelties, except that one group of people saw this as potentially very helpful: relatively wealthy couples who, biologically, were unable to have children now had a possible route to pregnancy.

This interest inspired entrepreneurial doctors to create clinics devoted to in vitro fertilization (IVF). Today, 50,000 or more couples in the United States choose to use IVF to have children each year. IVF doctors now make considerable incomes in the field and new opportunities for social and technological innovation have opened up, including markets for sperm, eggs, and surrogate mothers.

The changes have not simply been economic but social and ethical as well. Some IVF procedures, for example, raise questions about parental rights and responsibilities. What happens if a surrogate mother decides not to give up the genetically unrelated baby she has carried to term to the child's genetic parents? In this case, the courts have become the venue for deciding the legalities of parenthood when three persons rather than two are involved. Another aspect of parental rights is raised by new tests that allow for genetic assays of embryos. Do parents have the right and/or responsibility to conduct genetic tests on their unborn children? If they do, what decisions are they subsequently allowed to make on the basis of the information provided by those tests? Can they abort the embryo? Under what conditions: never; only if the test shows that the child will acquire a deadly childhood disease; if the test shows a disposition for cancer or other major disease; or if the genetics show that the child will show a socially undesirable trait?

These questions and others like them arise because a new technology has given us the ability to know and act in new ways. Answers to such questions are often controversial precisely because they represent departures from settled notions of morality and social behavior. Thus, answering these questions entails social deliberation through which individuals and communities decide for themselves and others what kind of a world the future will be with the new technology in it (including, potentially, the outright rejection of a new technology as incompatible with individual or community values, although this is rare). This is how social change happens around new technologies.

Nanotechnologies raise similar questions. Such questions may seem relatively mundane today. The choice to wear stain-resistant pants or to use nanotechnology enhanced golf balls, for example, probably doesn't raise many moral eyebrows. It is not an accident that most of the early applications—stain-resistant pants and improved golf balls—are technologies can enter our lives quickly. These technologies are simple modifications of existing technologies that do not call into question our existing values, behaviors, or interactions with others. Of course, people may still choose to act in new ways—golfers may brag even more than they usually do—but people do not yet appear to see important social consequences to such changes (although some have speculated whether wearing stain-resistant pants might increase people's propensity to eat in the car, which is known to increase the chance of accidents).

On the other hand, the question of whether the Food and Drug Adminstration should regulate the use of nanoscale versions of chemicals currently used in cosmetics and sunscreens is more complex and controversial. Regulators and consumers must make difficult decisions about whether to treat nanotechnology-enhanced versions of current products as equivalent in terms of public and personal risk to their non-nanotechnology predecessors. These decisions have considerably greater moral import. Over time, we can expect developers of nanotechnologies to use consumer and regulatory responses to these initial nanotechnologies to plan for future nanotechnologies. In turn, future innovations may raise deeper questions about existing values, behaviors, and relationships, prompting us to ask if our norms, our social arrangements, and our institutions are still up to the task of keeping society safe.

Now imagine a hypothetical nanotechnology product (but one that several scientific laboratories are working on): an inexpensive detector that can identify the influenza virus. Such a detector might initially be developed because of ready-made markets in health care and homeland security. But if it is inexpensive enough, people will probably also use it in other circumstances, such as schools or the workplace. And while we may anticipate early on how health care workers or security experts will use the detector—perhaps even because such users were involved in its planning and development—we may not so easily foresee how others would respond. Might parents insist that schools send other people's children home if they test positive for the virus? Will schools fear lawsuits if they do not test children every morning? We may find our values, our behaviors, and our relationships changing if we adopt this new technology.

The first-order impacts of cheaper and faster detection of influenza—faster access to health care and fewer illnesses and deaths—are often easier to imagine than these more subtle second-order impacts. The latter appear only as society reorganizes itself around new technological possibilities, as a result of thousands or millions of individuals and groups making technological choices. The results can be extraordinary, however. Since the introduction of the automobile, for example, many societies have radically transformed themselves, creating urban and, especially, suburban infrastructures that differ vastly from prior cities. Future nanotechnologies, too, may facilitate radical new ways of organizing society.

This perspective offers a valuable opportunity for nanotechnology. Can we learn to anticipate potential “second-order” impacts of nanotechnologies? Scenarios of the future to assist our imagination or early-warning systems that identify early changes in peoples’ values and behaviors might help people to better deliberate and decide how to shape the development of alternative future nanotechnologies and societies.

4. There are many ways to design, implement, and use a given technology, and many technological solutions to any given problem

> *There is a common belief—a myth, really—that technologies exist the way they do because there is no better way—that equations, engineering practices, and the market allow for no other possibilities. But technologies are often highly flexible. There can be many different technical solutions to the same problem, many different notions of what the problem is in the first place, and many different possible ways that a given technology might be used to fix it.*

Technological systems and the societal arrangements that form around them are highly flexible. This results, in part, from choices available in the design and operation of technologies, as designers seek to meet a range of social, economic, and political criteria. Flexibility can also arise from the different meanings that different groups may give to the same technologies or from the different technologies used by different groups to solve the same problem. As a consequence of this technological flexibility, there is not one nanotechnology but rather many different nanotechnologies, driven by different agendas and choices, as well as by different ways they are interpreted and used.

Consider the problem of getting to work each day. Many people in the United States conclude that the best way to accomplish this is to drive a gasoline-powered vehicle. Automobiles seem the obvious choice to many because they are relatively fast and can take them wherever they want to go whenever they want to go. But while the automobile meets certain needs and values that are important in modern society, these are not the only needs people have and they do not embody all of the values that people have. And we should note that, the use of an automobile only seems easy because the driver can depend on others to build and repair it; find, mine, and refine oil into gasoline; deliver gasoline to businesses for sale; etc.

There are many solutions to the question of how to get from one place to another. The solution one develops is shaped by a wide range of criteria including economic, political, and social factors. Public transportation may be an option, if it is available, and if the person cannot afford a car or values environmental goals, the time to read, or even the ability to interact with others. A bike may be possible, if the distance is not too great, the weather amenable, or the person is concerned about getting exercise. With enough money, a person might choose to live close to work and walk each day, unless perhaps there are concerns about personal safety or the quality of schools or other services nearer to the workplace. Or perhaps the person identifies with the culture and lifestyle of skateboarding and he or she rides a board to work everyday – again assuming the terrain is friendly.

Another aspect to technological flexibility is that the same technology may mean very different things to different people. The same automobile that one person sees as a means of getting to work may be for others a source of identity, a hobby to enjoy in one's spare time, an icon of freedom, or a symbol of excessive consumption. A vivid cartoon in a South Asian newspaper shows an overweight gentleman with a cigar, leaning out of a Cadillac saying to a poor farmer in Latin America, "Yo amigo. We need that tree to prevent global warming." A person might buy a hybrid car because they think it will help the environment, because they like its futuristic looks, or because their favorite Hollywood star just bought one. A parent might buy a Japanese economy car because it is inexpensive and easy to maintain. Their son, on the other hand might add some accessories and decals, join a car club, and go drifting with it.

Nanotechnologies are also flexible, both in application and in interpretation. For instance, a handful of scientists are working to use nanotechnology to build interfaces between humans and machines that they believe will allow those who can afford the technology to live greatly extended lives. Other scientists and politicians contend that not only are such efforts technically impossible but also that the values motivating such efforts are misguided and dangerous. These latter groups are attempting to steer nanotechnologies to solve health problems that will benefit a much broader array of people. The discussions between these groups, and the influence that each can exert on engineers, corporations, politicians, consumers, and citizens will shape the technologies that we develop and the world we will eventually live in.

The directions we take in research and innovation are not preordained. There is thus no one best route to creating nanotechnologies. Nor is there necessarily one best nanotechnology for the job. We must recognize that we always have choices in how we design nanotechnologies and which nanotechnologies (if any) we use to solve problems. We must therefore decide what kinds of nanotechnologies we want – or are willing to tolerate.

5. **Technological systems are frequently highly complex, interdependent, and difficult if not impossible to predict**

> *Technologies are rarely stand-alone objects. They rarely work or have much impact unless they are part of complex systems. These systems connect individual technologies to far flung networks of people and machines. They can create unanticipated impacts and make it easier for technologies to break down or result in disasters.*

If your whole idea of technology is a simple electronic device like your MP3 player, a computer, or a pacemaker, then you are getting only a few notes of a very large score. A lot of work went into designing and building each of these objects. Engineers distilled corporate goals, technical requirements, and industry and regulatory standards into a design. Metals and plastics were fashioned into components that must work together seamlessly. A manufacturing facility was built to assemble these components. Market researchers analyzed people like you to see how best to sell you such items (which may also have fed into design choices). The manufacturer designed a way to package and distribute the devices. Retail shops and websites stocked the items and developed ways to get them to you. And marketing teams made you aware of the product and convinced you to buy it.

But these efforts describe only part of what makes the device possible. If you want it to do anything you have to cast your net still wider. The device may come with a battery (which, in turn, had to be made), but you'll want to plug into the electric power grid—which is of course linked to generating facilities that turn fossil fuels (or nuclear decay or falling water) into electricity.

And then, if it is the MP3 player we're talking about, there is the music. Musicians must record their work, and these recordings must then be transferred faithfully onto CDs or into digital music files for you to buy at the store or on the Internet. The intellectual property rules that protect their creative work must be in place. All of this interconnectedness is essential to making the MP3 player work. If any of the steps were missing or just a little bit different, what the device does and means might be very different.

The complexity of such systems also makes it difficult for the creators, regulators, and users of technologies to foresee the implications of their choices. Recently, for example, regulators in the United States required gasoline to contain a higher concentration of ethanol, which in the U.S. is most often made from corn. They hoped that such gasoline would help reduce both dependence on foreign oil and global warming. This seemingly simple change, however, rippled through a number of very different systems. Commodities traders decided that this policy change would make corn more valuable in the future, and so they began to buy it all over the world. Their rush to buy corn caused its price to shoot up, which increased not only the cost of ethanol, but also the cost of tortillas in Mexico. In Mexico City, thousands protested the impact of a more expensive staple food on their families. While such small changes do not always ripple into such big effects, the pervasive and integrated technological systems we have created are always open to the possibility that what may seem to be local decisions will have significant and broad reaching effects.

Because small disturbances can have large effects, technological systems can be very vulnerable to disruptions. The electricity grid is a good example. Over the past few years there have been a number of blackouts because small errors at a relay station or in computer software have given rise to widespread effects that shut down systems hundreds of miles away. Such blackouts may be inconvenient for some, but hazardous for others because we live with and through our technologies. Hospitals need to keep life support systems running, for example. And during a heat wave, or an average summer day in Phoenix, the absence of air conditioning can actually be deadly (and one common cause of blackouts is the demand on electricity grids from excess air conditioning used during heat waves). These vulnerabilities also make such systems potential targets for terrorists. A knowledgeable person with the intent to bring down a large technological system could have an even more disastrous effect.

Some scholars warn that the more complex and interconnected we make our systems—even those designed to increase our security—the more vulnerable we become to terrorism.

The complexity of technological systems is important to keep in mind in the analysis of new nanotechnologies. The interlocking systems that make our technologies possible also make it very difficult to forecast or control the outcomes of decisions. Whenever we develop new technologies, we must be very careful to think about the potential ramifications for a broad array of people. What we think are small discrete decisions may ultimately have broad effects in places we would not expect. Unanticipated consequences should be seen as the norm rather than the exception. And we must think about ways to monitor such effects and take steps to remedy them.

6. Social and technological change can be incremental—or disruptive—and it can be hard to forecast which

> *As technologies and societies change together, sometimes that change is incremental as a new technology provides a small improvement on an existing technology. Stain-resistant nano-pants are but one example. Other times, however, new technologies can be highly disruptive. In the 1990s, for example, many agricultural chemical and seed companies began to worry about the potential impact of new genetic engineering technologies on their own products. Pest resistant crops, for example, would eliminate the need for farmers to use – or buy – pesticides. A major reorganization of the two industries followed, as the chemical industry bought up the seed companies and invested in its own biotechnology products. Where once there were hundreds of small seed companies, today fewer than ten large companies control most of the US market share.*

The complexity of the interactions between technology and society makes forecasting social and technological changes difficult. In wrestling with questions about what new technologies mean for their lives, people imagine the changes that might occur around inventions.

Sometimes, people imagine huge changes that later turn out to be modest. In the 1950s, many politicians, scientists, and futurists claimed that nuclear power would make electricity "too cheap to meter." While nuclear power plants have had some impacts on our world, they have not produced the unlimited, costless electricity that was once predicted.

Sometimes the reverse happens as well. Looking back in history, we often see that major changes occurred unexpectedly and, at first, without notice. Thousands of years ago, women who saved seeds and put them into the soil instead of eating them contributed to the invention of agriculture, thus initiating profound changes in how food is produced, stored and processed, as well as how humans cooperate, build communities, trade with others, relate to the environment, etc. Perhaps motorized farm equipment appeared initially to farmers as merely labor-saving devices to improve agricultural efficiency. Now we know they contributed to the large-scale mechanization of agriculture in the United States and the subsequent urbanization of American life.

While there are some predictions that nanotechnology will contribute trillions of dollars to the global economy in the relatively near future, we still have very little idea what particular products will be involved. Equally unclear is how their production will be organized, e.g., in a few big firms, in many small ones, concentrated in a few industrialized nations, or spread across the globe. And we have little idea whether those products will provide only incremental modifications—e.g., longer-lasting tennis balls, stain resistant pants, or dirt-repellent windows—or whether radical and even disruptive products will be created.

At times it behoves those interested in promoting or opposing nanotechnology to emphasize that it will create vast social changes that will either make the world a better place or create enormous problems. Thus some claim that nanotechnology enabled power systems will fulfil the original ambitions of nuclear power to produce electricity that is "too cheap to meter." Others worry that nanotechnology may enable us to reprogram human biology to design and create "super soldiers". At other times it may be more expedient to downplay possible changes. At the same time that a corporation is telling its customers that a nanotechnology-enhanced product is revolutionary in its design, it may tell government regulators that the same product is nothing new and thus does not need to be regulated any differently from its non-nanotechnology counterparts.

Instead of attempting to predict the social changes that technologies may cause—in ways that would likely be both short-sighted and self-serving—we need to ask hard questions about both the beneficial and disruptive changes that might be possible, as well as their potential magnitude. For example, scientists are working with nanotechnology in an effort to create devices such as "labs-on-a-pill" that, while passing through a person's intestine, can detect and respond to illness. What would such a lab-on-a-pill mean for the practice of medicine? Others have suggested that nanotechnology may revolutionize energy production, perhaps by developing a nano-photoreceptor that can make any device powered by the sun. How would our lives—and global economic and political systems—change if we were no longer reliant on fossil fuels, or if we were no longer limited in how much energy we could use?

To battle security threats, nanotechnology-enabled surveillance devices might watch, identify and track the movement of people and goods—everywhere. What, in turn, would this mean for privacy, civil liberties, and the relationship between citizens and their government? Nanotechnologies may also bring about significant changes in national security and warfare possible by providing new devices to infiltrate foreign countries, observe and target certain groups or populations, equip soldiers, and expand arsenals. Might they also, like other military technologies, spark new arms races, as the know-how behind nano-weapons spreads?

Nanotechnologies might even become part of new human-machine combinations that will enhance the performance of physical, cognitive, emotional, or other functions. What would such developments mean for human identity, health, and therapy?

In all of these cases of potentially disruptive change, both individuals and societies need to find appropriate ways to reflect on and deliberate how to respond to scientific and technological change on the one hand, and on how science and technology might best serve to solve human needs and problems on the other. A key part of this effort is to recognize that new technologies may be more or less disruptive then the rhetoric surrounding them may at first make them appear.

7. New technologies are often controversial and may create new risks

> *As a consequence of the flexibility of technological design and use, as well as the different meanings attributed to them by different groups of people, new technologies are often controversial. The same kind of novelty that makes new technologies innovative and interesting to some groups and in some contexts may also make them risky or unpopular to other groups and in other contexts. Variations and inequalities in the distribution of risks and benefits can also foster controversy. Such controversies do not so much reveal anti-technology or "Luddite" tendencies as they indicate the existence of robust social debate over how to design the ways we will live with technologies in the future.*

Because new and emerging technologies are often complex—and occasionally disruptive—they are also often controversial. Consider cell phones. While many people in wealthy countries have cell phones (and many in poorer countries, too), their spread has not happened entirely without disruption. Responding to concerns about safety, some locales have outlawed the use of cell phones while driving vehicles. Libraries and commuter trains have instituted quiet zones, while theaters, restaurants, meetings, and classrooms remain vexed by ringing cell phones and their owners who tend to them—and by participants who are busy text messaging or reading email. Some athletic facilities have even banned their use because the cameras included on many cell phones have been used on unsuspecting guests in the showers.

Indeed, in many cases, the changes that occur around new technologies are even more significant and cause deeper conflict than cell phones have to date. Questions arise about how to adjust our moral, legal, and political sensibilities and understandings to new technologies and the new kinds of behavior they enable. At the same time, controversies emerge as a result of the complexities of technological systems. Different groups of people interact with complex systems in very different ways. Some may be consumers who want cheap products, while others are laborers who want to be well paid for their work.

A good example of the potential controversy associated with new nanotechnologies is the possibility discussed above that nanotechnology may enable the production of inexpensive, accurate detectors of an illness like influenza. Such detectors might be put to use, for example, to screen airplane, train, or subway passengers, raising questions about the conditions under which it is permissible for the government to prevent someone from traveling. Similar questions might be asked about whether commercial venues like malls, movie theaters, or sports stadiums might be legally obliged to install such detectors to protect the health of workers and customers.

In the United States, the courts have become central to managing conflicts over new technologies. Congress and state legislatures have generally been reluctant to set standards of design, behavior, and use for new technologies, and so people who believe they have been harmed by new technologies have little recourse besides the legal system. The result has been an explosion of technology-related lawsuits. Infertility treatments, for example, which have gone largely unregulated by states or the federal government, have led to dozens of court cases on the rights, responsibilities, risks, and benefits associated with in vitro fertilization techniques.

Controversies may also arise around new risks. One of the central claims about nanotechnology is that, as the size of materials change, so too do their properties. Many nano-sized materials have different electrical, magnetic, physical, and biological properties than larger particles of the same material. Gold, for example, is used in jewelry because at that scale it does not react with other substances in the environment (for example, tarnish). At the nano-scale, however, gold is very highly reactive. The special properties of nano-scale materials are one reason why people are so excited about the potential of nanotechnologies. At the same time, these novel properties also create the possibility that nanomaterials will interact in surprising new ways with complex biological systems, both in nature and in our bodies, creating new environmental and health risks.

At the moment, there are few if any processes in place to monitor either the presence of nanoparticles or their effects in most air, water, soil, ecosystems, or human bodies. Scientists are also unsure what the long term effects of nanotechnologies may be on human development or ecological health.

This uncertainty about the effects and dangers of nanotechnology is matched by uncertainty about how to manage such risks. Who is responsible for preventing nanotechnology risks? Who decides what an acceptable level of risk is? While regulations and safety standards exist for other chemicals, most of these regulations do not seem to apply to nanoscale materials. Indeed, nanotechnology crosses many different fields of use and thus may fall into gaps between existing regulations. Even where nanomaterials do fall under existing regulations, those regulations may not make sense. For example, titanium dioxide has long been used in sunscreen and is regulated by the Food and Drug Administration (FDA). But now sunscreen manufacturers are using titanium dioxide nanoparticles, which have different properties. Can they be treated the same for regulation, or do we need new regulations?

Controversies about new technologies should not be seen as simply roadblocks to new “advances.” They are an important way in which we evaluate new technologies and debate about what values are most important. If we are to develop and accept technologies that promote our goals, we must actively discuss the pros and cons of new developments. Deliberations over how to best employ technology—and how to best organize our world around this technology—are a vital part of building better societies.

8. **Our technological imagination shapes our future**

> *Because of our inability to foresee all of the possible consequences of new and emerging technologies, our imagination becomes crucial in how we understand, interpret, and give meaning to technology in our lives. History, fiction, art, and even speculation are key elements in the stories we tell*

> *ourselves about why we should or should not support new technologies, why we should choose this design over that one, or how we envision a technology will impact our lives. Different ideas of progress and different experiences with technology shape our perspectives on whether a particular technology will be good or bad for society. Our ideas and expectations for the future also take on a life of their own, influencing the technologies we design, create, and choose.*

New technologies are often accompanied by elaborate promises of future benefits, and nanotechnologies are no different. The proponents of nanotechnology promise that it will alleviate human suffering by developing new diagnostics and pharmaceuticals and that it will end pollution through clean production and the development of new techniques to clean up old messes. On the other hand, some people fear the future of nanotechnology, suggesting that it will aggravate existing inequalities, allow surveillance of everyone and everything, and disturb what it means to be human by merging humans and machines in troubling ways.

These hopes and fears about whether new and emerging technologies will be good or bad for society are shaped by different notions of human progress. For some people, progress means healthier, more meaningful lives. For others, it means greater material wealth. For yet others, it means a life more attuned to nature and the environment. These ideas are crucial to how we understand and give meaning to technology.

The consideration of nanotechnology encourages the use of our imagination because so much of its potential is still to come. We use history, fiction, art, and speculation in the stories we tell ourselves to draw analogies, explore possibilities, or instill warnings about what might happen in the years to come. These imaginations can influence decisions about whether we should or should not fund new research, why we should choose this design over that one, or how to adjust our lives to the possibilities of new technologies.

In his early propaganda on behalf of nanotechnology, for example, Eric Drexler focused his imagination (and that of his readers) on billions of tiny machines working to solve many kinds of problems. Futurists like Bill Joy and science fiction writers like Michael Crichton picked these ideas up and gave them a more troubling twist, imagining a world of nano-machines run amok. In turn, Mihail Roco, who is in charge of nanotechnology research at the US National Science Foundation, explicitly rejected the idea of creating tiny machines and has, instead, imagined and funded a very different vision of where the field of nanotechnology research should go.

Science fiction writers often present worlds that are shaped by technology in an effort to show us where some of today's technological decisions may be headed. In a similar way, scientists often include visions of the future in their grant applications and solicitations for venture capital investment. They may justify their research with a picture of a world that could be made possible if only they had the funds to carry out the projects they have outlined.

This technological imagination is important because what we imagine informs what we create. Our visions about the future always contain an element of self-fulfilling prophecies—technologies come about a certain way because, at least in part, we expect or imagine them to do so. High School students who get excited about a particular vision presented in *Scientific American* or *Popular Science*—or a science fiction story—may decide to become an engineer in order to actively create such a future. One nanotechnology researcher, for example, was inspired by the movie *Gattaca* to try to create a portable device for rapidly sequencing samples of DNA. The way that we choose to design and invest in new technologies reflects a vision of the future. The futures that we imagine today thus help to shape the futures that we actually get tomorrow.

We should always keep in mind, however, that the future still has a tendency to surprise. There are always a great number of unknowns, and the technological imagination can deceive as well as inform. It is always important to ask which visions we are attributing to new technologies, why we are attributing them, and to whose ultimate benefit and cost? Whoever controls the visions of the future controls the decisions made today—even if those decisions do not necessarily result in the ultimate achievement of the visions that inspired them.

Being reflective about the future and exercising our technological imagination is particularly important in the context of nanotechnology. Nanotechnology remains relatively unformed as a technology, but the imagined possibilities of nanotechnology—good and bad—are already circulating. It is important that we subject those imagined futures to critical scrutiny and recognize that no one should have a monopoly on the construction of futures. It is important that a wider array of citizens become involved in imagining the nanotechnological future. Scientists and entrepreneurs may invent nanotechnologies, but we will all have to live in the future that those technologies imagine and create.

9. People already play an important role in governing new technologies, and they can play an even bigger role

> *People can and do play important roles in governing technological change, but they can also do so more actively. In many countries, citizens are being encouraged to become more active in debating new technologies through a range of activities that bring scientists and citizens into conversation (these sometimes go by the names of Science Cafés, consensus conferences, museum forums, and nanotechnology dialogues). These activities recognize the importance of citizens talking to scientists about the latters work, as well as citizens talking to one another about what the latest science means. In this way, people can learn about various possibilities for technology governance.*

People play an important role in governing new technologies in many ways. As parents, they imagine and plan futures for themselves and for their children. As consumers, they influence the market through their purchases, and they use new products in ways that their inventors anticipated and in others that they never imagined. As citizens, people help choose the political leaders who invest in the creation of new knowledge and technologies. As scientists and engineers they choose what knowledge gets pursued, elaborated, and reduced to practice. As activists they seek to assure that knowledge is pursued and applied in the public interest.

But while a large fraction of us plan for the future, buy new products, and even vote, only a very small fraction of us get to participate directly in the pursuit of new knowledge or in helping to ensure that its technological application is directed toward the public good. There are a number of ways to increase this fraction, ranging from opening science and engineering careers up to more diverse groups of people, to encouraging citizens to become more active in debating new technologies (for example, through Science Cafés, consensus conferences, museum forums, and nanotechnology dialogues), to finding ways for citizens to become involved in designing research priorities and technological development. These activities recognize the importance of ordinary people talking to scientists about their work and to one another about what scientific research means.

It is also important to understand that we have choices in how to guide or govern new technologies. Too often, it seems, that choice is portrayed as banning a new avenue of research or a new technology, or leaving it to an unfettered marketplace. This is a false choice. We have significant experience in varied and even nuanced approaches to managing technological change. We require laboratory researchers to follow a variety of rules regarding human and animal research subjects, occupational safety, and bio-hazards. We have regulatory agencies like the Food and Drug Administration, which oversees the testing of new pharmaceuticals for their safety and efficacy, and the Environmental Protection Agency, which performs a similar task for the toxicity of new chemicals and pesticides. We mandate safety and fuel efficiency standards for automobiles, "do-not-call" lists for telephones, and privacy requirements for medical records. We require licenses and operating standards, including age and competency requirements, for technologies like cars and guns that may be particularly dangerous in the wrong hands. We indemnify some technologies, like nuclear energy, against major accidents to protect their early adoption. We require that knowledgeable professionals prescribe, handle, and distribute new drugs.

These are only some of the many tools with which to govern scientific and technological change, and citizens have access to many of them either directly or through traditional political processes. In the case of nanotechnologies, we will need to figure out as a society precisely how we want to set up rules governing its use. This will not be easy, but it will be a crucial part of choosing our nanotechnological future.

10. We need to be more reflexive about how we assess nanotechnology

> *Each of the above points speaks to the need for many kinds of people, not just scientists, politicians, and CEOs, to reflect on and become more involved in decisions about new technologies. By "more reflexive," we mean many things: to better understand and use our ability to shape technology to achieve good societal outcomes; to recognize and better manage the uncertainties that come with complex technological systems; to watch carefully for unanticipated outcomes; to promote robust social debate about the kind of technological world we want to live in; and more. To help us do all these things, each of us needs new approaches for assessing social and technological changes in our own lives and more broadly in society.*

Each of these "big ideas" about nanotechnology-in-society can help us to become more reflexive about new technologies. That is, they assist us in thinking through the role of technologies in our lives and societies that we often take for granted. This kind of thinking is important because, in order to make better decisions about the future, we need to understand not only the role of science and technology in society but also our own role in shaping science and technology.

One way to improve this reflexive understanding involves asking just what it would be like to live without a particular technology, for example, email or a cell phone. How would you get along without it? How would you relate to people who continued to use it? You might even consider giving up the technology for a short period of time, the way some religiously observant people refrain from some activities during certain holidays, or the way campers go "back to nature" without some modern conveniences. The experience of being without a technology provides you with the opportunity to reflect on the technology itself, your relationship with it, and how it shapes your relationship with other people. Thinking through technology in this way can help us to realize the impact of our technological choices on the basic structures of our life and help us to evaluate such choices.

It's one thing to imagine putting down your cell phone for a day. It's another to try to think about such things for technologies that don't even exist yet. That's why this reflexive attitude toward science and technology needs to be distributed broadly through society—among ordinary people who have hopes and dreams for a better future; among the politicians and bureaucrats who are setting priorities for scientific research and development; among the scientists and engineers who are conducting the research itself; among the entrepreneurs, clinicians, and other professionals who help translate what is discovered in the laboratory into something that the rest of us can use; and among all of us who use technologies every day.

What does reflexivity mean? It means recognizing that social and technological systems are closely intertwined and that changes in one will likely be accompanied by changes in the other. It means recognizing that we have choices about which technologies to design and use and how to govern them. It means developing a deeper understanding of the complexity and interconnectedness of technological systems and the ways that they could fail. It means understanding how technologies are connected to people's hopes, dreams, and fears, and how those visions are connected to decisions to design, build, and use new and emerging technologies. It means, perhaps most of all, not taking the technological world that we live in for granted, recognizing what it takes to create and maintain that world, as well as what changes in it might mean for each of us, as individuals, and for all of us, collectively.