Bringing Nano to the Public:

A Collaboration Opportunity for Researchers and Museums

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NISE NETWORK

Nanoscale Informal Science Education Network (NISE)

"Advances in nanoscale science, engineering, and technology are revolutionizing medicine, computing, materials science, energy production, and manufacturing. Yet to the general public these advances remain largely invisible and difficult to understand. Nanoscale research challenges the education and research communities to come together to create new methods and approaches to communicate the work of nanoscale scientists and engineers, to inform the public about advances in the scientific research, and to capture the imagination of new generations of diverse communities of youth who may choose careers in nanoscale science and engineering."[1]

The NISE Network is intended to foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology through establishment of a national infrastructure that links science museums and other informal science education organizations with nanoscale science and engineering research organizations. This $20 million, five-year effort represents the largest single award that the National Science Foundation has given to the science museum community, and is a cornerstone of the Foundation's multidisciplinary Nanoscale Science and Engineering Education program.

The lead institutions of the NISE Network are the Museum of Science in Boston, MA; the Exploratorium in San Francisco, CA; and the Science Museum of Minnesota in St. Paul. Other contracted partners include OMSI, Sciencenter (Ithaca), the Forth Worth Museum of Science and History, the Museum of Life and Science (Durham), the New York Hall of Science, the University of Wisconsin-Madison's Materials Research Science and Engineering Center (MRSEC), Purdue University's Envision Center for Data Perceptualization, Cornell University, the Materials Research Society, and the Association of Science and Technology Centers. For more information, please contact the Network at nisenet.org/resource.

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Acknowledgements

The author would like to thank Susan Koch of the Science Museum of Minnesota for her guidance and editing expertise during the development of this guide. Gratitude is also expressed to the following individuals for their feedback: Jim Roe, Science Museum of Minnesota; Richard Souza, Materials Research Society; Deborah Perry, Selinda Research Associates; Eric Marshall, New York Hall of Science; Carol Lynn Alpert, Andrea Durham, and Doug Smith, Museum of Science, Boston; Cynthia Needham, ICAN Productions; Petra Reinke, University of Virginia; Frank Armatis, 3M; and Bob Reynolds, Oregon Museum of Science and Industry.

This guidebook 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.

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Introduction

This booklet invites scientists and engineers who work in nanoscale science and engineering to collaborate with museums to present nanoscience and technology to the general public. It is written by a researcher for other researchers, and it's designed as an introduction to what museums call the "informal science education" field. This field includes the presentation of science in museums, community centers, the media, and other places where people come to learn something and have fun. This booklet will describe how researchers can get involved with museums to present nano to the public, and provide background about how museums work. It will also review what the public currently understands about nano and the challenges that these (mis)understandings create for museums and researchers. The NISE Network hopes that it will motivate you to consider collaborating with your local museum(s) to help engage the public in nanoscale science, engineering, and technology.

Why should researchers care about informal science education?

Researchers in nanoscale science and engineering communicate all the time. We give talks, present lectures and write papers regularly. But the audiences we speak with generally consist of our peers or students who are experienced learners in our research areas. The general public—the consumers who will use the products of our work and the voters who indirectly set the national research agenda—do not hear us. Earth scientist Chris Paola from the University of Minnesota notes that "At present, the great majority of scientific researchers interact with the public on only a limited basis, if at all. In the long run, this situation is not good for either the research community or the public that funds it."[2]

Informal science education—including museums, TV, public lectures, popular press, etc.—is a way to connect with broader audiences in a variety of fun and effective ways. More than 286 million people visit museums each year in the US.[3] Museums have a long tradition of credible public service in the area of informal education in the arts, humanities, and sciences, and they have credibility with scientists, as well.[4]

Museums are popular because they are skilled at making abstract and complex phenomena comprehensible to people from all walks of life, and making the whole experience fun. Museums are creative spaces, trusted by the public, and they can provide a bridge between the research lab and everyday life.

> *"Science centers and museums, already accustomed to dealing with a variety of audiences, have staff trained in the communication of science concepts. They are well situated to assist research facilities in meeting outreach goals. The relationship is beneficial for both partners. The researchers gain greater visibility and reach a bigger audience, and the science [museum] gains effective and interesting public programming that can help boost attendance."*
>
> —Daniel Steinberg, Princeton University[5]

What are the benefits of partnering with museums?

Perhaps the most important reason for getting involved in informal science education is that having an informed public is a good thing. We need scientifically literate people with a basic vocabulary of terms and a general understanding of the process of scientific inquiry, or as Jon Miller, Director of the Center for Biomedical Communications at Northwestern University, states, "a level of understanding […] sufficient to read and comprehend the Tuesday science section of *The New York Times*."[6] Unfortunately, only about 17% of US adults can be classified as scientifically literate today, but the good news is that this figure has been climbing over the last two decades.[7]

One benefit of a more scientifically literate public is increased support for funding of research.[8] A substantial majority of Americans support government spending for scientific research, including basic scientific research. The better our research and its implications for society are understood, the better the general public can make responsible decisions about public funding.

> *"Today it is commonplace that science and science-based technologies occupy a central place in our society. This basic fact has multiple implications for science as well as for wider culture. It means, for example, that decisions about what science is done and how that science is done are influenced by factors far beyond the narrow confines of the professional scientific community—by questions about the availability of research funding, about the potential distribution of benefits and risks, and about economic, environmental, ethical, social, and legal implications. By the same token, it also means that the wider community has a considerable stake in the outcomes of scientific inquiry."*
>
> —John Durant, At-Bristol[9]

Another motivating factor is to encourage the next generation of scientists. We need children to consider and pursue careers in science and engineering. The best way to maintain their interest during their formative years is for them to have multiple, positive interactions with science. Museums provide an indispensable way for kids to have fun, memorable science experiences that may ultimately attract them to careers in science.

This isn't all altruism; doing outreach in informal settings can also provide a number of personal benefits to researchers. When kids get excited about the work that we do, we share in that excitement and become energized by it. Creating effective ways to talk to general audiences about science and engineering concepts helps us to develop better explanations, demonstrations and visuals that can also be used in the undergraduate and graduate classrooms. Informal science education experiences can even have unanticipated positive effects on research because of the questions posed by novice audiences and the connections made with others in related fields. Finally, outreach can provide connections with informal science education colleagues and open up avenues for collaboration that will address broader impacts requirements for proposals to the National Science Foundation and other agencies.

OK, but do museums even care about nanoscale science?

Nanoscale science is a perfect subject to bring to the public. We are currently in the early stages of public awareness, and the term is new and has few negative connotations. You might hear a middle-school student mutter "I hate chemistry," but they are not saying "I hate nanotechnology." Yet. This gives us an opportunity to inform and educate while people's minds are still open. However, we cannot treat the public as naïve and only present the hype and provide positive spin to our work. "A strong belief in the benefits of science and technology does not mean that individuals have no reservations about the impact of science and technology."[11] Thus, it is important to present a balanced picture of potential benefits and risks.

Museums are interested in bringing nanoscale science to the public because they are aware of its wide-ranging implications both within scientific disciplines and in the larger society as a whole. One of museums' main purposes is to offer experiences and products that interest and engage the public, and presenting current science and technology topics is one way to do this.

> ***"With science changing so rapidly and with so many quick-response media ready to cover news at a moment's notice, it is commonly argued that museums are not the best place to present current scientific research. […] Yet over the past decade, museum visitors have demonstrated an appetite for contemporary science programming in natural history museums and other types of science museums. It is plain that we are now in an era in which these institutions are becoming less focused on the past, more responsive to the present, and more willing to look to the future."***
>
> —Graham Farmelo, in *Creating Connections: Museums and the Public Understanding of Current Research*[12]

Nanotechnology is a particularly challenging topic for museums because the science is very complex and museums sometimes don't have content experts on their staff. To help visitors engage with nanoscale phenomena, we need sustained relationships bringing informal science education institutions together with universities, research centers, scientific societies and individual researchers.

The NISE Network: Researchers and museums working together

These needs prompted the National Science Foundation to call for proposals that "…intended to foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology through establishment of a Network, a national infrastructure that links science museums and other informal science education organizations with nanoscale science and engineering research organizations."[13] Funding was

Reasons Researchers are Motivated to Partner with Museums on Informal Science Education[10]

Addresses funding agency requirements for broader impacts

Reduces time needed for development of an organizational infrastructure

Provides an existing venue and public audience

Capitalizes on museum's ability to generate public interest and media attention

Reduces need for researcher to be an expert in pedagogy and communication

Utilizes museum's experience on how to best convey science concepts to general audiences

granted to the network plan developed by the Museum of Science (Boston, MA), the Science Museum of Minnesota (St. Paul, MN) and the Exploratorium (San Francisco, CA). The Nanoscale Informal Science Education (NISE) Network, established in 2005, brings the education and research communities together to create new ways to communicate the work of nanoscale scientists and engineers, inform the public about advances in the scientific research, and capture the imagination of youth who may choose careers in nanoscale science and engineering. There are three major project deliverables:

- A set of interactive exhibits and programs that effectively communicate and engage the public with nanoscale science and engineering;
- Essential new knowledge about design for learning in these subject areas; and
- A sustainable network of new relationships, alliances and professional development.

The work of the NISE Network is building on a significant amount of past and current work on presenting nano to the public. A number of excellent examples of exhibits, demonstrations, performances, films and programs have been developed for informal science venues. Examples include:[14]

- Ithaca Sciencenter's traveling exhibit *It's a Nano World*, developed with the Nanobiotechnology Center at Cornell University.
- *Strange Matter* traveling exhibit developed by the Ontario Science Centre and the Materials Research Society.
- *Nanozone*© exhibit and multimedia project at Lawrence Hall of Science, Berkeley, CA.
- The *Nanotechnology* exhibit at Tokyo's Museum of Emerging Science and Innovation.
- Los Angeles County Museum of Art's installation of the art and science of *Nano*.
- Nanotechnology-related live presentations, guest researcher presentations, cable newscasts, podcasts, web media, and workshops at the Museum of Science, Boston, MA produced in collaboration with Harvard-MIT-UCSB-MOS Nanoscale Science and Engineering Center (NSEC).
- A Fred Friendly Seminars/ICAN Productions 3-hour series entitled *Nanotechnology: Small Matters* produced for broad cast on public television and available for distribution to informal and formal education institutions.
- South Carolina Citizens' School of Nanotechnology sponsored by the USC NanoCenter.

For more information about past and current exhibits and programs about nanoscience, visit the NISE Network's web resource center, which provides links to extensive resources: www.nisenet.org/resource.

This booklet is one tool created by the NISE Network to help create and strengthen relationships between researchers and museums interested in bringing nano to the public. In the following sections, we'll fill you in on what the public currently understands about nano, then we'll describe some of the options for collaborating with museums on nanoscience projects and outline some of the roles you can play in helping to bring nanoscience to the public. In Part II, we will provide a general introduction to how science museums approach the process of conceptualizing and producing exhibits and programs, which will give you more background should you accept our invitation to collaborate with a museum in your local community.

What the Public Knows About Nano

Nanoscale science, engineering and technology, or "nanotechnology," has the potential to revolutionize aspects of our society. Advances in the field are already influencing medicine, computing, materials science, energy production, and manufacturing. These applications will affect our lives in the future, presenting society with both challenges and opportunities. However, these advances remain largely invisible and difficult to understand for the general public. In order to effectively inform the public about nanotechnology, we need an understanding of the audience and the challenges we face in communicating with them.

> “*Visitors are smarter than we think they are, but they know less than we think they do!*”

—Deborah L. Perry, Selinda Research Associates[15]

Public perception of nanotechnology is generally positive

Nanoscale researchers and many of the people they interact with in their day-to-day lives have heard of nanotechnology and can give a good, if not very detailed, definition of the term. This, however, is not representative of the general public. In a 2005 survey, only 40% of respondents reported that they had heard of nanotechnology, and of that 40% less than half could correctly define it.[16]

Currently, public perception of nanotechnology is somewhat positive or, at worst, neutral.[17] When asked about nanotechnology specifically, people on average believe it is at least somewhat beneficial, important, and safe.[18] However, given the low level of public awareness of the field, we shouldn't assume that these feelings run deep.

The positive attitudes reported are largely due to the fact that in the US the public is relatively positive about technology in general and sees technology as improving opportunities for their children.[19] Polls show that 90% of US adults believe that science and technology are making their lives healthier, easier, and more comfortable.[20] Additionally, roughly one adult in five is interested in finding out more about scientific developments.[21]

Although knowledge of nanotechnology is low, the public still has concerns. First is privacy because of the potential for tiny surveillance devices. Although anxiety about "grey goo" (popularized in *Prey* by Michael Crichton) is minimal, there is concern that nanotechnology may lead to a new arms race.[22] In contrast, however, the public sees the positive potential for nanotechnology in health, medicine, environment and national defense applications.[23] Regardless of the current perceptions of the field, we must learn from the mistakes of other emerging areas of technology, keeping the public's mind open to the field and its possibilities by engaging in honest conversations about both benefits and risks.

Public understanding of the nanoscale is generally poor

Unfortunately when it comes to the public's understanding of science concepts, we face a much greater challenge. General scientific literacy is already a major problem in the US given that, for example, "four out of five Americans do not understand the concept of a scientific study sufficiently well enough to provide a short sentence or two of explanation."[24] Additionally, the public's understanding of atoms and molecules is particularly low, which leads to problems when discussing many concepts important to nanotechnology.

> "*[T]he public generally lacks the vocabulary and visual framework for understanding atomic scale, structure, or behavior—and [...] these 'gaps' are quite apparent in relation to topics of nanoscale and nanotechnology.*"

—Knight-Williams Research Communications [25]

From definitions to concepts, there are a number of substantial holes in the public's understanding of nanotechnology. Put succinctly, "The scale is incomprehensible, and the language is inaccessible."[26] A review of the literature on people's understanding of atoms and molecules conducted for the NISE Network revealed that people of all ages:[27]

• *Do not have a good grasp of the terminology and concepts regarding atoms and molecules.* At the Franklin Institute in Philadelphia, they found that "only slightly more than half of the visitors knew that atoms or their components are the basic unit of matter; they confuse atoms with cells."[28]

• *Have difficulty understanding or relating to differences in size and scale.* "As soon as we confront the scale that nanotechnology works within, our minds short circuit. The scale becomes too abstract in relation to human experience. Consequently, any intellectual connection to the nanoscale becomes extremely difficult. [...] [T]he nanometer itself does not do justice in describing nanotechnology, but is rather the starting point of understanding complexity."[29] "Because all small things smaller than what we can see are beyond our normal perceptual experience, most peoples have no way of knowing the size differences between small scale objects."[30]

• *Tend to think of matter as continuous rather than particulate.* "Students of all ages show a wide range of beliefs about the nature and behavior of particles. They lack an appreciation of the very small size of particles; believe there must be something in the space between particles; have difficulty in appreciating the intrinsic motion of particles in solids, liquids and gases; and have problems in conceptualizing forces between particles.[31]

• *Generally lack knowledge of atomic structure.* The Science and Engineering Indicators study reported that 13% of US adults were able to provide a correct explanation of a molecule;[32] "[M]any adults knew that molecules are very small but did not know whether atoms are composed of molecules or molecules are composed of atoms. Some individuals knew that a molecule is a basic building block and is very small but could not say anything else about it."[33]

• *Incorrectly reason that the atoms and molecules in a substance have the same properties that the substance has in familiar macroscale form.* "It is difficult for students to see the connection between the submicroscopic world of atoms, ions, and molecules, and the macroscopic properties of matter."[34] For many, "materials at the atomic or molecular level are simply shrunken versions of their real-world manifestations and the atoms/molecules retain the materials' macroscopic properties."[35]

All of this evidence indicates that helping the public understand nanoscale science isn't going to be easy. While people have a generally positive attitude toward nanoscale science, that attitude is apparently more a general predisposition to think positively about new science and technology than a reasoned conclusion based on a deep understanding of the topic. Furthermore, the public has only a tenuous grasp on the fundamental concepts that underlie this science, which will make providing context and background difficult. The following section summarizes the challenge that nanoscience presents for informal science education.

The challenge for informal science education

The public's lack of understanding and the misconceptions surrounding basic concepts present significant challenges to communicating nanoscale science technology to a general audience. On top of that, we are dealing with nanoscale objects not visible to the naked eye and ideas that are complex and difficult to visualize.

> "*Cognitive penetration of the nano world may require something beyond the normal textbook or classroom lecture experience approach. Because that world is so counter-intuitive, so contrary to practical experience and so inaccessible to the senses, new multi-dimensional approaches should be explored, possibly involving large-scale interactive models enhanced by audio-visual media, and kinesthetic, sensory, and motor experiences. The task demands expert and research-savvy communicators, skillful at creating mental and physical analogs for atomic-scale processes and making them centrally relevant to diverse audiences.*"

—Alpert, Isaacs, Barry, Miller and Busnaina, museum and university collaborators in a Nanoscale Science and Engineering Center [36]

The challenges posed by nanoscale science and technology can be summarized as follows:

- Nanotechnology is a broad, emerging and rapidly changing field, making it difficult to discuss in any comprehensive way or keep current with the fast pace of the research findings and emerging applications.
- Museums have little experience with nanoscale science and engineering and are unlikely to have knowledgeable content area experts on their staff.
- Few people have heard about nanotechnology and fewer still know what the term means.
- Much of the vocabulary needed to explain nanoscale concepts is unfamiliar. Recognizable terms such as "atom" and "molecule" are poorly understood.
- Claims about the promise of nanotechnology can be seen as hype. Hearing it touted as being able to do everything from cure cancer to solve our energy problems provokes skepticism.
- The nanoscale is outside of our everyday experience. It's difficult for people to imagine the size or behavior of something that can't be seen.
- Fundamental misconceptions about atomic structure are prevalent.
- Atomic models can help show some aspects of structure, but any model is imperfect and may perpetuate other misconceptions.
- People reason that atoms have the same properties as the macroscale substance.

The difficulties may seem insurmountable, but museums and other informal science education institutions are experienced at engaging the public, even on such difficult science topics. In the following section, we review the basics of how science museums, particularly, achieve this engagement.

Science Museums Know How to Reach the Public

When we think of museums we often remember our childhood favorite, and the particular exhibits or programs that kept us coming back time and again. However, science museums—the term museum will be used to mean science museum, science center, science and technology museum, or natural history museum—come in all shapes and sizes. They range from large national institutions with hundreds of people on staff, to small local venues with a handful of staff members. Each museum has its own unique personality.

The audiences attracted to museums are also multifaceted. Visitors come from everywhere and they are everyone—all ages, all backgrounds. This heterogeneity drives museums to create exhibits and programs that work for all kinds of people.

> "*Museum visitors come in all shapes and sizes, with an infinite variety of interests and capabilities. Schoolchildren and scholars, bank presidents and butchers, baby sitters and pipe fitters all attend our museums. They come in groups and they come alone. They come to fill time and to kill time. Some visitors eagerly attend museums, while others are dragged along in varying degrees of willingness by a friend, spouse, parent, or teachers. Once they arrive, they all interact with the exhibitions in different ways.*"

—Kathleen McLean [37]

Museum exhibits are designed for interactivity

Most science museums position themselves as places for "hands-on, minds-on" learning. Active learning techniques can excite an audience about a topic and encourage deeper conceptual understanding. Audiences are more receptive and retain more knowledge when they're actively engaged with the exhibit or presenter as opposed to just passively listening.[38]

In exhibits, engagement is often achieved through some form of interactive, hands-on display. In the strict sense, "hands-on" simply means that the visitor is able and encouraged to touch the exhibit. This can be as simple as pushing a button to activate motion, light or sound. However, just because something is "hands-on" doesn't necessary mean that it's "interactive." Interactive means the visitor is involved in some sort of exchange. "Interactive exhibits are those in which the visitor can conduct activities, gather evidence, select options, form conclusions, test skills, provide input, and actually alter a situation based on input."[39] This is desirable because "[p]articipation and interaction personalize the exhibition environment for visitors."[40] For this reason, interactivity is considered the gold standard of visitor engagement.

Museums provide forums for discussion

However, museums are not just about exhibits. They provide the public with a variety of ways to interact with and engage in science, and a range of flexible timeframes in which to learn. "In seeking alternative ways to be more responsive to the public's need to understand research, some museums have expanded their public programs to include workshops, consensus conferences, and other inquiry-based learning activities."[41] The products and programs produced by science museums cover a vast array of formats, and target the general public (both young and old) as well as education professionals.

Examples of Museum Exhibits, Products, and Programs

Exhibits/exhibitions	Classes
Forums	Movies/3-D/Large-format
Science clubs	Docent training
Demonstrations	Videos
Newsletters	Resource/Library areas
Curriculum connections	Take home activities
Lectures	Science kits
Public websites	Swap shops
Teacher training	Play areas

Particularly important to museum experiences are opportunities for visitors to interact with others. As museum professional Kathleen McLean points out, "The presence of people—whether they are visitors or staff—transforms a constructed exhibition setting into a dynamic public space."[42] Visitors learn from each other and, in fact, research shows that visitors gain the most from museum experiences that promote interaction with other individuals.[43] A trained staff member, volunteer or docent can positively influence visitors' experience and learning by modeling and assisting with the processes of "making observations, gathering details, making inferences, creating hypotheses, suggesting applications, and being analytical in their thinking."[44] In addition to the docents, explainers and employed staff who may have training and expertise in informal science education, museums need scientists and engineers to interact directly with the public, giving demonstrations and leading activities, and participating in forums for discussion.

Museums also sponsor forums for public discussion of scientific issues. This format has been used in Europe (e.g. Café Scientifique) "to move from a 'monologue' model of communication, with scientists lecturing the public on what it should know, to a 'dialogue' model, in which scientists meet the public in forums that are evenhanded, giving nonspecialists much more time to air their concerns and share them with the 'experts.'[45] This change has been motivated by what is widely seen as the failure of the comparatively authoritarian monologue style of communication to win public trust during the two most contentious debates of the 1990s: genetically modified foods and mad cow disease."[46]

> ***"Dialogue and deliberation are dynamic processes which can be empathy-enhancing, relationship-changing, problem-solving, action-planning, organization-developing, community-building, conflict-resolving, skill developing, prejudice reducing, consciousness-raising, and more!"***
>
> —John Durant[47]

Although not always at the forefront of researchers' minds, there are often significant implications to the research that they do: economic, environmental, ethical, social, political and legal. The serious nature and widespread impact of these issues require public dialogue and deliberation about the future directions of research, as well as the ultimate use of the outcomes. Forums provide ways for researchers and citizens to learn from each other about the research process, the technical specifics of the research, and the options for society.[48]

In all of these ways—exhibits, programs, written materials, web sites, forums, etc.—museums invite people to learn more about science and have fun while they do it. With the help of the scientific community, the experiences that museums offer could be richer, more varied, and more extensive. In the following sections, we describe some ways for researchers to play a role in informal science education.

Researchers in Museums

Museums offer researchers a tremendous opportunity to present the science or engineering that we do to a wider audience. Taking advantage of this opportunity requires real partnerships between the museum, its staff, and the scientists and engineers with the content expertise. As is well known, "[e]xpertise in a particular domain does not guarantee that one is good at helping others learn it. In fact, expertise can sometimes hurt teaching because many experts forget what is easy and what is difficult for students."[49] The ideal situation is for scientists to be partnered with "enthusiastic novices" who bring their own professional expertise in areas such as exhibit design and informal education.

Connecting with a museum can be a large or small endeavor, depending on your interests. For many researchers, time constraints permit them to engage with public audiences only a few times a year. But even a minimal level of involvement is valuable to science museums that often have a range of needs that researchers can fulfill. This section focuses on how the individual researcher can be involved in museums as content experts, interpreters, and facilitators. The next chapter discusses more complex collaborations, as when university researchers or centers decide to work with local museums on long-term projects.

Roles for researchers in museums

A researcher can facilitate informal science education in several different ways. One obvious role is that of the content expert. Some museums have scientists on staff, but when they do not, access to scientific expertise is crucial. Content experts provide their expertise on science topics to museum staff developing exhibits and programs.

Researchers can also interact directly with the public. Visitors are often interested in talking with scientists and hearing about their research and their career paths. Museums need researchers, scientists and engineers who can successfully engage the public in discussions about science, applications of research, and their societal implications.

Finally, researchers can act as liaisons between the museum and the broader scientific community. Connections that may start as a one-time volunteer opportunity can grow into long-term relationships. You may decide to establish an internship program that allows your graduate students to get some experience working in museums, or to organize an annual "Nano Saturday" at your museum. By becoming even more involved, you may connect your university research center with a local museum in an ongoing partnership, to connect people within both institutions to each other and with the public. This latter form of collaboration is discussed in the next chapter; here we focus on roles for individual scientists.

Roles that Researchers Can Play in Museums

Content Expert: **brainstorm ideas and messages for exhibit and programs; provide information; check the accuracy of products; assist with visualization; provide samples, images, and videos; serve on boards and external advisory committees; provide mentoring for youth programs; judge science competitions; coauthor or collaborate on grant proposals.**

Presenter (on area of expertise, or using materials provided by the museum): **provide lectures in an engaging format; give demonstrations on the museum floor; speak at or provide background for discussion forums; do interviews or lab tours for media pieces.**

Liaison: **recruit students and colleagues for volunteer opportunities; network with peers and colleagues to identify particular content expertise; make contacts with other ongoing outreach efforts; support museum's public relations, development or marketing staff.**

Finding a museum to work with

There are over 500 museums, science centers, zoos, aquariums, nature centers and other similar institutions in the US.[50] Many of these cover topics connected to nanoscale science and engineering. You can connect with a museum by:

- Visiting the Association of Science-Technology Centers' website and using their "Find a Science Center" search tool at http://www.astc.org/sciencecenters/find_scicenter.htm to locate a museum near you.
- Locating a museum through the NISE Network. The NISE Network website is located at www.nisenet.org.
- Connecting with the NISE Network through the Materials Research Society website at www.mrs.org/nise_survey.

When you contact museums, you will usually be connected with the museum's Volunteer Coordinator (if the museum is medium or large), or directly with Exhibits or Program staff (if the museum does not have specialized staff for coordinating volunteers). You will be asked about your science and education background, the kind of help you would like to provide, and the amount of time you have to contribute. With that information, the museum will determine where your skills could be best used. Because some museums do not have specialized staff to work with volunteers, it can sometimes take some time to make connections with just the right people. If you are having trouble with this, working through the MRS or the NISE Network can help you connect more directly to the appropriate museum staff.

Tips for researchers when presenting in museums

Part II of this booklet provides a more detailed picture of learning in museums, but it all comes down to *engaging* the public in science. One key, as a presenter, will be your ability to interact with visitors—to draw them in and get them excited about your research or topic. For instance, taking a poll allows you to assess the visitors' prior knowledge on a topic. This tells you what basic concepts need to be reinforced or re-taught. Prompting members of the audience to discuss their prior experiences can also help. Done correctly and in a non-threatening manner, engaging the audience in dialogue increases their confidence to explore science and lets them know their thoughts and opinions are valuable.[51] Becoming familiar with the audience also allows you to gear the tone and level of the presentation to the needs and abilities of the audience. Keep checking in with your audience to gauge their reactions, and make changes if you need to.

Active learning techniques that you might consider include:

- Using inquiry activities
- Creating a hands-on opportunity to interact with real phenomena, models, equipment, etc.
- Doing a small experiment
- Taking a poll
- Generating a discussion
- Inserting a personal aspect to the stories you tell

The museum knows its audience best, and they may provide you with a briefing or training prior to your presentation at the museum. It's important to respect whatever parameters they set. For example, if they suggest a five-minute presentation, keep it to five minutes.

People interact with the museum environment in a nonlinear way, and devote limited time to any one activity. Therefore, the type and depth of information you can present differs from what might work in a formal classroom setting. "Visitors devote most of their time to looking, touching, smelling, and listening, not to reading."[52] Carefully choose messages and learning goals appropriate for the audience and the time allotted. Do not compromise the accuracy of the science, but realize that it must be presented in condensed form. Ideally, repeat the main message several times and explain it in several different ways. "Don't try to force people to swallow more information than they can comfortably digest. People don't have to learn everything there is to know about a subject at that very moment. Try instead to stimulate people and provide guidance for those who want to pursue the topic further."[53]

Practical Strategies for Presenting in Informal Settings

Review successful examples of similar products

Know the intended audience

Define a limited set of learning goals (2-3 at most)

Be aware of the length and attention span of the audience

Use multiple modalities to address a range of learning styles

Don't assume prior knowledge

Define terms and avoid jargon

Avoid graphs, especially multidimensional graphs and log scales

Explain what you see in scientific images and diagrams

Use metaphors and analogies that explain and enlighten

Include personal aspects of the story, not just the scientific facts

Repeat the message, explaining it in multiple ways, but be concise

Make it concrete

Provide clear directions for an activity

Encourage visitor conversation

Test for misconceptions

Evaluate at every stage

Define terms, even if they seem obvious. Visitors have a remarkable capacity for misinterpreting some seemingly basic vocabulary.[54] For instance, one difficult term is "nanoscale." Many people associate this with a bathroom scale and have trouble understanding the prefix "nano."

Be prepared for many possible audience reactions and behavior. For example, even the most exciting speaker or the most engaging interactive may have people leaving in the middle, for reasons that have nothing to do with the style or content of the presentation. Perhaps someone in the family has to go to the bathroom, or maybe the tour bus is leaving. A big part of presenting science to the public is to relax one's expectations about successfully imparting the whole story, and just enjoy the opportunity to talk with new people about your work and interests.

Tips for Speaking with Young Audiences

The North Carolina Museum of Life and Science[55] provides some tips for scientists and engineers speaking with young audiences:

Make eye contact, smile, be comfortable

Share yourself as a real person

Involve the students in doing hands-on activities

Wait to distribute handouts or materials until it is time to use them

Involve students in the process of science

Model good safety practices

Stimulate thinking by asking questions

Ask for volunteers, but require that they raise their hands to participate

Call on many different members of the group, but wait several seconds before choosing someone to call on

Use language students will understand

Make what you are talking about real to students by connecting to their everyday lives

Prepare students for unexpected load noises or bright lights

Leave more than a memory behind you by giving students experiments they can do on their own

In short, when presenting in museums: avoid overload, create turn-ons, tell one story at a time, avoid unnecessary detail, communicate with visuals, be careful with jargon, connect with people, and with every small taste of science provide a big bite of fun. If you want more background about learning in museums, skip to Part II of this booklet.

Collaborations: Museums and Researchers

After developing an initial connection with a museum—perhaps speaking at a forum or helping out with a weekend program—your involvement may grow into something larger. You may begin recruiting your colleagues to volunteer at the museum, or establish an ongoing internship program for your students to get experience working in the museum. As these relationships evolve and strengthen, you may begin writing these activities into grant proposals, helping to ensure that there is an ongoing source of revenue to fund outreach and providing the host museum with the funding it needs to offer those programs.[56]

Growing relationships: From one-time-interactions to joint grant proposals

> ***"The different cultures and pedagogical philosophies of universities and science [museums] provide a rich environment for sharing expertise when joined in partnership[.]"***

—Payne, deProphetis, Zenner, Derenne, Ellis, and Crone, museum and university collaborators in an Internships in Public Science Education Program[57]

Ongoing collaborations require resources, so collaborations often coalesce around the preparation of grant proposals for new projects. If you wish to partner with a museum on a grant proposal, start working with them early in the planning stages so that adequate attention can be paid to all facets of the process, including:

- Conceptualizing the project and outlining the museum role
- Selecting a museum partner
- Defining the partnership and the specific role for the museum
- Developing a funding structure and preparing a budget
- Writing and reviewing the proposal

Researchers often do not fully appreciate the constraints and needs of their potential museum partners. Keep in mind that:

- Informal science education costs real money and must be included in the budget at the appropriate level. Developing an interactive 5,000 square foot exhibit can cost $1.5–2 million or more, including the covering of overhead costs, although costs vary widely based on the nature of the visitor experiences being considered. There are many less-expensive outreach products and programs, however, to fit almost any budget.
- Synergistic activities like developing an exhibit or program require lots of time. A full-size exhibit with accompanying programs usually takes 2-3 years from project conceptualization to opening. Even developing a small interactive component or a program can take several months.
- Museums need your commitment to follow through with collaboration after funding is granted. Because of the iterative nature of the exhibit or program prototyping process, the specific nature of an exhibit or program cannot just be determined at the outset and then implemented in a linear process. Instead, it takes an ongoing collaborative relationship and ongoing decision-making to produce an exhibit or program that is truly engaging and educational for visitors.

All of these caveats point to the importance of allowing enough time to define collaborations well. Museums are institutions with bureaucracies, like universities or national laboratories, so decisions to commit funds and/or staffing take time. In addition, museums are understaffed, and their employees overworked, which expands the amount of time decisions can take. This means that you can't call up the museum the day before your grant proposal is due and ask them to be your "outreach partner." It takes careful planning, and plenty of time. As museum consultant Kathryn Hill remarked, "at the speed museums move, glaciers just *whiz* by!"

Effective collaborations

Collaborations can be an effective way to bring together a wide range of talents and resources and to make a project more economically feasible. In some cases, collaborations are encouraged or even required by a funding agency, as they can make programs higher quality and accessible to a broader population. US funding agencies like NSF and NIH usually expect grantees to work through existing community networks in order to reach the public, and collaborations are a great way to tap into these networks.[58]

> ***"Collaboration is a mutually beneficial and well-defined relationship entered into by two or more organizations to achieve common goals. The relationship includes a commitment to mutual relationships and goals; a jointly developed structure and shared responsibility; mutual authority and accountability for success; and sharing of resources and rewards.[.]"***

—Mattessich, Murray-Close, and Monsey in Collaboration: *What Makes It Work*[59]

Extensive research on collaborations formed by nonprofit organizations, government agencies, and other organizations has shown that a range of factors influence the outcome of a project.[60] For the greatest likelihood of success, you should approach the collaboration by:

- Involving a cross-section of members, representing all the interests of the collaborating partners.
- Learning about the other team members' jobs and their background and expertise.
- Developing a collegial relationship involving mutual respect, understanding, and trust.
- Defining clear roles and guidelines for making decisions.
- Promoting open and frequent communication.
- Being willing to compromise and remain open-minded.
- Defining attainable goals and objectives.
- Encouraging a shared vision among the partners.
- Ensuring that the project has sufficient funds, staff, materials and time.

Nanoscale science research centers have established several very productive collaborations with science museums in the past decade. The following table provides a few examples of what has been accomplished. These examples could serve as models for future collaborations.

Museum/Research Center Collaborations

Museum	Research Institution	Collaboration
Discovery World Museum, Milwaukee, WI	University of Wisconsin–Madison Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces	Created hands-on activities and the “Nanoworld Discovery Center” exhibit through an Internships in Public Science Education Program. www.mrsec.wisc.edu/nano
Lawrence Hall of Science, Berkeley, CA	Center of Integrated Nanomechanical Systems, UC Berkeley	Created the “Nanozone” permanent exhibit along with media and website. www.nanozone.org
Museum of Science, Boston, MA Harvard-MIT-UCSB-MOS Nanoscale Science and Engineering Center (NSEC)	Northeastern-UMass/Lowell-UNH NSEC Center for High-rate Nanomanufacturing, with the Massachusetts Technology Collaborative	Producing daily live presentations, guest researcher presentations, cable newscasts, podcasts, web media, and workshops. Creating educational multimedia products and organizing an annual Nanotech Symposium for Educators. www.mos.org/nano
Museum of Science & Industry, Chicago, IL	Northwestern University Nanoscale Science and Engineering Center (NSEC)	Collaborating on exhibit development.
New York Hall of Science, Queens, NY	Columbia University Materials Research Science and Engineering Center (MRSEC)	Collaborated on the creation of five discovery carts on materials science to support demonstrations.
Ontario Science Center, Toronto, Ontario, Canada	Materials Research Society	Created “Strange Matter” traveling exhibit and website. www.strangematterexhibit.com
Sciencenter, Main Street Science, & Painted Universe, Ithaca, NY	Cornell Nanobiotechnology Center	Collaborated on two traveling exhibits: “It’s a NanoWorld” www.itsananoworld.org and “Too Small Too See” www.itsananoworld.org.

Conclusion

Museums and researchers need each other. Museums often find themselves shorthanded when it comes to content expertise, presenters who are practicing scientists or engineers, and connections to larger networks within the scientific community. At the same time, researchers benefit from partnering with museums for a host of reasons—from ready access to public audiences who want to learn more about science, to the organizational infrastructure needed to address outreach goals for a federal grant.

It is challenging to develop new ways of inspiring wonder, creating a spectacle and making science and engineering concepts memorable for a broad audience. Whether one-time opportunities or large, ongoing programs, partnerships between museums and researchers have the capacity to break new ground and invent creative new strategies for communicating complex ideas to the general public.

Nanoscale science and technology are perfect topics for museum/researcher partnerships. The applications of nanoscale science are likely to have significant economic, social, and political implications, making them an important piece of science for the public to understand and explore. Museums will need help presenting these breakthroughs to the public, and you, as a nanoscale scientist or engineer, can help.

The NISE Network and the Materials Research Society are partnering to help create connections among museums and researchers to bring nanoscale science and engineering to the public. We hope that this booklet has given you some ideas about how you could get involved, and provided the motivation that will actually move you to contact your local museum, NISE Net www.nisenet.org/resource, or MRS www.mrs.org/nise_survey. We look forward to making the connections that will help you share your scientific expertise and your excitement about science with people in your community.

Part II: A Brief Introduction to Science Museums

The museum field is its own professional discipline, with advanced degree programs, professional associations, academic and professional journals, and various certification programs. While it is not possible to condense the entire discipline to just a few pages, this part outlines some basic information that will be useful if you decide to pursue a relationship with your local museum. We begin with some background about what museum professionals have found out about how people learn in museums, and then give a quick glimpse of the exhibit and program development process.

Some Basics about Learning in Museums

Informal Science Learning is Self-Motivated and Social

Although there's some overlap in the methods and approaches used by informal science education and the formal settings of schools and classrooms, the two are often defined in contrast to each other. One of the most significant differences between most informal and formal environments is the aspect of free choice. People participate in informal science education opportunities because they want to. In contrast, formal settings are often mandatory. Students are there to learn; the teacher controls the content, space, and style of presentation; and information is "pushed" from the teacher to the student. Informal settings are more of a "pull" model, where learning is "voluntary, unencumbered by curriculum or standards, and open ended."[62]

In museums, people show up for their own reasons; and they attend to activities at their own pace, order and depth. Motivation is critical in this setting because it affects how much time people are willing to devote to engaging with an exhibit or program.[62]

> ***"Unless we are forced to learn, say, as students in a classroom, most of what we learn in our lives we learn not because we have to but because we want to, because events in our life intrinsically motivate us to find out more. We learn what we want, where we want, when we want, and with whom we want; in short, most human learning is free-choice learning—lifelong learning that is intrinsically motivated, nonassessed, and largely under the choice and control of the learner. And while learning is a continuous process with knowledge derived from many different sources and in many different ways—there are a few important generalizations that apply to all learning situations—what people learn depends on what they already know and understand, whom they are with when they learn, where they are when they learn, and perhaps most important, why they are motivated to learn in the first place..[.]"***
>
> —Martin Storksdieck and John Falk, Institute for Learning Innovation[63]

Another critical characteristic of learning in museums is that it is social, not individual. People usually attend museums in groups, and their experience of any exhibit or program is a co-production of the entire group. This opens up opportunities for rich engagement because family members, for example, can tie aspects of an exhibit back to the family's culture and experiences. This makes it possible to connect to the exhibit or program in ways that are truly meaningful for the visitors, making it more likely that the science in the exhibit will be understood and remembered later.

These two aspects of museum learning—that it is intrinsically motivated and that it is social—are much of what makes museums such lively places for learning. They are often busy and loud, filled with many activities and opportunities for engagement (and distraction). Visitors usually bounce from exhibit to exhibit in a nonlinear interaction format, as group members try to satisfy everyone's curiosity while staying connected. This usually means a short time of engagement at any particular exhibit. Beverly Serrell, a museum evaluator, provides some enlightening statistics in a summary of research on the allocation of visitors' time within 110 different museum exhibitions across the US. The statistics showed that for most exhibitions (a thematic set of individual exhibit components), the average total visit time was less than 20 minutes. Most visitors spend relatively little time while a few visitors stay longer, and visitors typically stopped at about one-third of the exhibit components.[64]

Museum Strategies for Effective Learning

Every day, our museum colleagues face a significant challenge: "[t]o be more aware of the people who actually attend our exhibitions, and to experience our museums from a visitor's point of view."[65] For researchers engaged in informal science education, the challenges are similar: to be more aware of the people we are presenting our science to, and to think about that science from the audience's point of view. In informal science education, learners get to choose whether on not they want to learn about a topic. Thus "[s]cience and technology communication programs should be directed to addressing an audience's needs and interests, not by the research enterprise's ideas about what the public 'should know.'"[66]

Different people learn in different ways, and a museum must be sensitive to all of them to reach a general audience. Kathleen McLean points out, "Some people like to read and some don't. Some people interact with others, and some prefer a solitary experience. Some people are primarily visually oriented, others are oriented verbally or physically. A limited approach will appeal to only a limited segment of the audience."[67] In the formal classroom setting, the preferred learning style may be skewed by self-selection, but museum visitors cover the full range of learning styles. Thus, in developing exhibits and programs for informal settings, one must incorporate multiple types of interaction.

Museum professionals have done extensive research on the most effective ways to engage visitors in informal education settings. Deborah Perry of Selinda Research identified six key components to intrinsic motivation in a museum experience:[68]

- *Play:* an engagement that seems fun; enjoyment. The benefits of play are "fun, cognitive and language development, imagination and creativity, and social competence."[69]
- *Curiosity:* an interest due to intrigue or surprise.
- *Challenge:* a goal to work towards. "Challenges, however, must be at the proper level of difficulty in order to be and to remain motivating. Tasks that are too easy become boring; tasks that are too difficult cause frustration."[70]
- *Confidence:* a feeling of competence during the experience.
- *Control:* a sense of self-determination by making choices.
- *Communication:* a meaningful social interaction. "Social opportunities also affect motivation. Feeling that one is contributing to others appears to be especially motivating."[71] Peer teaching can help make these motivating social connections.

Incorporating these components promotes effective learning in an informal setting. As this research points out, fun and enjoyment are not to be discounted or seen as detrimental. On the contrary, enjoyment promotes engagement and learning. In an environment where visitors have complete freedom to choose the activities they pay attention to, an exhibit or program that is not engaging will definitely generate little learning; visitors will just move on to something more compelling.

This introduction to learning in museums provides some background for researchers who are interested in working in museums to bring science and engineering concepts to the public. As you get more connected to the public, you will begin to develop your own sense of your audience and your own style of interaction with them. The bottom line always seems to involve showing yourself and communicating your excitement about your work.

Recommendations for Maximizing Intrinsically Motivated Learning[72]

Provide connections between the museum experience and people's lives

Ensure that learners have the opportunity to personalize the experience

Provide a variety of entry points

Create layers of complexity and depth

Scale challenges and rewards to the learner's abilities

Reinforce and reshape prior understandings, attitudes and behaviors

Build emotion into the experience through humor, surprise, suspense and human interactions

Make experiences enjoyable and entertaining

Provide choices and put the learner in control of their own learning

Exhibit & Program Development Teams

In most science museums, new exhibits and programs are developed by teams. A range of specialists with complementary skill sets work together to create the product, including:

- *A project leader:* responsible for managing the project and keeping everyone working toward the common goals.
- *Exhibit developers:* conceptualize the content and story line of the visitor experiences within the exhibit or program.
- *Exhibit designers:* conceptualize the look-and-feel of the visitor experiences within the exhibit or program.
- *Graphic designers:* oversee the appearance and integration of the graphics within the exhibit or program.
- *Label writers:* write the copy on panels, posters and other written materials.
- *Prototypers:* experiment with the best ways to convey content in specific physical experiences and test the technical parameters of the interactives.
- *Media, computer, and web designers:* create content and experiences for media- and computer-based displays and interactives.

- *Content experts:* provide scientific background and check scientific accuracy of exhibits or programs.
- *Fabricators:* build the prototypes and final exhibits or program props.
- *Educators/interpreters:* present the programs to visitors on the floor of the museum.
- *Evaluators and visitor studies experts:* lead evaluation and provide consultation on visitor interaction and behavior.
- *Exhibit maintenance specialists:* consult on the stability and robustness of exhibit designs, and keep the exhibits working once they are on the floor.
- *Promotion and marketing experts:* plan and implement the marketing of exhibits or programs.

Large museums may have more than one person in some of these roles; smaller museums will have a few people wearing many hats. Sometimes museums contract out parts of the conceptualization, design, and production process to other museums or to commercial firms that have capacity in all of these areas.

These team members may be involved to a greater or lesser extent at various stages of the project, but this range of expertise is usually required at some point during development and production. Although the interactions among these people may be complex, it is commonly believed that team-generated exhibits provide:[74]

- Broader perspectives, given the wider range of disciplines represented.
- Stronger integration of design, programming, communication and other skills.
- Products oriented more strongly toward visitors and diverse audiences.
- Better ties to other museum functions such as educational programming, marketing, fundraising, operations, and retailing.

The Prototyping Process: Developing Visitor-Centered Exhibits and Programs

To be truly visitor-centered, the development process for museum exhibits and programs must be iterative, with cycles of prototyping and evaluation. Museums use evaluation to collect information to understand the visitor experience. Ideally, this begins with some *front-end* assessment before planning and design work even begins. Visitors are not blank slates; they often come knowing something about the subject. Prior knowledge, preconceptions, attitudes, beliefs and interests must be identified in order to understand what the main messages of the exhibit or program should be, and how to create hooks and connections between the visitors and the topic.

Armed with this knowledge of their audience, developers begin developing and refining ideas for exhibits and programs. These are continually tested with visitors in a process of *formative evaluation*. For an exhibit component, formative evaluation—watching visitors use a working prototype and getting their reactions—is a way to test how visitors will use and understand the prototype, what meaning they get out of it, and how much they enjoy the experience. It's also a way to test physical and mechanical aspects of the exhibit, as well as ergonomic factors. Later, once the basics of the experience are worked out, it can help fine-tune text, ensuring that directions are clear and the language level is appropriate for the audience. Rapid prototyping—modifying the exhibit "on the fly" in response to visitor feedback—lets the developer try out alternatives quickly. Through iterative formative evaluation, exhibit components evolve from first ideas to proven interactive experiences. Then the final versions are constructed and the exhibition is opened to the public.

Even after a rigorous process of formative evaluation, the final context for the entire exhibition can have a significant impact on visitor experience, and developers continue to find things they'd like to improve about the components or the exhibition as a whole. Museums often conduct *remedial evaluation* at this stage. It can reveal issues that call for further refinement, and allow designers to test hypotheses about visitor use and impact. After these final changes, museums may conduct *summative evaluation* to assess the overall impact and effectiveness of the exhibition. Funding agencies usually require summative evaluations, which can provide useful guidance for future projects.

Evaluations may be conducted through both quantitative and qualitative methods. Techniques include: interviews with visitors, focus groups, written surveys, Web statistics, monitoring usage (timing and tracking), observation, responses to concept questions, public forum feedback, and systematic analysis of anecdotal information.

Conducting visitor observation and evaluation can be an eye-opening experience. It's worth spending a few hours with an existing exhibit or a prototype on the floor of a museum. It will quickly become apparent that visitors interact with the exhibit in many varied and surprising ways—often quite differently from what you may have expected. This can give you much needed insight into the challenges and opportunities of informal science education.

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