Year 5 Summative Evaluation of Exhibits and Programs

Summative Evaluation

Marjorie Bequette, Gina Svarovsky, Kirsten Ellenbogen

April 10, 2011

Acknowledgements

Thanks to the members of the data collection, analysis, and reporting team that has been part of the NISE Network evaluation efforts for the SMM Department of Evaluation and Research in Learning: Marjorie Bequette, Daniel Bernstein, Sarah Cohn, Kirsten Ellenbogen, Amy Grack Nelson, Denise Huynh, Zdanna King, Kathleen Miller, Al Onkka, Gayra Ostgaard, Gina Svarovsky, and Scott Van Cleave.

Thanks to Beth Robelia, who managed data collection and initial analysis during spring and summer of 2010.

Thanks to those at SMM who arranged for nano programming. SMM Program Manager Shari Hartshorn coordinated volunteers to present the short nanoscience programs evaluated for this report. Volunteers Dan Anderson, Natasha Bursch, Merri Moody, Carolyn Ocampo, Annette Phillips, Liz Schlesky, Richard Tong, Kevin Veenstra, and Angela Zhang presented the short programs at SMM. Stephanie Long, Director of SMM Public Programs, coordinated the presentation of the longer programs. These were presented by Michael Ritchie, Jen Scott, Damian Johnson, Amanda Whisner, Rebecca Wall, and Melanie Wehrmacher.

Thanks to all who helped at locations beyond Minnesota:
In Boston, at the Museum of Science Boston: Christine Reich, Juli Goss, Anna Lindgren-Streicher, Sarah Cotterill, and Iyar Mazar.

In Portland, at the Oregon Museum of Science and Industry: Marcie Benne and Scott Pattison.

In Little Rock, at the Arkansas Museum of Discovery: Diane LaFollette.

In Pine Bluff, at the Arts & Science Center for Southeast Arkansas: Janelle Powell, Howard DaLee Spencer, and Brenda Hengel.

Additional thanks to the many and various participants, evaluators, and developers of the NISE Net programs, exhibits, forums, and other activities.

In addition we would like to thank all the museum visitors who took time to complete surveys and answer interviewers questions about the exhibits and programs.

This report was based on work supported by the National Science Foundation under Grant No. ESI-0532536. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the author(s) and do not necessarily reflect the views of the Foundation.

Marjorie Bequette
Science Museum of Minnesota
120 West Kellogg Boulevard
St. Paul, MN 55102
mbequette[at]smm[dot]org
(651) 221-4778

Table of Contents

Executive Summary

The NSF-funded Nanoscale Informal Science Education (NISE) Network produced exhibits and programs designed to develop awareness, engagement, and understanding of nanoscale science, engineering, and technology in the museum-going public. As part of the overall summative evaluation of the first five years of this grant, the Exhibits and Programs Study examines the measurable impacts of these public products on museum visitors. These exhibits and programs were developed during the first four years of the project as the NISE Network itself was growing and developing; the products show the strength of the network overall, and of its development of new ways to engage the public successfully in nano. Many of the gaps or missed opportunities identified in this report are already being addressed in the current work in Year 6 of this project; opportunities for further exploration are being considered by the Research team.

The measurable impacts were separated into four main areas for the purpose of this study: enjoyment and interest; broader awareness of nanoscale science, engineering, and technology (often referred to as “nano” in this report); more specific content knowledge or understanding of nano; and perceived relevance of nano. These areas correspond to particular categories defined in the recent NRC-authored book, “Learning Science in Informal Environments” (2009).

This evaluation was focused on how visitors interact with the exhibits or programs in as realistic settings as possible. This required studying the exhibition in locations where it is currently on display (permanently in Boston, and in Portland Oregon, and traveling through a museum network in Arkansas), as a whole (not as individual pieces), and using regular, not cued, visitors. It also meant looking at programs as presented by ‘typical’ presenters (trained volunteers or paid staff members, none of whom are experts in nano or were the developers of the program). These more realistic assessments required a more complex study, but one that more accurately reflects what a typical visitor might learn, wonder about, and connect to when seeing NISE Network exhibits or programs at a museum.

Whenever possible, the evaluation included questions that reached beyond the exhibition to explore how people might use or think about nano in their lives beyond the walls of the museum. These more challenging sets of goals allow readers to see future possibilities of nano exhibits and programs; in many cases these were beyond the original goals of the project and should be seen as exploratory work, not as a report on the success of the Network.

Key findings include:

Exhibits and programs effectively engage visitors with nano content

Through the course of the project, the network has been successful at increasing the enjoyment and interest that visitors find in the exhibits and programs, with later versions outdoing earlier ones. Though visitors enter with low expectations for the nano topic, they rate the exhibits and programs as reasonably enjoyable and interesting – indicating that the Network has risen to meet a key challenge for

this topic. Adult descriptions of engagement center on the nano subject matter itself; children are more likely to discuss interactive exhibit elements.

Visitors who see exhibits and programs show higher levels of nanoawareness

Museum visitors rate their awareness of nano somewhat higher than the general public rates its awareness of nano. Visitors who see the nano exhibits and programs express higher confidence in their general nano knowledge than those who don't see the exhibits or programs; regression analysis suggests this difference is due to their time at the exhibition or program.

Many visitors associate "nano" with small, even before seeing nano in the museum

In all adults groups that we sampled (at all sites, including those who had seen the Network products and those had not), at least 60% of visitors answered an open-ended prompt to explain what nanoscale science is about with a response that included the idea of "small." This number was higher than anticipated, and only increased slightly among those who saw exhibits or programs, suggesting that (perhaps thanks to popular consumer products with "nano" in their title) the general public has developed a new definition of nano as meaning small, a definition that may or may not include scientific accuracy or convey associations having to do with nanoscale science, engineering, and technology.

Exhibits and programs offer ways for visitors to deepen their nano knowledge

We investigated visitors' understanding of nano in more depth by analyzing the definitions of nano they gave us, and by observing how they operationalized those definitions when sorting everyday objects into nano and non-nano groups. Visitors who saw the exhibition did not offer definitions of nano that differed in significant ways (they generally continued to use the "small" definition, and did not change in the level of accuracy present), but they did show more sophisticated understanding of nano as they sorted everyday objects. Visitors who saw the programs gave more accurate definitions of nano, with higher levels of scientific accuracy and a lower rate of alternative conceptions than their comparison group. (Program visitors did not complete interviews with an object-sorting activity and so their operational definitions could not be analyzed.)

Visitors find relevance in the exhibits and programs, and may find more ways to connect their everyday lives to nano when they encounter it in the future

Visitors who have not seen exhibits or programs perceive nano has having less of a connection to their everyday lives than those who have seen Network products.

When the NISE Network began, appropriate approaches for engaging the general public in this emerging area of science and technology were not clear, and success was not a given. After five years, it's clear that the Network has found successful approaches to initially engage the public on the museum floor, communicate important content and help visitors connect nano with their everyday lives, which may well allow those visitors to have more meaningful and sustained encounters with nano when they come across it in the future, in a world where nano is only increasing in ubiquity. As the Network continues to grow, this work (and the process used to produce it) provides a firm footing for further development of public products.

Background

Developing the Evaluation

This evaluation is designed to answer the broad question:

What are the measureable impacts of NISE Net-produced exhibit and program deliverables on a public audience?

This evaluation offers a snapshot response taken in Year 5 but reflects the entirety of all five years of the grant. Not all deliverables produced during the five years of the grant were analyzed for this evaluation; however, the team made specific and intentional choices regarding what contexts and educational products to study while developing the evaluation in order to account for the work done over the project as a whole.

For exhibits, all exhibit elements currently on view in permanent exhibitions (in Boston, MA and Portland, OR) or in a traveling exhibition (in Arkansas) were included. For programs, the NISE Net team (evaluators and developers) selected programs for analysis in this evaluation that were representative of the work of the project over Years 1-5 of the grant, could be presented by typical museum staff, and considered representative of what is often chosen by museums throughout the network. Whenever possible, the focus of this evaluation was on real world implementation. For example, maintaining this emphasis meant the exhibition was analyzed as a whole, not as individual elements; and program presenters included in the study are typical of staff who would normally present these kinds of programs.

Measured impacts are grouped into four main areas (enjoyment and interest, awareness of nano topics, understanding of nano content, and relevance), as used in the Year 4 evaluation; new in Year 5 is a richer qualitative, in-depth approach to investigating interest, attitude, and understanding. Each of these constructs is explained in more detail later in this report; internal definitions of awareness and content are the ones that changed in more significant ways through the project. Over the five years of the project, main messages were established and refined, even as the exhibits and programs were formatively evaluated and redesigned. For the purpose of this evaluation, the two areas of Awareness and Content were evaluated in some cases against big ideas that were determined in Year 5 by the NISE Net team, who agreed that these concepts comprised a legitimate framework to use in evaluating work done before those big ideas were commonly used in the network. The evaluation also uses criteria established as important early in the project, as well as using open-ended outcomes where appropriate.

This evaluation builds on and extends the work of the Year 4 evaluation of a smaller number of programs. The lessons learned from that evaluation – not only the results found, but also the methods used and their effectiveness – informed this evaluation.

Exhibit Development

Nano exhibits were developed by the NISE Net over the first four years of the grant. All elements were prototyped and formatively evaluated according to standard NISE Net protocol.

Each exhibit component was developed to be able to operate independently, as a "standalone," if necessary, or to be grouped with others into a small cluster around a theme (such as nanomedicine). Currently, the group of exhibits on display in Boston and Portland, and traveling through a network of museums in Arkansas, consists of nearly identical elements across all sites. In addition, visitors experience these exhibits as being part of a grouped set, and so they were analyzed as an exhibition and not as individual pieces or smaller clusters.

The versions in Boston and in Portland are the first version developed by the network. Small changes, including graphical changes, were made before producing the traveling exhibition in Arkansas.

More details about the individual elements, including a short description of each exhibit and goals of each exhibit are included in Appendix A.

Program Development

Ten programs from the NISE Net catalog were selected for evaluation, representing the range of programs developed overall; all ten programs were deemed reasonably successful and also likely to be implemented by institutions in the future by NISE Net partners. These programs were developed by several different NISE Net institutions. All had been formatively evaluated and revised according to standard NISE Net protocol. The institution that developed each program is listed in Appendix B, along with learning objectives and target audience.

Previous NISE Net evaluations have looked at programs as presented by their creators in order to evaluate the program as it was intended. For this evaluation, programs were presented by individuals other than the original developer, done in the way they are most likely to be implemented – by trained volunteers or floor staff who are knowledgeable about science but are not specialists in nano.

Four types of programs were evaluated as part of this study: museum theatre, stage presentations, facilitated activities, and cart demonstrations. For the purpose of this evaluation, all were presented at the Science Museum of Minnesota. Theatre and stage presentations are typically delivered to larger groups of visitors, while facilitated activities and cart demonstrations are typically presented for smaller groups of visitors.

Information about NISE Net Goals

Some information about the development of NISE Net goals provides context for this evaluation. These goals remind the reader what the exhibits and programs were designed to achieve.

The public goals presented in the original proposal were:

NISE Net overarching goals
1) Increased awareness of nanoscale science, engineering, and technology and its multiple potential benefits and impacts on lives and communities;

2) Increased understanding of the structure of matter and the forces at work on the nanoscale.

3) Increased understanding of societal issues including risk assessment and abatement, and of the importance of broad citizen participation in discussions about responsible research and development of new technologies. (This goal is for science attentive adult public only.)

As the project began, a set of main messages were developed for the exhibits and programs. The tone used in these goals reflects in some ways the tone of the programs and exhibits developed to meet these goals.

Main Messages for Exhibits and Programs
1. Nanoscale effects occur in many places. Some are natural, everyday occurrences; others are the result of cutting-edge research.

2. Many materials exhibit startling properties at the nanoscale.

3. Nanotechnology means working at small size scales, manipulating materials to exhibit new properties.

4. Nanoscale research is a people story.

5. No one knows what nanoscale research may discover, or how it may be applied.

6. How will nano affect you?

In Year 5, the Content Steering Group and the network leadership team revisited the main messages, developing a Content Map outlining the key concepts for NISE Net educational products. The map as adopted in Fall 2010 is included in Appendix D; the main ideas are very close to what was in development as the evaluation was underway. As part of this process, and in a spirited debate, the leadership team and others revisited the idea of what counted as awareness of nano (candidates included recognition of the word nano, scientific content, recognition of a field of research and development, and more). Ultimately, the team agreed on the four areas described below as the definitions of 'nanoawareness.' These four areas now frame the Content Map and served to organize data collection and analysis for this evaluation.

Year 5 Nanoawareness
1: Nanometer-sized things are **very small** and often **behave differently than larger things do.**
2: Nanotechnology is **manipulating matter with control at a small (size) scale.**
3: Nanoscience and nanotechnology **lead to new applications.**
4: Like any technology, nanotechnology has **risks and benefits.**

Detailed Evaluation Questions

The overarching question, *What are the measureable impacts of NISE Net-produced exhibit and program deliverables on a public audience?,* was then broken down into smaller parts.

Consistent with the Year 4 evaluation, this study focuses on public impact in terms of (a) enjoyment and interest, (b) awareness, (c) understanding, and (d) relevance. Where possible, these topics are connected with the appropriate strand in the framework presented in the recent National Research Council report, "Learning Science in Informal Environments" (2009). Survey and interview questions explore visitor ideas about nanoscale science in these four areas:

Enjoyment and Interest

Strand 1 of the NRC report (2009) states, "Learners who engage with science in informal environments experience excitement, interest, and motivation to learn about phenomena in the natural and physical world;" this strand is noted as a particular strength of informal science in that report. And yet conventional wisdom among the NISE Net members suggests that generating interest and excitement over nanoscale science, engineering, and nanotechnology is more challenging than other topics commonly presented in informal science education. Reasons suggested include visitors' unfamiliarity with nano, the difficulty of showing nano phenomena, and the challenge of conveying a sense of the scale of nano. Exploring the extent to which and ways in which the exhibits and programs are interesting and enjoyable to visitors is key given that challenge.

Evaluation Questions

- Do visitors find the exhibition/programs interesting and enjoyable?
- What makes the exhibits or programs interesting or enjoyable?
- Do the exhibits or programs create additional interest in nanoscale science, engineering, and technology?

Data Collected to Address Evaluation Questions

Pre-exhibition and pre-program surveys asked visitors rate their interest in a list of hypothetical exhibitions or programs, including a nano option.

Post-exhibition and program surveys asked visitors about their levels of interest and enjoyment for the products as a whole. Surveys identified specific elements of current exhibitions that drew visitor interest, and asked visitors to indicate the components they most enjoyed. Interviewers further asked visitors about what specific features made the exhibit components enjoyable. Exhibit survey questions asked how their interest in the exhibition compared with other things they had seen in the museum, and both exhibit and program survey questions asked about anticipated interest in learning more about nano in the future.

Awareness

Strand 2 of the NRC report states: "Learners who engage with science in informal environments come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science." Awareness is a precursor of this; it indicates whether (or how much) people have heard of a topic; it creates the conditions for attention for future campaigns or messages. At its most basic level, it asks whether or not people recognize the term nano and how much people have heard of it from any source. After extensive discussion in the Content Steering Group and leadership team, the definition of Awareness within NISE Net was adjusted in Year 5. For this evaluation, people show nanoawareness by their confidence or ability to explain any one of the following ideas:

Awareness Part 1a: Nanometer-sized things are **very small.**
Awareness Part 1b: Nanometer-sized things often **behave differently than larger things do.**
Awareness Part 2: Nanotechnology is **manipulating matter with control at a small (size) scale.**
Awareness Part 3: Nanoscience and nanotechnology **lead to new applications.**
Awareness Part 4: Like any technology, nanotechnology has **risks and benefits.**

Evaluation Questions

- How many museum visitors have heard of nano before visiting the exhibit or seeing the program? At what levels do these visitors show nanoawareness?
- Do visitors to the NISE exhibits or programs show higher nanoawareness, using the NISE Net definition?
- Where do museum visitors get information on nanotechnology and nanoscience?

Data Collected to Address Evaluation Questions

All visitors were asked about their overall awareness of the field of nano, both in order to compare samples to ensure equivalence but also to get a general rating of how much they had heard about nano.

Survey items from Dyehouse et al. (2008) were adapted for use in pre- and post-program instruments in this evaluation. Dyehouse uses a different definition of nanoawareness so some items were altered for use here. These questions asked how confident visitors were in their ability to name a nanoscale sized object, describe one way nanoscale objects behave differently, name an application of nanoscience, describe a process used to produce objects at the nanoscale, explain some risks and benefits of nanotechnology.

Interviewers asked exhibition visitors to finish the sentence, "Nanoscale science is the study of . . .." (This question was also asked on the program survey.) This more open-ended question allowed people to define nano in their own words; we matched their definitions back to the definitions accepted by the network.

Exhibition visitors who had learned about nano before were asked about their sources of information to better understand how they develop nanoawareness.

Understanding

Strand 2 of the NRC report states: "Learners who engage with science in informal environments come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science." This construct explores the general topic areas outlined in the definition of nanoawareness above, but looks for the details of what people understand in each area, and also allows for alternative conceptions, exploration of nuanced definitions, and closer connections to specific exhibit or program elements.

Evaluation Questions

- How well do general museum visitors understand nanoscale science, engineering, and technology?
- How do these understandings differ for visitors who have seen the exhibit or program?
- How do these understandings connect to the specific exhibits or program seen?
- What alternative conceptions exist?

Data Collected to Address Evaluation Questions

The question analyzed in the awareness section, asking visitors to complete the sentence "Nanoscale science is the study of . . ." is also used here. It is combined with questions about what visitors think the exhibit or program is intended to show in order to understand the nuance presented by individual exhibits or programs.

A sorting activity (completed in the interview at exhibit sites), in which visitors identified objects as containing nano or not containing nano, gives insight into alternative conceptions. Interviewers also presented visitors with new nanotechnologies and asked how they would be likely to respond to them; their answers were coded for understanding of nanotechnology.

Relevance

Strand 6 of the NRC report states, "Learners who engage with science in informal environments think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science." We are interested in how visitors currently see a connection between nano and their own lives, and how they suggest they might engage with nano in the future.

Evaluation Questions

- Does the general museum visitor think of nano as relevant?
- Do visitors find the exhibition/programs relevant to their everyday lives?
- What elements make the exhibits or programs relevant to visitors? (Topics, approaches, etc.)
- Do the exhibits or programs make nanoscale science, engineering, and technology seem more relevant to visitors' lives?
- How do visitors envision interacting with nano in the future?

Data Collected to Address Evaluation Questions

The surveys included a question asking visitors to rate how well a list of topics connected with “things in your everyday life that you know or wonder about.” Some of these topics were explicitly ‘nano’ – nanoscience, nanotechnology, nanomedicine – while others were topics related to the exhibit or program – the hooks that were designed to attract people to the exhibit or program in the first place. These questions help better understand how well those topics worked, and also show whether people found nano topics more relevant after seeing the program or exhibit. Open-ended questions about elements that people connected with in the exhibit or programs further explore how well the hooks worked and why.

Interview questions about new nanotechnologies were analyzed for how people thought they might interact with those or other nanotechnologies in the future. Visitors to the museum were asked in all of the pre-surveys and in long program post-surveys how interested they would be in informally teaching someone about nanoscience, reading a news story or popular magazine article about nanoscale science, learning more about the use of nanotechnology in medical treatments, learning more about the use of nanotechnology in personal care products, changing what products they used based on what they knew about nanotechnology.

Relationships between Interest, Awareness, Understanding, and Relevance

Though examined separately, these four areas are closely related to each other. One way to examine the overlap is to look at them in relation to the four-phase model of interest development proposed by Hidi and Renninger (2006). In this model, individuals can develop their level of interest through phases: from 1) triggered situational interest, to 2) maintained situational interest, to 3) emerging (less-developed) individual interest, to 4) well-developed individual interest. The first two – the situational interests – examine the ways people interact with topics when in a situation where those topics are presented; the second two – the individual interests – explore how people might engage with ideas independently of a trigger or stimulus. Each stage is a precursor for the next one, without the assumption being made that any individual will necessarily move through all four stages. In fact, for most topics an individual might encounter in everyday life (for instance, a new idea in a magazine or mentioned by a friend), individuals are unlikely to move much beyond the first stage simply for reasons of capacity; there are too many ideas present in the world for individuals to become fully immersed in them all.

Our construct of Interest is a narrow one with a different meaning than used by Hidi and Renninger; it is situated squarely within the triggering context of the museum, asking visitors to assess how interesting they found the exhibits and programs, essentially looking to see whether the trigger (the exhibit or program) could lead to maintained situational interest by the visitor. Within the context of this study, we cannot look at whether or not people reach the stages beyond, and Interest, as it was designed in this study, does not encompass those stages.

That does not mean, though, that these stages are ignored – the other areas examined, Awareness, Understanding, and Relevance, can all serve as contributors to individuals moving through the full set of stages of interest development.

For Awareness and Understanding, we first need to distinguish these two nuanced categories from each other. While both are concerned with what traditionally is thought of as content knowledge – strand 2 in the "Learning Science in Informal Environments" (2009) framework – awareness is focused on the ways that people recognize an overall name ("nano") and connect it with a set of general ideas, while understanding explores the detail and depth of their understanding of those concepts. These ways of framing content knowledge can contribute to the development of new stages of interest – information can provide learners with new ways to ask questions, to engage with material, and more, and both later stages are characterized by the presence of stored information about a topic. This developing content knowledge is a requirement for, but not a guarantee of, progression through the stages of this model.

Relevance, unlike Interest, asks visitors to imagine and assess the connections between nano and their lives beyond the museum; it explores the ways in which visitors might be able to move from the ideas about nano presented in the exhibit or program (or which a visitor comes in with already) into incorporating them into their own contexts. Relevance is a more particular construct, then, and one which provides ways for people to ask questions, explore ideas, and make connections (all aspects of interest in multiple stages of the model, though developed at different levels). Relevance as we have framed it can support the movement of a visitor from one stage to the next, as they see ways that nano might be worth engaging in more deeply.

Overall, the NISE Network goal is to engage a visitor effectively within the museum (stage 2, maintained situational interest), and perhaps to provide them with tools that might allow for stage 3 and 4 outside of the museum, or a deeper, differently triggered stage 2. There is no expectation that every visitor (or even most visitors) will achieve stage 4 – rather, the hope is that people will leave with more ways to engage with nano than they entered with. Given the methodological constraints of this study, there were no ways to see whether visitors had in fact advanced to a further stage (or showed evidence of stages 3 or 4), but in looking at the categories of Awareness, Understanding, and Relevance, we can see whether visitors are provided with additional resources for a more developed stage of interest (as defined by Hidi and Renninger) in nano. Some of the lines of questioning do explore ways in which people might interact with nano in the future; these hypothetical scenarios can be seen not as evidence of the development of later stages, but as sketches of what those stages might look like if they occur.

Methods

Study Contexts

As stated earlier, not all deliverables produced during the five years of the grant were analyzed for this evaluation. However, the NISE Net team made specific and intentional choices regarding what contexts and educational products to study in order to account for the work done over the five-year project as a whole.

Exhibition
Permanent NISE Network exhibitions have been installed in Portland, OR and Boston, MA. An updated, traveling version of the same exhibition, called "Nanotechnology: What's the Big Deal?" is currently moving between museums in Arkansas and was evaluated in two sites: Little Rock and Pine Bluff. These diverse institutions allowed for assessment of nano exhibits with different audience types, with audiences who are familiar and unfamiliar with nano, and in very different institutions.

The exhibits were designed to be set up in clusters with four exhibits in the Intro cluster, five in the Nano Medicine cluster, two exhibits in a younger audience cluster, and three stand-alone exhibits. Table 1 below shows all the exhibits by cluster and at which location they were on display.

Table 1: Exhibit Components on Display by Location

Exhibit Title	Cluster	Little Rock, AR	Pine Bluff, AR	Portland, OR	Boston, MA
At the Nanoscale	Intro	●	●	●	●
Creating Nanomaterials	Intro	●	●	●	●
Unexpected Properties	Intro	●	●	●	●
Intro to Nanotechnology Video	Intro	●	●	●	●
Intro to Nanomedicine Video	Nano Medicine	●	●	●	●
Detecting Disease	Nano Medicine	●	●	●	●
Treating Disease	Nano Medicine	●	●	●	●
Regenerating Tissue	Nano Medicine	●	●	●	●
Nanomedicine Explorer	Nano Medicine	●	●	●	●
NanoLab	Younger audience	●	not on display	not on display	not on display
Fact or Fiction	Younger audience	●	not on display	not on display	not on display
Bump & Roll	Stand-alone	●	●	●	●
Changing Colors	Stand-alone	●	●	●	●
Nano Buzz	Stand-alone	●	not on display	●	not on display
Intro Panel	Stand-alone	●	●	not on display	not on display

As seen in Table 1, the configuration and number of exhibition components on display varied across the study venues. For example, all of the exhibits were on display in Little Rock, while only a subset was on display in Pine Bluff. Similarly, the Portland and Boston exhibitions include only a subset of the total exhibition. Additional components included in the full exhibition include an introductory title and credits monolith, the NanoLab room of interactive experiences, reading area, and the Nanotechnology: Fact or Fiction? exhibits. Maps of exhibit configurations at each location can be seen in Appendix E of the report.

Programs

Program descriptions are provided in the Appendix B of this report. Titles and approximate length of each program are provided in Tables 2, demonstrating how much time presenters had to deliver their main message.

Table 2: Approximate Length of Programs

Program Title	Approximate length of program (min)
Intro to Nano (cart)	10-15
Magic Sand	5
Exploring Forces—Gravity	5
Exploring Properties—Surface Area	5
Exploring Products—Nano Fabric	5
Electric Squeeze	5
Attack of the Nanoscientist	10-15
Intro to Nano (stage)	15-20
Treating Tumors with Gold	15-20
Energy and Nanotechnology	15-20

These programs fell into four general formats (two small-group program formats, and two large-group program formats):

- Three hands-on activities provided by a trained volunteer to a small group of visitors: Exploring Forces—Gravity (colloquially known as “tiny teacup”), Exploring Properties—Surface Area (colloquially known as “Alka Seltzer”), and Exploring Products—Nano Fabric (colloquially known as “nano pants”). These facilitated activities were presented at a permanently installed Activity Station that hosts a wide range of volunteer-facilitated activities throughout the day.

- Three interactive demonstrations provided by a trained volunteer to a small group of visitors: Magic Sand, Electric Squeeze, and Intro to Nano (cart). This program format is called ‘cart’ demonstrations by the network, but for this study the programs were done at a permanently installed Activity Station that hosts a wide range of volunteer-facilitated activities throughout the day. The Intro to Nano cart demo contains several short activities, including some (like Exploring Properties: Surface Area and Exploring Products: Nano Fabric) also presented separately as short, stand-alone activities.

- One museum theater production featuring professional actors, aimed primarily at children. This program, Attack of the Nanoscientist, was performed at the Atrium Stage, which sits in the middle of the bottom floor of exhibits.

- Three longer stage presentations, delivered in a large auditorium by a professional actor using a slide presentation and props. These programs are: Intro to Nano (stage), Energy and Nanotechnology, and Treating Tumors with Gold (colloquially known as “gold nanoshells”).

For the purposes of this evaluation, programs were divided into two categories: Short programs, which included the shorter, facilitated activities, cart demonstrations, and the “Attack of the Nanoscientist” theater program; and Long programs, which included the lengthier stage presentations. The theater program, “Attack of the Nanoscientist,” is between the two other types of programs in length and has fewer main messages than the Long programs, and so was grouped with the Short programs for this study.)

Instrument Construction

The authors drew items for the surveys and interviews from a variety of sources. Dyehouse, Diefes-Dux, Bennett and Imbrie (2008) were an important source of items on nanotechnology awareness; their instrument was developed with relatively large groups of college students (N= 335, N=1,426). Items were taken from the nano awareness and nano motivation scales of that study. Other items are identical to ones used in the Year 4 NISE Net Summative Evaluation (Onkka, Cohn and Ellenbogen, 2009) and in other NISE Net surveys. Still other items were derived from the Summative Evaluation Report of the "Too Small to See" Exhibition developed by the Sciencenter in Ithaca, New York (Spencer, Phillips, Angelotti, and Murphy 2007). Finally, a large number were developed and piloted independently for the particular requirements of study.

Demographic questions were taken from a standardized set often used on evaluation and research instruments at the Science Museum of Minnesota.

Members of the evaluation team, particularly the lead author, piloted the surveys and interviews in connection with the exhibit at the Museum of Science, Boston. The evaluation team used the results of the pilot to refine both the exhibit and program instruments. Program surveys for the shorter programs were piloted at the Science Museum of Minnesota and then refined for the Long program surveys. All items on the Short program survey also appeared on the Long survey; one question was changed slightly between the two in order to gather more specific information. No interviews were done with program visitors, though questions were included on the Long program survey that resembled some of the interview questions.

Lastly, one important note about the exhibit survey instruments is that the map used for the Little Rock data collection was, unfortunately, incomplete. The At the Nanoscale exhibit component was not labeled on the map, and as such, was not included in the analysis presented in this report.

Data Collection

NISE Net staff collected data over the course of April, May and early June of 2010. Data on the exhibition were collected at Museum of Science in Boston, Oregon Museum of Science and Industry in Portland, Museum of Discovery in Little Rock and The Arts & Science Center in Pine Bluff, Arkansas. All program data were collected at Science Museum of Minnesota.

Exhibition

Data were collected in the form of surveys and interviews. Individuals were approached and asked if they would be willing to complete a survey, and perhaps an interview; some chose just to complete the survey. Interviews were conducted with willing visitors after they had filled out the pre- or post-exhibit survey. Sampling in the museum lobby provided pre-exhibit survey and interview information, while sampling near the exhibit site after the visitors were clearly finished with their exhibit experience provided post-data. To understand the impact of the exhibition on visitors' perceptions of nanoscience, responses from visitors who had not seen the nano exhibition were compared to responses from visitors who had viewed the exhibition. Visitors were queried for either pre- or a post-measure, not both. Not all visitors who took a pre-survey toured the exhibition.

The type, location, and number of pre-exhibition and post-exhibition surveys is included in Table 3; also included is which museum was responsible for collecting the data. SMM survey associates and MOS research assistants traveled to Little Rock to collect data from the exhibit at Museum of Discovery (MOD). In Boston, MOS staff collected interview and survey data, including data from adult chaperones on weekdays. SMM survey associates collected pre- and post-survey data and conducted interviews at OMSI. Internal staff at the Arts & Science Center (ASC) in Pine Bluff collected pre- and post-survey data from both school-aged children and adult chaperones during the weekday.

Table 3: Number of Surveys and Interviews Collected at the Four Study Locations

Type of survey	Location	# of Surveys	# of Interviews	Collected by
Pre-exhibition	MOS – Boston, MA	130	56	MOS
	OMSI- Portland, OR	75	51	SMM
	MOD -Little Rock, AR	44	25	SMM, MOS
	ASC -Pine Bluff, AR	11	0	ASC*
Post-exhibition	MOS – Boston, MA	129	55	MOS
	OMSI- Portland, OR	101	60	SMM
	MOD -Little Rock, AR	76	66	SMM, MOS
	ASC-Pine Bluff, AR	14	0	ASC*
Child Survey (Post Survey Only	ASC-Pine Bluff, AR	74	0	ASC

*The number of adult interviews from Pine Bluff was too small for reliable analysis and is not included in this report.

Interviews were conducted at exhibitions in Little Rock, Arkansas, Boston, Massachusetts and Portland, Oregon. The type, location and number of pre-exhibition and post-exhibition interviews are included in the table above. Pre- and post-interviews differed in length; interviewers asked visitors who had visited the nanoscience exhibition additional questions. The sample included adults and children age 16 and above.

Programs

Data were collected in the form of surveys only. Different surveys were used for Short and Long programs. Sampling in the museum lobby and on the museum floor provided pre-program survey information; sampling at the program site provided post data. Visitors were queried for either pre- or a post-measure, not both. All programs were performed at The Science Museum of Minnesota; SMM survey associates collected all program survey data.

Most post-program surveys were collected on weekends, when more adult visitors were present. Pre-program surveys were collected at the Atrium Stage from both weekday and weekend visitors or in the museum at large. The pre-program sample did contain chaperones, as children were attending to a performance that was unrelated to nanoscience and did not require intense supervision. For programs, each adult in a group was given a survey; this differs from exhibition data collection in which only one adult from each group filled out a survey and completed an interview.

Unlike the exhibitions, where no recruitment took place, visitors were recruited for program participation. For Short programs, visitors were encouraged to participate if they passed near the cart, a gentle form of encouragement. Participants were most actively recruited for the Long programs. Prior to the presentation of the Long programs, an announcement was made over the public address system announcing the opportunity for visitors to attend a new program, fill out a survey, and receive a small gift. These programs were also advertised on the Museum's social networks (e.g., Facebook) the day or so before they were presented. Survey associates announced the opportunity to complete a survey for pre-program surveys collected near the Atrium Stage. For the "Attack of the Nanoscientist" theater program, no special recruitment happened beyond what happens for all theater programs, such as an announcement of the program over the museum loudspeaker (but no mention of a survey or gift).

Table 4: Number of Surveys Collected for Programs at SMM

Type of survey	Location	Number of surveys	Collected by
Pre-program Short	SMM- St. Paul, MN	201	SMM
Post-program Short	SMM- St. Paul, MN	409	SMM
Pre-program Long	SMM- St. Paul, MN	157	SMM
Post-program Long	SMM- St. Paul, MN	360	SMM

To allow for comparisons between exhibits and programs, most questions were identical between exhibit and program surveys, but some questions were shifted slightly to account for differences in objectives and for the different types of experiences, and for the differences in data collection.

Data Analysis

After all collected data were cataloged and organized, surveys and interviews were prepared for analysis. Surveys were entered by SMM survey associates into a statistical software package for quantitative analysis. These data files were also cleaned by the survey associates, who randomly selected 5%-10% of cases and checked for data entry accuracy. Interviews were transcribed and imported into qualitative research software (Nvivo) in order to search for common and emergent themes amongst visitor responses. Survey associates from SMM transcribed interviews from the Little Rock exhibition site. Data Shop (a transcription company in Janesville, WI) transcribed the remainder of the interviews from Boston and Portland.

Exhibition

The exhibition data set consisted of both visitor surveys and interviews. Survey data were subjected to frequency analysis in order to uncover trends and patterns in visitor responses. Interview transcripts were segmented into units of analysis consisting of 1-2 questions and any relevant follow up questions that were posed by the interviewer. Questions intended to uncover levels of visitor nano awareness were initially coded with a prescribed coding scheme based on the NISE Network definition of nano awareness. Other questions were coded for emergent themes within a grounded theory framework (Strauss & Corbin, 1998). Throughout the coding and qualitative analysis of the interview data, coding categories and assignments were developed as a result of discussion and reflection by the authors. Once the coding schemes were agreed upon, SMM survey associates were trained on them and also participated in the coding process. After the coding of interview transcripts was complete, the codes were exported from the qualitative research software for more sophisticated numerical analysis within the statistical software.

Frequencies of visitor responses and emergent coding themes were calculated and presented to provide the reader with a descriptive portrait of the data and findings. In addition, regression analysis (linear or binary logistic, depending on the format of the outcome variable) was performed for instances where a deeper understanding of the relationships between visitor learning, exhibit attendance, and demographic and psychographic variables was desired.

Programs

Unlike the exhibition data, the program data set consisted only of visitor surveys. As with the exhibition survey data, frequencies and regressions were performed as appropriate. In addition, open-ended survey questions were coded by SMM survey associates and Gina Svarovsky. Certain open-ended responses, particularly those exploring visitors' nano awareness, were coded with the prescribed coding scheme based on the network-accepted definition of nano awareness. Other open-ended responses were coded for emergent themes within a grounded theory framework (Strauss & Corbin, 1998).

Findings: Exhibition

Introduction

The bulk of the Exhibits section compares data between three sites: Portland, Boston, and Little Rock. The evaluation team collected data from adult visitors in similar numbers in all three sites. In Pine Bluff, the different nature of the museum and of the visitors required a different approach: surveys of students who visited the museum for field trips provide a different perspective on this exhibition. This information is presented separately at the end of the Exhibits section.

Rather than ask visitors to look at particular exhibit elements (which would have given more in depth information about each piece), the evaluation team decided to look at this exhibition as a whole. This allowed for visitors to interact with the elements at their own pace, making independent decisions about which elements to visit, and provides information about their experience which more accurately reflects the experience of the average visitor.

Aggregated and disaggregated data about the location or the exhibit element is presented here to assist in letting readers make their own interpretations; disaggregated data is included where it adds information. Disaggregation by exhibit element (where possible) allows for better understanding of each exhibit experience; disaggregation by location allows for understanding the interaction between the exhibition and its location. These differences may reflect regional characteristics and/or differences in the typical audience at each museum; regional variations in data collected on the exhibition may also be an artifact of the type of exhibition.

Demographics

Because separate samples were queried for the pre- and post-questionnaires and interviews, extra attention is required to make sure these groups are equivalent. These samples of visitors are compared here on standard demographic measures as well as on questions relating to their interest and exposure to science and nano. Each site is compared separately, and where possible the two samples are compared to known standard visitor demographics during the period over which data was collected.

Demographics collected from participants in the pre- and post-exhibition surveys include gender, age, ethnicity, language, education, income, and presence or absence of any disability. Questions for visitors about science and nano include questions about their interest in science, their use of science in their daily work, their previous exposure to nanoscale science, engineering, and technology, their previous visits to the museum, and any previous visits to nano exhibits or programs at the museum.

Non-parametric Mann-Whitney U tests were performed on each of the demographic and psychographic indicators to determine whether visitors in the pre- and post-samples from a given location were members of the same general population. In most cases, the response categories used in these statistical tests were the same as those reported by

visitors. However, at each location, the data for ethnicity and language included several outlier responses reported by less than 5 visitors. Based on this initial frequency analysis, categories were simplified for ethnicity (into White and Non-white) and language (English and Non-English) for the purposes of the statistical testing.
.
Some adjustments were also made to the categories used for age and income levels. Visitor ages were categorized into ranges which included Under 21, 21-29, 30-39, 40-49, and 50-59, 60+. Annual household income data were also categorized into ranges, which included Under $20,000, $20,000-$39,999, $40,000-$59,999, $60,000-$79,999, $80,000-$99,999, $100,000-$149,999, and $150,000+.

Descriptions of the setting of each exhibition are included to help the reader understand how visitors approach each site, which may help to interpret the demographic differences observed and whether they might indicate intentional decisions made by visitors. These decisions might be related to the nano content or they might relate to proximity to other exhibitions, general layout of the museum, or other factors. Research suggests that exhibition layout (particularly accessibility and visibility) more strongly predicts patterns of visitor movement than characteristics of exhibit elements (Peponis & Wineman, 2002).

Boston Exhibition

In Boston, the exhibition sits in the middle of the lowest floor of the museum, closely surrounded by a number of other exhibits. While the exhibition pieces are all grouped together, and are on a tiled section of floor that allowed evaluation staff to draw visitors' attention to the pieces being evaluated, they do not sit far away from other exhibitions. Nearby exhibits include model cars and trains, a solar car (part of an exhibition on energy), and medical technology exhibits; the highly popular dinosaur area is on the same floor and not far away. A casual visitor could easily drift from other exhibitions into the nano exhibition without realizing it.

Mann-Whitney U tests performed on each of the demographic and psychographic indicators examined whether the pre- and post-samples were taken from the same general population. No statistically significant demographic differences were identified in gender, age, education level, income level, presence or absence of a disability, visits to the museum, previous visits to the nano exhibits in the museum, use of science in daily work, interest in science, or previous exposure to nano between the Boston pre- and post-samples.

Differences in pre- and post-exhibition survey responses may be from other individual differences not measured in this study.

Little Rock Exhibition

In Little Rock, the exhibition was located on the lower level of the museum (the entrance is on the upper level). Visitors went down a staircase and past a theater stage before walking through the NISE Net exhibit. Several exhibitions (one on Arkansas history, one on the natural world) were located beyond the nano exhibition. The individual elements of the nano exhibition are coordinated in appearance, and it was clear that they were a unified exhibition, that frequent visitors to the museum well would easily recognize as new. In this smaller museum, many visitors seemed to visit almost all or all of the exhibitions instead of picking and choosing as they might in a larger museum.

Mann-Whitney U tests performed on each of the demographic and psychographic indicators examined whether the pre- and post-samples were taken from the same general population. No statistically significant demographic differences were identified in gender, age, education level, income level, presence or absence of a disability, visits to the museum, visits to the nano exhibits in the museum, use of science in daily work, or previous exposure to nano between the Little Rock pre- and post-samples.

However, a statistically significant difference ($U = 1149.5$; $Z = -2.52$; $p = 0.01$) was identified in the levels of interest in science for pre- and post-sample visitors. On average, the Little Rock pre-exhibition survey group (mean = 7.65, standard deviation = 2.181) rated their interest higher than the Little Rock post-exhibition survey group (mean = 6.43, standard deviation = 2.527), indicating the pre-exhibition survey group may have had more interest in science than those in the post-exhibition survey group.

Differences in pre- and post-exhibition survey responses may be from the greater interest in science indicated by the pre-exhibit group, however, it is possible that some of the differences seen between those who saw the exhibit and those that did not are due to other individual differences not measured in this study.

Portland Exhibition

The Portland exhibition is located on the second floor of the Oregon Museum of Science and Industry, in the Life Hall, where several other health and human biology exhibits in this large museum are located. It shares a large open area with other exhibitions, with little clear distinguishing features between the nano elements and other elements. Nearby exhibits include a computer-based simulator that shows the effects of aging on the human body, and the Life Lab, which has the only live animals in the museum. Some visitors who were asked to complete surveys were not aware that the nano exhibition was a separate exhibition. As in Boston, it seems that it sits close enough to exhibits on other topics that visitors could easily drift in and out of this exhibition.

Mann-Whitney U tests performed on each of the demographic and psychographic indicators examined whether the pre- and post-samples were taken from the same general population. No statistically significant demographic differences were identified in gender, age, education level, income level, presence or absence of a disability, visits to the nano exhibits in the museum, use of science in daily work, interest in science, or previous exposure to nano between the Portland pre- and post-samples.

However, a statistically significant difference ($U = 2975.5$; $Z = -2.59$; $p = 0.01$) was identified in the number of visits to the museum for pre- and post-sample visitors. The pre-exhibition survey respondents were more frequent museum goers, with higher proportions of respondents having visited the museum 3-4 times or 5 or more times in the last two years. There were higher proportions of post-exhibition survey respondents that had not visited the museum or had only visited 1-2 times in the last two years.

The differences in the number of previous visits to the museum may account for some of the differences in the pre- and post-exhibition responses. Other differences not measured here may also account for some of the differences described below.

A summary of significant demographic differences in pre- and post-exhibition samples for all locations can be seen in Table 5.

Table 5: Summary of Significant Demographic Differences Between Pre- and Post-samples at Exhibition Sites

	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age	Education	Income	Ethnicity	Disability	Lanugage	Museum Visits	Seen nano ISE
Boston												
Little Rock		√ *										
Portland											√ *	

*Significant at the $p<0.05$ level.

Enjoyment and Interest: Exhibition

Evaluation Questions and Overview

- Do visitors find the exhibition interesting and enjoyable?
- What makes the exhibits interesting or enjoyable?
- Do the exhibits create additional interest in nanoscale science, engineering, and technology?

In this section, we present data that suggest a majority of visitors found the exhibition both interesting and enjoyable. Not surprisingly, reasons visitors liked the exhibits also varied by location.

Initial Levels of Interest

Museum exhibit developers have expressed concerns about how excited the museum public is likely to be about nanoscale science, engineering, and technology. In order to explore the typical level of interest, the pre-exhibit questionnaire asked visitors about exhibitions they might be likely to stop and explore. Table 6 shows the mean and standard deviation of the ten-point scale given for each topic. Compared to four other typical museum exhibit topics, nanoscience (labeled “Strange Matter” for this item) received the lowest interest rating for both mean and median. Visitors apparently do not consider nano topics or exhibits to be as likely to be interesting as other museum topics or exhibits, though this difference is not pronounced.

Table 6: Central Tendencies of Museum Visitors' Responses to "How Likely Are You to Stop and Explore an Interactive Exhibit About Each of the Following Topics?"

Exhibit element	Mean (n=248)	Standard Deviation
Journey to Space: Take a trip to the International Space Station. Investigate how low gravity will impact your muscles and how you will react to being in space.	7.7	2.68
Life in the Cretaceous: Travel back in time 65+ million years and be a dinosaur. Learn about dinosaurs' environment and the plants, animals and insects that shared it.	7.5	2.67
Biomechanics: Fish that project their jaws out to half their body lengths to capture prey? Spider webs stronger than steel? Discover the marvels of natural engineering.	7.1	2.40
CSI - The experience: Go from crime scenes to laboratories and autopsy rooms, bringing to life the most advanced scientific techniques used by today's crime scene investigators.	7.1	2.96
Strange Matter: Zoom to the nanoscale and explore the super small. Manipulated molecules and test new nanotechnologies, like the odor resistant socks and antibacterial teddy bears.	6.6	2.67

Overall Interest and Enjoyment

Visitors to the exhibition rated their experiences as both interesting and enjoyable. Table 7 shows percentages of visitors from pooled Portland, Boston, and Little Rock data who gave each rating for the question "How interesting was the exhibit you just saw?" A majority (73%) of the visitors gave the overall exhibit the highest rating; most chose "I was so interested I would encourage others to see it," indicating that exhibition were successful in generating public interest in nanoscience. Another 24% chose the next highest rating, "I was interested but I wouldn't encourage others to see it." Only about 3% chose ratings indicating they were not interested in the exhibit.

Table 7: Percent of Respondents Choosing Each Answer for "How Interesting was the Exhibit You Just Saw?" (Three Locations Pooled Compared with Previous Evaluations)

Response options	Percent of respondents (n=296)	Percent for all *formative* nano exhibit evaluations (n=258)
I was so interested I'd encourage others to see it.	72.6%	57.8%
I was interested, but I wouldn't encourage others to see it.	24.0%	33.7%
I wasn't really interested.	2.7%	5.0%
I didn't find it interesting at all.	0.3%	3.5%

To look for improvement, we compared interest levels for this exhibit to interest levels for all formative evaluations of nano exhibits from years 1-5. These numbers are listed in the far right column of Table 7. As expected for an improved version of the exhibition, levels of interest for visitors in the Summative study are higher than in the formative studies. Both the overall positive ratings improved (97% positive compared with 91.5% positive), as well as the number of people giving the highest possible rating. These numbers don't differ appreciably when disaggregated by location.

Table 8 shows the percentages of visitors that gave each rating to the question "How enjoyable was the exhibit you just saw?" Again 97% of the visitors chose one of the two highest ratings, indicating they enjoyed the exhibit. Not as many visitors gave the highest rating as they did for interest; 42% of visitors gave the highest rating for enjoyment compared to 73% for interest.

Table 8: Percent of Respondents Choosing Each Answer for "How Enjoyable Was the Exhibit?" (3 Locations Pooled Compared with Previous Evaluations)

Response options	Percent of respondents (n=298)	Percent for all *formative* nano exhibit evaluations (n=179)
It was so enjoyable I'd encourage others to see it.	41.9%	41.9%
It was enjoyable.	56.0%	49.2%
I didn't really enjoy it.	2.0%	6.7%
I didn't find it enjoyable at all.	0.0%	2.2%

When compared to formative evaluations of nano exhibits that asked this question (a smaller number than asked about interest, hence the lower N), there is an improvement from earlier iterations of the exhibits, with fewer respondents (2.1% compared with 8.9%) not finding them enjoyable, though there is no change in the fraction giving the highest possible rating.

Levels of enjoyment differed by location. While overall positive numbers (top two categories combined) are about the same, the proportion giving the highest ranking was largest in Little Rock, followed by Boston, and then Portland.

Table 9: Percent of Respondents Choosing Each Answer for "How Enjoyable Was the Exhibit?" by Location

Response options	Post-exhibit Boston, MOS (n=126)	Post-exhibit Little Rock, MOD (n=74)	Post-exhibit Portland, OMSI (n=98)
It was so enjoyable I'd encourage others to see it.	42.9%	48.6%	35.7%
It was enjoyable.	55.6%	48.6%	62.2%
I didn't really enjoy it.	1.6%	2.7%	2.0%
I didn't find it enjoyable at all.	0.0%	0.0%	0.0%

Individual Exhibit Elements

Slightly different versions of the exhibit were displayed at each location data was collected (refer to maps of each site in Appendix E). Table 1 from the Methods section, which provides information about which exhibit components were included at each data collection site, is repeated here for the convenience of the reader.

Table 10: Exhibit Components on Display by Location

Exhibit Title	Cluster	Little Rock, AR	Pine Bluff, AR	Portland, OR	Boston, MA
At the Nanoscale	Intro	●	●	●	●
Creating Nanomaterials	Intro	●	●	●	●
Unexpected Properties	Intro	●	●	●	●
Intro to Nanotechnology Video	Intro	●	●	●	●
Intro to Nanomedicine Video	Nano Medicine	●	●	●	●
Detecting Disease	Nano Medicine	●	●	●	●
Treating Disease	Nano Medicine	●	●	●	●
Regenerating Tissue	Nano Medicine	●	●	●	●
Nanomedicine Explorer	Nano Medicine	●	●	●	●
NanoLab	Younger audience	●	not on display	not on display	not on display
Fact or Fiction	Younger audience	●	not on display	not on display	not on display
Bump & Roll	Stand-alone	●	●	●	●
Changing Colors	Stand-alone	●	●	●	●
Nano Buzz	Stand-alone	●	not on display	●	not on display
Intro Panel	Stand-alone	●	●	not on display	not on display

Again, as noted in the Methods section of the report, the map of exhibits used for the data collection in Little Rock was unfortunately incomplete, and the At the Nanoscale exhibit was not properly labeled. As such, the presence of that component at the Little Rock Museum of Discovery is not included in the analyses described below.

On the post exhibit survey, visitors were asked to indicate at which exhibit elements they had spent time. As Table 11 (below) shows, most exhibit elements attracted 30-45% of visitors.

Table 11: Percent of Visitors Visiting Individual Exhibit Elements (Pooled Data for Three Locations from Post Visit Survey)

Exhibit element	Post-exhibit Boston, MOS (n=127)	Post-exhibit Little Rock, MOD (n=75)	Post-exhibit Portland, OMSI (n=101)	Three sites, pooled (n=303)
Changing Colors	46.5%	52.0%	54.5%	50.5%
Treating Disease	51.2%	48.0%	50.5%	50.2%
Detecting Disease	55.1%	38.7%	34.7%	44.2%
Regenerating Tissue	40.2%	40.0%	45.5%	41.9%
Creating Nanomaterials	36.2%	56.0%	36.6%	41.3%
Unexpected Properties	33.9%	37.3%	38.6%	36.3%
Bump and Roll	28.3%	37.3%	39.6%	34.3%
Nanomedicine Explorer	36.2%	26.7%	29.7%	31.7%
Intro to Nanotechnology Video	33.9%	32.0%	26.7%	31.0%
Intro to Nanomedicine Video	26.0%	9.3%	18.8%	19.5%
At the Nanoscale	31.5%	N/A	27.7%	N/A
Nano Buzz	N/A	26.7%	10.9%	N/A
NanoLab	N/A	46.7%	N/A	N/A
Fact or Fiction	N/A	29.3%	N/A	N/A

Several highly visited exhibits combine interactive elements with medical topics – which, as we'll see below, visitors find interesting and relevant (see Table 14 in the interest section and Table 31 in the relevance section). These include Treating Disease, Detecting Disease, and Regenerating Tissue. The popularity of the most highly visited exhibit, Changing Colors, on how butterfly wings exhibit nanoproperties, is perhaps less easily predicted by those criteria. When asked how relevant butterfly wings were to their everyday life, visitors rated this topic low; however, it was one of the most visited elements in the exhibition. It is a visually striking exhibit, and covers very different subject matter than the other exhibits, and so perhaps attracts a higher number of visitors who are less interested in medical applications. All three lowest rated elements (of those present at all three sites) include video components; Intro to Nanotechnology and Intro to Nanomedicine both are short videos, while Nanomedicine Explorer is an interactive multimedia kiosk.

Variations by location may be due to individual museum layouts, visitor interest, visitor demographics, or other factors.

After marking which exhibit elements they had visited (above, and second column in Table 12), the visitors starred the element(s) they found most enjoyable (third column in Table 12). By combining that data with visitorship rates, a fairer assessment of favorites is produced; this information is shown in the third column:

Table 12: Percent of Visitors Who Had Visited an Exhibit Marking it as Particularly Enjoyable (Pooled Data for Three Locations from Post Visit Survey)

Exhibit element	Total number of visitors surveyed	Percent of possible visitors who used component	Percent of possible visitors who marked as most enjoyable	Of those who visited, percentage marking it as most enjoyable
NanoLab*	75	46.7%*	26.7%	57.1%
Treating Disease	303	50.2%	22.4%	44.7%
Creating Nanomaterials	303	41.3%	14.9%	36.0%
Regenerating Tissue	303	41.9%	13.9%	33.1%
Nanomedicine Explorer	303	31.7%	10.2%	32.3%
Detecting Disease	303	44.2%	12.9%	29.1%
Bump and Roll	303	34.3%	8.6%	25.0%
Intro to Nanomedicine Video	303	19.5%	4.6%	23.7%
Fact or Fiction*	75	29.3%*	6.7%	22.7%
Changing Colors	303	50.5%	11.2%	22.2%
Unexpected Properties	303	36.3%	7.3%	20.0%
Intro to Nanotechnology Video	303	31.0%	6.6%	21.3%
At the Nanoscale*	228	29.8%*	5.7%	19.1%
Nano Buzz*	176	17.6%*	2.3%	12.9%

*Only present at select locations: At the Nanoscale (Boston and Portland), Nano Buzz (Little Rock and Portland), NanoLab (Little Rock) and Fact or Fiction (Little Rock).

In some cases, highly visited exhibits are also well-liked (Treating Disease and Creating Nanomaterials, for instance), but some more rarely visited exhibits score reasonably well on enjoyability and some more frequently visited exhibits rate lower than hoped on enjoyability. Ideally, exhibits will both attract visitors and be enjoyable for those who see them.

During the follow-up interview, visitors described what features of one of their favorite exhibits made it enjoyable for them. Subject matter (general or medical) and interactive elements ranked high, but visitors' reasons vary greatly by exhibit. Values of 50% or higher are marked in bold; the low response rates for many of these exhibit elements mean this table should be interpreted with caution.

Table 13: Percent of Visitors Choosing Each Reason for "What made that part of the exhibit enjoyable for you?" by Exhibit

	General subject matter	Medical subject matter	Inter-active elements	Child enjoyed inter-actives	Info easy to under-stand	Visual elements	Real world scientific activity	Other	n
At the Nanoscale	**62.5%**	12.5%	25.0%	12.5%	0.0%	**50.0%**	0.0%	0.0%	8
Bump and Roll	**60.0%**	13.3%	**53.3%**	26.7%	6.7%	0.0%	0.0%	0.0%	15
Changing Colors	**68.8%**	0.0%	31.3%	31.3%	6.3%	12.5%	6.3%	0.0%	16
Creating Nanomaterials	44.0%	8.0%	**52.0%**	44.0%	4.0%	16.0%	4.0%	0.0%	25
Detecting Disease	40.0%	40.0%	40.0%	6.7%	6.7%	20.0%	6.7%	0.0%	15
Nanomedicine Explorer	16.7%	**61.1%**	11.1%	11.1%	22.2%	11.1%	0.0%	0.0%	18
Intro to Nanomedicine Video	**78.8%**	44.4%	0.0%	11.1%	22.2%	0.0%	0.0%	0.0%	9
Intro to Nanotechnology Video	**62.5%**	25.0%	12.5%	12.5%	25.0%	0.0%	0.0%	25.0%	8
Regenerating Tissue	25.0%	**60.0%**	25.0%	10.0%	10.0%	5.0%	0.0%	0.0%	20
Treating Disease	22.0%	**61.0%**	19.5%	22.0%	12.2%	14.6%	2.4%	2.4%	41
Unexpected Properties	**55.6%**	16.7%	27.8%	11.1%	22.2%	27.8%	5.6%	0.0%	18
NanoLab	38.5%	7.7%	30.8%	**53.8%**	7.7%	23.1%	23.1%	0.0%	13
Fact or Fiction	**50.0%**	0.0%	**50.0%**	**75.0%**	**50.0%**	0.0%	25.0%	0.0%	4
Nano Buzz	**100.0%**	0.0%	0.0%	**100.0%**	0.0%	0.0%	0.0%	0.0%	1

Comparing Nano to Other Exhibitions

The second question in the post-exhibit interviews provided evidence that the museum exhibition succeeded in getting those who visited the exhibit more interested in nanoscience. Evaluators asked visitors if the exhibition they had just seen was more, less or about as interesting as other exhibitions they had seen. In Boston, over 70% of the visitors who had seen other exhibitions thought the nanoscience exhibition was of equal or greater interest, with 45% calling it more interesting. In Little Rock and Portland, over 60% said it was at least as interesting or more interesting than other exhibitions, with over 35% calling it more interesting. Compared to the perceptions of visitors who had not seen the nano exhibition (Table 6), who ranked a nano exhibit as the least interesting among five typical museum exhibitions, the exhibition appears to outperform visitor expectations.

Table 14: Categorized Interviewee Responses to "Was this Exhibit on Average, More or Less Interesting Than Other Things You Have Seen Today?"

	Post-exhibit Boston, MOS (n=55)*	Post-exhibit Little Rock, (n=66)*	Post-exhibit Portland, OMSI (n=60)*
More interesting	45.5%	36.4%	38.3%
About the same	25.5%	24.2%	23.3%
Less interesting	9.1%	18.2%	30.0%

*Not all visitors who were interviewed had been to other exhibitions in the building.

Interviewers asked visitors to elaborate on their responses to find out why the nanoscience exhibition was more or less interesting than other exhibitions they had been to at the museum. Table 15 summarizes the responses.

Table 15: Categorized Interviewee Justifications Given for Interest Level

	Post-exhibit Boston, MOS (n=55)*	Post-exhibit Little Rock, (n=66)*	Post-exhibit Portland, OMSI (n=46)*
More interesting – general subject matter	3.6%	18.2%	6.7%
More interesting – new or applied content	16.4%	13.6%	10.0%
More interesting – medical content	1.8%	4.5%	1.7%
More interesting – interactive elements	0.0%	10.6%	8.3%
Less interesting – kids spent less time	0.0%	3.0%	1.7%
Less interesting – understood other exhibits better	1.8%	4.5%	3.3%
Less interesting – other	7.3%	4.5%	15.0%

*Not all visitors that answered the first part of this question gave justifications for why the exhibition was more or less interesting. Interviewees' responses may have been placed in more than one category.

Answering the Evaluation Question

- Do visitors find the exhibition/programs interesting and enjoyable?
- What makes the exhibits or programs interesting or enjoyable?
- Do the exhibits or programs create additional interest in nanoscale science, engineering, and technology?

Did visitors find the NISE Network exhibition interesting and enjoyable? Data from surveys and interviews showed a majority of visitors found the exhibition both interesting and enjoyable. Almost 73% of visitors were so interested they would recommend the exhibit to a friend, the highest level of interest, and another 24% counted it as interesting but not recommendable. All but 2% of visitors found the exhibit to be enjoyable in some way.

Not surprisingly, the nature of the exhibit element affected why visitors liked it. Subject matter and interactive elements were two commonly cited reasons for which exhibits people liked best. Reasons visitors liked the exhibits also varied by location. Overall, visitors with children in Little Rock enjoyed the interactive exhibition because their children were interested. Visitors in Boston were more drawn by the content of the exhibition. Portland visitors who rated the exhibition more interesting also enjoyed the content. Visitors in all locations enjoyed their experience and showed interest in nanoscience.

More than 60% of visitors found the nanoscience exhibit as interesting as, or more interesting than others they had seen, which is especially noteworthy given that visitors who had seen no exhibitions ranked a nanoscience exhibit last among a choice of typical museum exhibits they would visit. Visiting this exhibit seems to have given people access to the world of nanoscale science, engineering, and technology, creating interest in the exhibit, and it seems, the topic, where interest was low beforehand.

Awareness: Exhibition

Evaluation Questions

- How many museum visitors have heard of nano before visiting the exhibit or seeing the program? At what levels do these visitors show nanoawareness?
- Do visitors to the NISE exhibits or programs show higher nanoawareness, using the NISE Net definition?

Evaluating different aspects of nanoawareness took many forms, as the definition of awareness utilized in this study is complex:

Awareness Part 1a: Nanometer-sized things are **very small.**
Awareness Part 1b: Nanometer-sized things often **behave differently than larger things do.**
Awareness Part 2: Nanotechnology is **manipulating matter with control at a small (size) scale.**
Awareness Part 3: Nanoscience and nanotechnology **lead to new applications.**
Awareness Part 4: Like any technology, nanotechnology has **risks and benefits.**

This definition was established and agreed upon by the NISE network as appropriate for this study. It is crucial to note that any one of these (1a and 1b should be combined though they are measured separately) constitutes nanoawareness; individual visitors are not expected to leave a program or exhibit having mastered all four kinds of nanoawareness.

In this section of the report, we present data that suggest visitors to these museums have generally heard something about nanotechnology at levels higher than in the general population. In addition, visitors who have seen the exhibition show a statistically significant difference in their confidence in their ability to explain something about nano in ways that matter to NISE Net when compared with visitors who have not seen the exhibition, and thus demonstrate a difference in nanoawareness.

Initial Levels of Nanoawareness

Visitors' perceptions of their own nanoawareness (using the simplest definition, how much have visitors heard of nano) provides a baseline measure. All those surveyed were asked, "Before today, how much have you heard about nanoscale science and technology?" using a scale from 0-10:

I have never heard about it		I have heard about it a few times					I hear about it often			I hear about it all the time
0	1	2	3	4	5	6	7	8	9	10

The mean pre-exhibition survey group response (4.33, SD 2.93) and mean post-exhibition survey group response (4.32, SD 2.73) indicate that visitors, on average, have some familiarity with the concept of nano but that most do not rate themselves as hearing about it often. An independent sample t-test (of pooled data for Boston, Portland and Little Rock) showed there was no significant difference [$t(539) = 0.034$, $p = .973$] between the mean of the pre-exhibition survey group and the mean of post-exhibition survey group.

A recent survey (Hart Research Associates, 2009) asked a similar question of American adults, “How much have you heard about nanotechnology?,” with a similar scale for responses: nothing, a little, some, a lot. By combining responses according to how they are positioned below to the anchors, a rough comparison with the scale used in this study is possible:

NISE Net study			*Hart study*	
Rating scale	**Pre-exhibit visitors (n=247)**	**Post-exhibit visitors (n=294)**	**American adults**	**Rating scale**
I hear about it all the time (9-10)	9.7%	7.1%	9%	A lot
I hear about it often (5.5-8)	30.9	31.3%	22%	Some
I have heard about it a few times (2-5.5)	40.5%	43.6%	31%	A little
I have never heard about it (0-1)	19.1%	18.1%	37%	Nothing

The percentage of people giving the highest rating is similar across groups, but the museum audience appears to have more people who have heard some or a little about nano, and fewer people who have heard nothing about it, compared with the general public.

Differences in Nanoawareness

Visitor awareness of nanoscience was assessed using five identical items included on both the pre- and post-exhibit questionnaire that asked visitors to rate their confidence in their ability to:

- name a nanoscale sized object (*)
- describe how nanoscale objects behave differently
- describe a process used to produce objects at the nanoscale (*)
- name an application of nanoscale science (*)
- explain risks and benefits of nanotechnology.

Each item mirrors part of the definition of nanoawareness developed by NISE Net. The starred (*) items in this list were adapted from the nanoawareness scale of Dyehouse, Diefes-Dux, Bennett and Imbrie (2008). Note that these are all self-rankings of confidence in their abilities, rather than actual tests of those abilities.

The response scale for these items was, again, a 0-10 scale with four anchors:

Not at all confident			Somewhat confident			Confident			Extremely confident	
0	1	2	3	4	5	6	7	8	9	10

Responses showed a difference between those who had and those who had not seen the exhibits, though generally they remain in the "somewhat confident" range of the scale, as shown in Table 16.

Table 16: Mean of Visitor Responses to "How confident are you in your ability to do each of the these?" (3 Locations Pooled)

Topic	Pre-exhibit survey (n=239)	Post-exhibit survey (n=292)	Mean Difference (Post-Pre)
Name a nanoscale sized object	2.70	3.59	0.89
Describe one way that nanoscale objects behave differently than other objects	2.35	3.86	1.51
Describe a process used to produce objects at the nanoscale	2.07	3.11	1.04
Name an application of nanoscale science	3.16	5.27	2.11
Explain some risks and benefits of nanotechnology	2.59	4.10	1.51

For further analysis, the 11-point scale (0-10) was compressed into a 6-point scale by transforming the values in SPSS in order to create a more normal distribution. The scale was compressed using the following algorithm: 0=0, 1=1, 2=2, 3=3, 4=3, 5=3, 6=4, 7=4, 8=4, 9=5, 10=5. The evaluation team felt that this compression balanced variability with meaningful responses; values in the middle of the scale were probably closer in meaning for respondents than those closer to the ends of the scale (e.g. 1 or 10).

These transformed values are presented, disaggregated by location, in Tables 17-19. All locations showed higher values for post-exhibition visitors for each item; among the largest or the largest difference for each site is for "name an application of nanoscale science," while the smallest difference for each site is for "name a nanoscale-sized object." These values are further analyzed for significance using linear regression below; they are presented here for those interested in differences by location.

Table 17: Mean of Visitor Responses to "How confident are you in your ability to do each of the these?" for Portland Visitors

Topic	Pre-exhibit survey (n=73)	Std. Dev.	Post-exhibit survey (n=99)	*Std. Dev.*	*Mean Difference (Post-Pre)*
Name a nanoscale sized object	1.64	1.63	2.27	1.71	0.63
Describe one way that nanoscale objects behave differently than other objects	1.36	1.45	2.49	1.65	1.13
Describe a process used to produce objects at the nanoscale	1.18	1.43	1.88	1.57	0.7
Name an application of nanoscale science	1.73	1.67	3.13	1.62	1.4
Explain some risks and benefits of nanotechnology	1.29	1.50	2.63	1.63	1.34

Table 18: Mean of Visitor Responses to "How confident are you in your ability to do each of the these?" for Boston Visitors

Topic	Pre-exhibit survey (n=125)	Std. Dev.	Post-exhibit survey (n=123)	*Std. Dev.*	*Mean Difference (Post-Pre)*
Name a nanoscale sized object	1.96	1.72	2.59	1.71	0.63
Describe one way that nanoscale objects behave differently than other objects	1.86	1.79	2.67	1.72	0.81
Describe a process used to produce objects at the nanoscale	1.65	1.69	2.36	1.68	0.71
Name an application of nanoscale science	2.23	1.83	3.35	1.65	1.12
Explain some risks and benefits of nanotechnology	2	1.76	2.67	1.67	0.67

Table 19: Mean of Visitor Responses to "How Confident Are You in Your Ability to do Each of These?" for Little Rock Visitors

Topic	Pre-exhibit survey (n=44)	Std. Dev.	Post-exhibit survey (n=74)	*Std. Dev.*	*Mean Difference (Post-Pre)*
Name a nanoscale sized object	1.98	1.61	2.32	1.55	0.34
Describe one way that nanoscale objects behave differently than other objects	1.55	1.49	2.34	1.54	0.79
Describe a process used to produce objects at the nanoscale	1.52	1.50	2.08	1.59	0.56
Name an application of nanoscale science	1.98	1.72	2.7	1.60	0.72
Explain some risks and benefits of nanotechnology	1.73	1.65	2.51	1.54	0.78

Further analysis using linear regression was performed on the aggregate exhibition data to get a better sense of the different relationships between visitor confidence, exhibit attendance, and other demographic and psychographic factors. The transformed values for the confidence items were used as the outcome variables in the linear regressions, with each regression using one set of rescaled confidence ratings as the dependent variable.

The covariates, or independent variables, included in each of the five regression models conducted on the confidence items were the same: exhibition attendance, whether visitors used science in their daily work, gender, visitor interest in science, age, prior exposure to nano, education level, and income level. These independent variables differed in range, as seen in Table 20 below. Other factors, including ethnicity, languages spoken at home, and the presence or absence of a disability, were not included in the regression analyses due to lack of variability within visitor responses.

Table 20: Summary of Numerical Ranges for Variables Included in the Linear Regression of Confidence Items

Variable	Numerical Range	Comments
Exhibition attendance	0 or 1	0 = no attendance 1 = exhibit attendance
Science at work	0 or 1	0 = does not use science in daily work 1 = does use science in daily work
Interest in science	0 to 10	Scale
Previous exposure to nanoscience	0 to 10	Scale
Gender	0 or 1	0=female 1=male
Age	Varies	Number reported by visitor
Education	0 to 5	Closed-ended question with 5 increasing levels
Income	0 to 12	Closed-ended question with 12 increasing levels

The results of the linear regression analysis suggested that exhibit attendance had a positive relationship with visitor confidence ratings for each of the confidence items asked in the survey (as demonstrated by model coefficients that were statistically significant at either the $p<0.05$ or the $p<0.01$ levels). Other factors, including education level, whether visitors used science in their daily work, visitor interest in science, and prior nano exposure, also demonstrated positive associations with the confidence items in the regression analysis.

It is important to note that we did not focus heavily on the magnitude of the significant coefficients of this, or any other, linear regression conducted in the study. Instead, we were more concerned with the general type of association – positive or negative – each factor in the model had with the outcome variable. Our intent was to simply explore the presence or absence of these relationships and speak about their overall nature, not to compare them to one another in order to make claims about one factor having more or less of an effect on the outcome than another factor. An overview of the regression model can be seen in Table 21 below, and more detailed tables reporting specific values for model coefficients can be seen in Appendix H.

Table 21: Summary of Significant Coefficients Within Linear Regressions Performed on Each Confidence Item (3 Locations Pooled)

Topic	Exhibition Attendance	Science at Work	Interest in Science	Previous Exposire to Nanoscience	Gender	Age	Education	Income
Name a nanoscale sized object	√ (+)		√ (+)	√ (+)				
Describe one way that nanoscale objects behave differently than other objects	√ (+)	√ (+)	√ (+)	√ (+)				
Describe a process used to produce objects at the nanoscale	√ (+)	√ (+)	√ (+)	√ (+)				
Name an application of nanoscale science	√ (+)		√ (+)	√ (+)				
Explain some risks and benefits of nanotechnology	√ (+)	√ (+)	√ (+)	√ (+)				

Open-Ended Data on Changes in Levels of Nanoawareness

When asked to complete the statement "Nanoscale science is the study of . . .?" some participants answered in ways that matched the official definitions of nanoawareness. Visitor definitions from were coded for the absence or presence of all the nanoawareness categories. In coding these responses the evaluation team was strict but not restrictive. For instance:

- For small, responses needed to indicate that items were small, but a specific definition using metric measurements was not required.
- For different, some indication of different behavior was required, but examples (e.g., different effects of gravity) were not needed.

For the most part, visitors responded with one idea: nano means small. Table 22 shows aggregated data:

Table 22: Nano Awareness in NISE Net Exhibits, Pooled Data

	Pre-Interviews (n= 132)	Post-Interviews (n=181)
1a: Nano is small.	72%	71%
1b: Nano is different.	2%	4%
2: Nano is manipulating matter with control.	7%	7%
3: Nano appears in new applications and technologies.	8%	12%
4: Nano involves risks and benefits	1%	2%
Don't know	11%	12%
Other	20%	12%

When disaggregated by location, notable differences include the higher levels of the "nano is small" and "nano is about applications" definitions in the Portland post-sample.

Table 23: Nano Awareness in NISE Net Exhibits, by Location (Percents Are Percents within Location)

	Pre-Interviews	Post-Interviews
1a: Nano is small.		
Boston	68% (n=56)	67% (n=55)
Little Rock	68% (n=25)	65% (n=66)
Portland	78% (n=51)	80% (n=60)
1b: Nano is different.		
Boston	0% (n=56)	6% (n=55)
Little Rock	4% (n=25)	3% (n=66)
Portland	2% (n=51)	5% (n=60)
2: Nano is manipulating matter with control.		
Boston	7% (n=56)	11% (n=55)
Little Rock	4% (n=25)	2% (n=66)
Portland	8% (n=51)	8% (n=60)
3: Nano appears in new applications and technologies.		
Boston	9% (n=50)	6% (n=55)
Little Rock	16% (n=26)	12% (n=66)
Portland	4% (n=51)	17% (n=60)
4: Nano involves risks and benefits.		
Boston	0% (n=56)	2% (n=55)
Little Rock	0% (n=25)	0% (n=66)
Portland	2% (n=51)	3% (n=60)
Don't know		
Boston	11% (n=56)	22% (n=55)
Little Rock	16% (n=25)	12% (n=66)
Portland	8% (n=51)	2% (n=60)
Other		
Boston	21% (n=56)	9% (n=55)
Little Rock	16% (n=25)	15% (n=66)
Portland	20% (n=51)	10% (n=60)

*Visitors' responses may have been placed in more than one category, therefore percentages may not add to 100%.

The prevalence of "small" in the definitions offered by both those who have seen the exhibition and those who haven't is important, as it is higher than anticipated by many involved in the project. As a brief answer to an interviewer's question, it's effective and accurate (if not exhaustive) and should not be interpreted as a complete account of how visitors understand nano, but instead as a reflection of what people seem to associate most with nano.

Coded loosely, as was done here, there are only small differences in how people who have seen the exhibits conceive of nano when compared with those who have not seen the exhibition. One important result to note is the higher rate of "I don't know" responses and lower rate of "other" responses in Boston among those who had seen the exhibition; the lower rate of "other" (usually inaccurate) responses may suggest visitors who had seen the exhibition were able to speak more knowledgably about nano, but the higher rate of "I don't know" responses is in opposition to this finding.

Further analysis, using binary logistic regression, was performed on categories where either pre- or post-visitors responded at a rate of 15% or above. This percentage was set as an initial cutoff in order to prevent unbalanced regression analyses that produced unreliable models. The regression allows for a better sense of the different relationships between visitor awareness of "nano is small," exhibit attendance, and other demographic and psychographic information such as age, gender, prior nano exposure, whether visitors used science in their daily work, and visitor interest in science. Instead of linear regression, however, we chose to implement logistic regression given the binary ("1" or "0," coded as an instance of "nano is small" or not) form of the outcome variable. Instead of producing linear coefficients as linear regression does, logistic regression produces odds ratios that indicate how likely an outcome is to occur in the presence (or unit increase in) a predictor variable. An overview of the regression can be seen in Table 24 below, which identifies any significant odds ratios in the model.

Table 24: Summary of Significant Odds Ratios Within Logistic Regressions Performed on Nano Awareness Items for the Pooled Exhibition Data

	Exhibition Attendance	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age
Nano is small				√ (+)		

In this regression, only one factor, prior nano exposure, was shown to have a significant odds ratio, suggesting that the more visitors have heard about nano before the exhibition experience, the more likely they would be to associate nano with "small." In addition, the regression suggests exhibit attendance did not have a significant effect on the definition offered by visitors to the prompt "Nanoscale science is the study of…." This is, perhaps, not surprising given the percentages reported in Table Z above, which shows a high percentage of museum visitors who have not seen the exhibition already associate nano with "small."

Again, as with the significant coefficients found in the linear regression models, it is important to note that we did not focus heavily on the magnitude of the significant odds ratios of this, or any other, logistic regression conducted in the study. Instead, we were more concerned with the general type of association – positive or negative – each factor in the model had with the outcome variable. Our intent was to simply explore the presence or absence of these relationships and speak about their overall nature, not to compare them to one another in order to make claims about one factor having more or less of an effect on the outcome than another factor.

Answering the Evaluation Questions

- How many museum visitors have heard of nano before visiting the exhibit or seeing the program? At what levels do these visitors show nanoawareness?
- Do visitors to the NISE exhibits or programs show higher nanoawareness, using the NISE Net definition?
- Where do museum visitors get information on nanotechnology and nanoscience?

Visitors to the museums (both those at the exhibition and those elsewhere in the museum) have generally heard something about nanotechnology, at levels higher than in the general population. Those who have not seen the exhibition express low levels of confidence in their abilities to do five things that would indicate some knowledge about nanoscale science, engineering, and technology. In open-ended definitions of nano, they seem to show awareness of the existence of something called nanoscience or nanotechnology that has to do with small things, but little understanding of what it's really about beyond that general idea.

Visitors who have seen the exhibition show a statistically significant difference in their confidence in their ability to explain something about nano in ways that matter to NISE Net – they show a difference in nanoawareness. Specifically, visitors who have seen the exhibition demonstrate greater confidence in naming a nanoscale sized object, describing how nano objects behave differently, describing a process used to produce objects at the nanoscale, naming applications of nano, and explaining some risks and benefits of nano.

Responses to open-ended questions reveal the widespread cultural understanding (among museum visitors, at least) that nano means small, and show that this definition is true both among those who see the exhibit and those who don't. Importantly, the groups who have seen the exhibition define nano in the same way those who have not define nano, even as they express higher confidence in their ability to discuss various aspects of nano. This may reflect the way the open-ended question was asked ("Nanoscale science is the study of small things" is an adequate and accurate if not exhaustive answer), it may suggest that visitors perceive that additional knowledge (about applications, for instance) is not the most important thing to know about nano, or it might suggest that the confidence they express cannot be backed up with more specific definitions.

The question about where visitors learn about nano is explored in the section "Learning about nano beyond the museum," beginning on page 86.

Understanding: Exhibition

Evaluation Questions

- How well do general museum visitors understand nanoscale science, engineering, and technology?
- How do these understandings differ for visitors who have seen the exhibit or program?
- How do these understandings connect to the specific exhibits or program seen?
- What alternative conceptions exist?

In this section, we present data that suggest museum visitors understand that nano means small, some with scientific accuracy, many in general terms, and some with inaccuracies in that definition. While coarse definitions of nano given by those who have seen the exhibition don't differ from those given by non-exhibition-viewing visitors, responses to other interview questions regarding nano in the everyday world do differ, suggesting that exhibit visitors have a more nuanced and sophisticated understandings of nano science, engineering, and technology.

Definitions of Nano Reveal Further Conceptual Understanding

Some open-ended definitions of nano were recoded to account for detail and for differentiated understanding of nano within and beyond the broader nanoawareness categories. Any nanoawareness category that was present in more than 10% of the pre- or post-sample was reexamined with a more differentiated and nuanced coding scheme. For the exhibition data, only nanoawareness items 1A (small) and 3 (applications), and the category of "other" appeared often enough to meet this criterion.

Within the "small" nanoawareness categories, we coded to differentiate between generic descriptions (for instance, nano is "small"), alternative conceptions (for instance, nano is "Cellular sized machines"), and specific and/or scientific explanations ("A billionth of a meter, a nanometer"). Coding results can be seen in Table 25 below.

Table 25: Nuanced Coding of Visitors' Understanding of "Nano is small"

	Pre-Interviews			Post-Interviews		
	Overall N= 132			Overall N= 181		
	n	*% within*	*% overall*	*n*	*% within*	*% overall*
Nano is Small	***95***		***72%***	***128***		***71%***
Generic Understanding	64	67%	48%	95	35%	53%
Alternative Conceptions	14	15%	11%	18	14%	10%
Scientific Understanding	17	18%	13%	15	12%	8%

Within the "applications" nanoawareness categories, we coded to differentiate between generic descriptions (for instance, nano is "about applications), alternative conceptions (for instance, nano "can make a thing have a strong power"), and specific and/or scientific applications (nano is used in "creating a material that is impervious to water"). Coding results can be seen in Table 26 below.

Table 26: Nuanced Coding of Visitors' Understanding of "Nano is about applications"

	Pre-Interviews			Post-Interviews		
	Overall N=	132		Overall N=	181	
	n	% within	% overall	n	% within	% overall
APPLICATION	11		8%	21		12%
Generic	8	73%	6%	14	66%	8%
Alternative Conceptions	0	0%	0%	0	0%	0%
Specific, viable examples	3	27%	2%	7	33%	4%

The general category of "other" responses was also dissected to separate responses which simply repeated words from the question ("nanotechnology"), showed misconceptions that did not fit into the above categories (nano is "gold/laser"), repeated general words about science (nano is "new technology"), referred to the future ("nano is the future"), or responded in some other way ("I would tell them to Google it").

*Table 27: Nuanced Coding of Visitors' Responses Originally Coded as "Other" for Nano Awareness**

	Pre-Interviews			Post-Interviews		
		Overall n=	132		Overall n=	181
	n	% of NA code	% Pre-interviews	n	% of NA code	% Post-interviews
OTHER	26		20%	21		12%
isolated nano vocabulary	9	35%	7%	5	24%	3%
alternative conceptions	13	50%	10%	10	48%	6%
general science/tech	6	23%	5%	14	67%	8%
related to the future	0	0%	0%	3	14%	2%
not related to nano	0	0%	0%	2	10%	1%

*Visitors could be coded for more than one nuanced response category.

Visitor Understanding of Exhibit Content

Interviewers asked visitors to describe the main message from the exhibit in their own words as a measure of how visitors interpreted what they had experienced. Table 28 shows that the largest number of visitors at each location interpreted the message of the exhibition as applications of nanoscience in everyday life or the medical field. Comments such as "just the technology" were placed in the Technology category. Several visitors mentioned new research, a category that also included comments such as "the future of nanoscience."

Table 28: Categorized Interviewee Responses to "In Your Own Words, What Would You Say the Exhibit was Trying to Show Visitors?"

	Post-exhibit Boston, MOS (n=55)	Post-exhibit Little Rock, (n=66)*	Post-exhibit Portland, OMSI (n=60)
Nano means small	7.3%	7.6%	8.3%
"Technology"	40.0%	22.7%	10.0%
Everyday applications of nano	36.4%	19.7%	43.3%
Medical applications of nano	38.2%	21.2%	35.0%
New research/future work	18.2%	6.1%	15.0%
Risks and benefits of nano	7.3%	0.0%	5.0%
Other	12.7%	6.1%	21.7%

* Interviewees' responses may have been placed in more than one category, therefore percentages may add to more than 100%.

Visitor perceptions of the goals of the exhibits reflect close enough to the original intent to suggest that visitors are understanding and processing the messages intended.

Content Knowledge Beyond the Exhibition

An object-sorting task in the interview offers insight into how visitors operationalize their definitions of nanoscience. While originally intended mainly as a warm-up for visitors before asking their definitions of nano, the evaluation team found in examining responses that they offered additional information about how visitors understand nano.

Interviewers presented the following items to pre- and post-visitors:

- An iPod Nano
- A doll-sized pair of Nano-Tex pants that were described as stain resistant
- CVS Pharmacy zinc oxide skin protectant ointment, not intended or described as a sunblock
- Coppertone Kids Continuous Spray Sunscreen, described as "spray-on sunscreen with zinc oxide"
- Silver Works ionic colloidal silver, described as colloidal silver as a treatment for burns, cuts or teeth
- A single cabbage leaf in a zipper-lock bag
- L'Oreal Paris Infallible Never Fail Powder, described as makeup with sunscreen
- Flex-pak clean scent topical cream by Flex Power (not included in Little Rock interviews)

A more detailed description of items can be found in Appendix B. Items were not described in any pre-determined order. Visitors were then asked to sort the objects into two piles, one containing items that exhibited nanoproperties or contained nanotechnology and another containing items that did not exhibit nanoproperties or contain nanotechnology. If visitors hesitated to start the sorting process, they were offered the option of a "don't know" pile. After finishing their sorting, they were asked to explain their process.

Many visitors appeared to use some sort of organizing system or systems for sorting their objects, and in their explanations would make this explicit. Coding for this organizing system was developed using Grounded Theory (Strauss & Corbin, 1998), through discussion between authors Gina Svarovsky and Marjorie Bequette. After several iterative cycles of reviewing the data and discussing themes, six main reasoning categories for sorting the materials emerged:

- nano products have special ingredients or components ("These have special particles in them");
- nano products belong to a type or class of product ("These are all electronic" or "These are all applied to your skin");
- nano products have to do with being small ("This has some really small circuitry in it");
- nano products are human-made and inorganic ("This is just cabbage, it happens naturally");
- nano products act differently or have improved performance as compared to other products ("This isn't ordinary, it resists water better"); and
- nano products have been on the market for a shorter period of time ("Zinc Oxide has been around since I was a kid, but this other sunscreen hasn't").

Frequencies of visitor responses can be seen in Table 29 below.

Table 29: Visitor Reasoning Behind the Sorting of Nano and Non-Nano Items (Sorting Question, Reasoning)

	Pre-interviews *n=132**	Post-interviews *n=181**
Product ingredients or components	50.8%	56.9%
Nano is a type or class of product (e.g., electronics)	50.0%	36.5%
Nano products have to do with "small"	42.4%	44.2%
Nano products are human-made, inorganic	37.9%	20.4%
Improved or different product performance	20.5%	30.9%
Time on market/familiarity with product	6.8%	8.8%
No reasons provided	8.3%	6.6%
Other	13.6%	12.7%

Responses could be coded for more than one category.

In the post-sample, a higher percentage of visitors identified items involving nanoparticles or nanotechnology based on product ingredients/components as well as improved/different performance than in the pre-sample. In addition, in the post-sample, a lower percentage of visitors sorted items according to the type of product or item, (e.g., electronics), suggesting a more sophisticated understanding and recognition of nano in everyday technologies. In particular, only 23% of visitors in the post-sample used the "nano is only about human-made items" reasoning as compared to the 39% of visitors that did so in the pre-sample.

Alternative conceptions can inform future nano programming. Important alternative conceptions to note that appeared among at least a few visitors include:

- That nano is only in electronic objects
- That nano is equivalent to sun protection
- That nano is only in manmade things
- That nano is a only chemical additive or coating
- That nano is only associated with newly released products on the consumer market

When the lack of difference in previous exposure to nano for pre- and post-sample visitors are taken into consideration, the differences shown here suggest that visitors who have seen the exhibition bring additional nano knowledge to new topics not specifically treated by the exhibition; they use different operational definitions of nano that suggest greater knowledge.

Answering Evaluation Questions

- How well do general museum visitors understand nanoscale science, engineering, and technology?
- How do these understandings differ for visitors who have seen the exhibit or program?
- How do these understandings connect to the specific exhibits or program seen?
- What alternative conceptions exist?

Many museum visitors understand that nano means small, some with scientific accuracy, many in general terms, and some with inaccuracies in that definition. This is true of those who have seen the exhibits and those who have not.

Visitors reported exhibit goals that matched intended goals closely enough to suggest that they understood the exhibits and that these ideas emerged from the exhibits, and in fact many of these ideas (e.g., improving existing technologies, nano in nature) are strong messages of individual exhibit elements.

While definitions given by those who have seen the exhibition don't differ from those given by non-exhibition-viewing visitors, the techniques offered by those who saw the exhibition for identifying nano in the everyday world do differ, suggesting that they have understandings of nano that incorporate more sophisticated ideas – that nano involves smaller particles in action, that nano is about improving existing technologies, that nano is in nature as well as in human-made technologies.

Even so, alternative conceptions about nano are expressed by visitors who have seen the exhibits and by those who have not. These notions should be further explored and central ones addressed specifically in future work.

Relevance: Exhibition

Evaluation Questions

- Does the general museum visitor think of nano as relevant?
- Do visitors find the exhibition/programs relevant to their everyday lives?
- What elements make the exhibits or programs relevant to visitors? (Topics, approaches, etc.)
- Do the exhibits or programs make nanoscale science, engineering, and technology seem more relevant to visitors' lives?
- How do visitors envision interacting with nano in the future?

In this section, we present data that suggest nano has only moderate levels of relevance for museum visitors who had not seen the exhibition, while visitors who had seen the exhibition indicated a higher level of connection to nano topics than those who had not.

Connections to the Exhibition

Interviewers asked post-exhibition visitors if they connected to anything in the exhibition. Of the 181 visitors queried, 61.9% said yes, 24.3% said no, and 1.1% answered that they didn't know. If visitors responded yes and gave a specific reason, their response was sorted into categories shown in Table 30.

Across the three sites, medical information was the most prevalent reason visitors connected with the exhibition – not surprising given the focus on medical applications in several individual exhibits. Keep in mind that this does not tell us that medical relevance is the most effective of all possible connections to visitors' lives, only that among the things that were attempted in this exhibit, medical connections often worked.

Table 30: Visitor Connections to Exhibit

	Post-Interviews *n=112**
Career relevance	26%
Medical relevance	79%
Other	27%

Responses could be coded for more than one category.

Connection to Nano

Museum visitors were asked how well different topics related to their lives. Their answers, on a scale of 0-10, indicate that those who had **not** seen the exhibition saw some connection with nano but not a particularly strong one. (The topics have been rearranged here to group the nano terms; on the survey these terms were randomly interspersed with the other topics.)

For those who had seen the exhibition, their reported connection to topics not associated with nano ('non-nano topics') does not differ greatly from the pre-exhibit group, but their reported connection to nano topics appears to be higher. Visitors who had seen the exhibit rated all topics as more connected to their lives, but the differences were small for the non-nano topics. All topics on this list were covered in some part of the exhibition (exhibit elements explored nano on butterfly wings, for instance), so the higher difference for nano topics cannot be attributed only to having just thought about the topic.

Table 31: Mean of Visitor Responses to "How Well Do Each of the Following Topics Connect to Things In Your Everyday Life That You Know or Wonder About?"

Topic	Pre-exhibit survey (n=238)	Post-exhibit survey (n=257)
Butterfly wings	4.11	4.10
Cancer treatments	6.45	6.57
Repairing bone and nerve tissue	6.32	6.42
Nanoscience	5.01	5.62
Nanotechnology	5.71	6.14
Nanomedicine	5.56	6.23

Further analysis, using linear regression, was performed on this data to get a better sense of the different relationships between visitor connection to nano and non-nano topics, exhibit attendance, and other demographic and psychographic information such as age, gender, education level, income level, prior nano exposure, whether visitors used science in their daily work, and visitor interest in science.

Because we wanted to compare how well visitors connected to nano topics in comparison to non-nano topics, we pooled visitor ratings into two corresponding comparison groups: nano topics (nanoscience, nanotechnology, and nanomedicine) and non-nano topics (butterfly wings, cancer treatments, and repairing bone and nerve tissue). Ratings for the three topics in one group were added together to get a new score, potentially adding to 30 if each topic within a group was rated by the visitor as a 10. Pooling the data in this way reflected our desire to examine how visitors connected to nano topics generally at the aggregate level, instead of focusing on each specific nano topic at the individual level.

The outcome variable for the linear regression was the *difference* between the pooled ratings for the nano topics and the non-nano topics. In other words, for a given visitor who answered this question, the visitor's pooled ratings for the three non-nano topics were subtracted from the same visitor's pooled ratings for the three nano topics, as seen in Equation 1:

$$Y = (\text{Pooled ratings for nano topics}) - (\text{Pooled ratings for non-nano topics}) \quad [1]$$

Because we used the difference between the pooled ratings as the outcome variable for the linear regression, any significant coefficients in the model would point to a relationship between this difference and a given factor.

Once the outcome variable was computed, a linear regression was performed. The resulting model is summarized in Table 32 below.

Table 32: Summary of Significant Coefficients Ratios Within a Linear Regression Model Exploring Relationships Between Factors and the Relevance of Nano for Pooled Exhibition Data

	Exhibition Attendance	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age	Education	Income
Difference between connection ratings for non-nano and nano Topics	√ (+)			√ (+)				√ (+)

The significant and positive coefficients in the regression model suggest that exhibit attendance was associated with a difference in visitor connection to nano topics. Two other factors, household income and prior nano exposure, also demonstrated associations with visitor connection to nano topics in the regression analysis.

Because both the nano and non-nano topics were included in the exhibition, the results suggest that in learning about nano, visitors may see relevance in new ways, whereas they do not learn new ways to relate cancer treatments or other non-nano topics (which serve as examples, not as the main message of the exhibition) to their lives through the exhibition.

Nano in real life

One scenario in which visitors might encounter nano in the future is as a consumer. In order to explore a hypothetical situation in which visitors might use information about nano in the future, interviewers asked visitors how they would respond if their dentist decided to use an epoxy or an adhesive on their teeth that utilized nanotechnology. In a follow up question visitors were asked how they would react to another product that utilized nanotechnology after their original questions were answered. (This product varied by location: in Boston and Portland, it was makeup; in Little Rock it was a tool for applying the dental adhesive.)

Although this is only one scenario of many possible ways that people can interact with nano in the real world, playing it out with visitors helps to show both the content that visitors know about nano but also some other ways that they might use nano information or hope for better nano knowledge to help with everyday decision-making – as close as we can get to relevance in action.

The interviews reveal common concerns in both those who had seen the exhibits and those who had not; the concerns include safety, how the product works, how well it works, and how long the product has been on the market. Visitors also suggested that they would need to know more about what nano is to make an informed decision, that endorsements by professionals or professional organizations would reassure them, or that knowing the ingredients would be important. Some visitors reported no concerns about the product.

Differences between the two groups suggest that viewing the exhibition changed the ways that visitors understand nano and view its role in their lives.

- Safety is the most important issue for visitors in both the pre- and post-sample and levels of concern do not change appreciably.
- A smaller percentage of visitors in the post-sample (24%) were concerned were how the dental resin worked than in the pre-sample (27%). This might suggest that the exhibits helped some visitors be more comfortable with how nanotechnology is commonly deployed in products and as such they may have less concerns about details involved with how the resin actually works.
- A higher percentage of post-sample visitors (28%) wanted to know more about the effectiveness of the product than visitors in the pre-sample (19%), perhaps suggesting that the exhibits helped visitors be more attentive to effectiveness when evaluating the tradeoffs of using a product.
- A lower percentage of visitors in the post-sample (3%) asked "What is nano?" when confronted with the dental resin than in the pre-sample (15%). This suggests that the exhibits helped visitors develop an initial understanding of nano that they could use and apply beyond the exhibit.
- The issue of "time on market" was notable for several reasons. A lower percentage of post-sample visitors (8%) would ask about how long the dental resin was in use as compared to the pre-sample visitors (10%). However, a higher percentage of post-sample visitors (9%) wanted to know about how long the second product was on the market than in the pre-sample (2%). The response might also reflect the nature of the product, and since the set of items varied by location, this number should be interpreted skeptically.

Table 33: Relevant Consumer Issues and Questions About Specific Examples of Nanotechnology as Reported by NISE Exhibit Visitors (Dental Question/Additional Nano Product Question)

	Pre-interviews *n=132**	Post-interviews *n=116**
Safety		
Dental Resin	66%	65%
Other nano product	22%	20%
How does it work		
Dental Resin	27%	24%
Other nano product	9%	8%
Effectiveness		
Dental Resin	19%	28%
Other nano product	4%	3%
Endorsements		
Dental Resin	15%	17%
Other nano product	14%	15%
What is nano		
Dental Resin	15%	3%
Other nano product	8%	2%
Ingredients		
Dental Resin	12%	16%
Other nano product	11%	9%
Time on market		
Dental Resin	10%	8%
Other nano product	2%	9%
No questions/concerns		
Dental Resin	2%	6%
Other nano product	14%	18%
Other		
Dental Resin	25%	8%
Other nano product	25%	8%

* Responses could be coded for more than one category.

Evaluators inquired about the second product in order to understand whether visitors view nano as a monolithic technology with a single mechanism and unified risks and benefits, or whether visitors more appropriately view each nanotechnology as a separate thing to be considered. This measure is a rough but suggestive one, because the nature of the first and second products can influence how people consider them. Because the first product in this scenario was suggested by a professional, some visitors considered that it had been endorsed and did not need to be questioned; the same was not true of the products used in Boston and Portland interviews. Separating these by location allows for a more nuanced view of visitor responses. Interviewers said, "Assuming that your concerns about the first products were answered to your satisfaction, would you have questions about the second product?," so even visitors who said they would ask the same questions about the second product are expressing that the products carry different risks and benefits.

Table 34: Additional Relevant Consumer Issues and Questions About Specific Examples of Nanotechnology as Reported by NISE Exhibit Visitors (Additional Nano Product Question) – LITTLE ROCK

	Pre-interviews *n=25**	Post-interviews *n=66**
No questions/concerns	16%	23%
Would ask generally the same questions	40%	27%
Questions about 2nd product are related to its different use or purpose	8%	11%
Would not use 2nd product	0%	0%

* Responses could be coded for more than one category; only particular themes of interest were reported in this table.

Table 35: Additional Relevant Consumer Issues and Questions About Specific Examples of Nanotechnology as Reported by NISE Exhibit Visitors (Additional Nano Product Question) - BOSTON

	Pre-interviews *n=56**	Post-interviews *n=55**
No questions/concerns	5%	11%
Would ask generally the same questions	32%	42%
Questions about 2nd product are related to its different use or purpose	14%	16%
Would not use 2nd product	11%	7%

* Responses could be coded for more than one category; only particular themes of interest were reported in this table.

Table 36: Additional Relevant Consumer Issues and Questions About Specific Examples of Nanotechnology as Reported by NISE Exhibit Visitors (Additional Nano Product Question) - PORTLAND

	Pre-interviews *n=51**	Post-interviews *n=60**
No questions/concerns	24%	20%
Would ask generally the same questions	33%	23%
Questions about 2nd product are related to its different use or purpose	41%	33%
Would not use 2nd product	6%	10%

* Responses could be coded for more than one category; only particular themes of interest were reported in this table.

Overall, these results broadly suggest that visitors were able to connect with nano products from a consumer perspective and ask a wide range questions about them. Many visitors treat different products differently, suggesting they see nano risks and benefits as individual to the product in question, not as identical across all products. Interesting differences in the most notable aspects of the products or their use existed between visitors who had seen the exhibition and those who had not, pointing to several potentially fruitful areas for future study.

Answering Evaluation Questions

- Does the general museum visitor think of nano as relevant?
- Do visitors find the exhibition/programs relevant to their everyday lives?
- What elements make the exhibits or programs relevant to visitors? (Topics, approaches, etc.)
- Do the exhibits or programs make nanoscale science, engineering, and technology seem more relevant to visitors' lives?
- How do visitors envision interacting with nano in the future?

Nano has only moderate levels of relevance for museum visitors who had not seen the exhibition. About two-thirds of visitors found the exhibition relevant, largely because of the medical content or connections with their own work. This fraction is lower than the fraction that found the exhibit interesting, supporting the idea that relevance is one way to create interest, but not a requirement for visitors to be interested.

Visitors who had seen the exhibition indicated a higher level of connection to nano topics than those who had not, perhaps developing new understandings of why nano might be relevant to their lives in the future. (This difference was not seen to the same degree for non-nano topics also included in the exhibition.)

One way that people might interact with nano in the future – as consumers – was explored in more depth. Visitors appear to draw on their content knowledge in these scenarios, but also rely on a larger web of information about product regulation and marketing, their personal values, and other information in their decisions about how to use nano.

Further information about how visitors might learn about nano in the future is found in the section "Learning about nano beyond the museum," beginning on page 86.

Children and the Exhibition

In Pine Bluff, Arkansas, the majority of museum visitors are school groups, allowing for an examination of how children interact with this exhibit in one particular setting. This cannot be used to extrapolate to all children seeing the nano exhibition, of course.

Full demographics charts are included in Appendix F. Of note is that this group includes 5-12 year olds, with 62% of student in the 9-12 category. Over three-fourths (78%) of students reported their ethnicity as African-American. When asked about their interest in science, the children reported comparable levels (mean = 7.54, standard deviation = 2.99, on a 0-10 point scale) to adult visitors in Boston, Little Rock, and Portland.

Over two-thirds of students rated the exhibition as more interesting than others they had seen that day (see Table 37). Their rankings of enjoyment, as seen in Table 39, are also enthusiastic, well beyond the levels expressed by adult visitors in Boston, Little Rock, and Portland (as seen in Table 9 on page 29).

Table 37: Interest Level of Nano Exhibit Compared to Other Exhibits (n=62)

	Percent of visitors
More interesting	69%
Less interesting	31%

Table 38: Exhibit Level of Enjoyment (n=74)

	Percent of visitors
Yes, I would tell my friends to see it.	80%
It was fine, but not great.	5%
It was okay.	14%
No, it was boring.	1%

Table 39: Percent of Respondents Choosing Each Answer for "How enjoyable was the exhibit?" by Location

Response options	Post-exhibit Boston, MOS (n=126)	Post-exhibit Little Rock, MOD (n=74)	Post-exhibit Portland, OMSI (n=98)
It was so enjoyable I'd encourage others to see it.	42.9%	48.6%	35.7%
It was enjoyable.	55.6%	48.6%	62.2%
I didn't really enjoy it.	1.6%	2.7%	2.0%
I didn't find it enjoyable at all.	0.0%	0.0%	0.0%

Students marked their favorite elements, as shown in Table 40 (these are not adjusted for which elements they actually saw, as was done in the report on adult favorites). The top pick is a highly interactive exhibit: magnetic pieces move around an air hockey table, demonstrating the principle of self-assembly. The video elements and Unexpected Properties (which shows how particles of different sizes appear to have different colors), ranked lower for this group.

Table 40: Favorite Part of the Exhibit (n=74*)
*Visitors were asked to check all that apply.

	Percent of visitors
Creating Nano Materials	46%
Changing Colors	38%
Treating Disease	32%
Detecting Disease	30%
Nano Buzz	28%
Intro to Nanotechnology Video	27%
Regenerating Tissue	27%
Bump and Roll	22%
NanoMedicine Explorer Kiosk	20%
Intro to Nanomedicine Video	19%
Unexpected Properties	18%

These children rank their previous exposure to nano more frequently at the extremes than adults in our comparison study do:

Table 41: Heard About Nanoscale Science Before Today (n=71)

NISE Net study		*Hart study*	
Rating scale	**Visitors (n=71)**	**American adults**	**Rating scale**
I hear about it all the time (9-10)	28.2%	9%	A lot
I hear about it often (5.5-8)	19.7%	22%	Some
I have heard about it a few times (2-5.5)	12.7%	31%	A little
I have never heard about it (0-1)	39.4%	37%	Nothing

The extremes expressed by children are seen in other studies we have done with children as well.

Unlike the adult data, where we were able to compare visitors who had seen the nano exhibition with those who had not, all these students had seen the exhibition. Their responses suggest that they feel some confidence about discussing some aspects of nano, but they must be interpreted with caution due to the lack of a comparison group.

Table 42: Questions Able to Answer

	I could not answer (0-2)	It would be hard (3-5)	I think I could do it (6-8)	I am sure I could do it (9-10)
Name a nano-sized object. (n=70)	16%	24%	**34%**	26%
Tell one way nanoscale things are different from other things. (n=70)	17%	**34%**	26%	23%
Tell how nanoscale science is used in real life. (n=67)	21%	22%	25%	**31%**
Tell how you make stuff nanoscale. (n=68)	28%	**29%**	22%	21%
Tell some good and bad things about nanoscience. (n=70)	19%	16%	31%	**34%**

Students were also asked about how interested they were in learning about different topics. Note that this question is different than the similar one asked of adults; it inquires about future engagement with nano as a learner but does not reflect whether students consider that nano connects with their lives. Nano topics scored about as well as medical topics and better than butterfly wings.

Table 43: Topics Interested in Learning About

	Percent of visitors
Cancer treatments (n=68)	79%
Repairing bones or nerves (n=67)	79%
Butterfly wings (n=65)	60%
Nanoscience (n=70)	83%
Nanotechnology (n=66)	77%
Nanomedicine (n=66)	70%

Finally, students were asked about something important they had learned from the exhibition. 46% of students referred to nano in their responses in a range of ways:

- That nano is very small and we are made up of them
- I did not know nano was little and I learn about nano
- Nanoparticles
- Liquids roll off of nano. It will not stain

While these responses range in their scientific detail and accuracy, they at least include the idea of nano.

Another significant subset (14%) discussed tumors and disease and most likely reflect the medical exhibits within the nano exhibition.

- You could kill tumors
- That you can cure disease by eating silver

Of the other responses, many likely reflect other exhibitions students saw. 13% discussed GPS and tracking, 5% discussed rodents, 7% referred to science generically, 2% (one student) said he or she didn't know, and the rest (13%) gave uncategorizable responses.

Overall, many students seem to show a connection between what they saw and the big idea of nanotechnology. They report positive interactions with the exhibition, and express confidence in their knowledge, though that confidence must be interpreted with caution.

Findings: Programs

Introduction

Program descriptions are provided in the Appendix B of this report. Titles and approximate length of each program are provided in Tables 44, to remind the reader how much time presenters had to deliver their main message.

Table 44: Approximate Length of Programs

Program Title	Approximate length of program (min)
Intro to Nano (cart)	10-15
Magic Sand	5
Exploring Forces—Gravity	5
Exploring Properties—Surface Area	5
Exploring Products—Nano Fabric	5
Electric Squeeze	5
Attack of the Nanoscientist	10-15
Intro to Nano (stage)	15-20
Treating Tumors with Gold	15-20
Energy and Nanotechnology	15-20

Pre-program survey data was collected using a long and a short survey in order to provide a comparison sample for each group. No visitor completed both surveys. These surveys were collected throughout the museum, by randomly approaching visitors, and also by asking adults supervising children watching other theater productions at the Atrium Stage to complete a survey during the program. More pre-Short program surveys were collected on the museum floor and more pre-Long program surveys were collected at the Atrium Stage (because these visitors were sitting down for a long enough period of time to complete the survey). During data analysis, comparisons were focused on pre- and post-survey differences within a given program length; in other words, Short program pre-surveys were only compared to Short program post-surveys, and Long program pre-surveys were only compared to Long program post-surveys.

Demographics: Programs

Pre- and post-program visitors were compared on a number of demographic measures. Questionnaires for the Short programs did not contain as many demographic questions as the longer questionnaires because of their shorter overall length.

Demographics collected from participants in the pre- and post-Short program surveys include gender, age, ethnicity, and presence or absence of any disability. In addition to these pieces of information, the pre- and post-Long program surveys asked about visitor education level, income level, and languages spoken at home. Both the Short and Long program surveys asked questions about science and nano, including questions about visitor interest in science, their previous exposure to nanoscale science, engineering, and technology, their previous visits to the museum, and any previous visits to nano exhibits or programs at the museum. The Long program surveys also ask about whether or not visitors used science in their daily work.

As with the exhibition data, non-parametric Mann-Whitney U tests were performed on each of the demographic and psychographic indicators to determine whether visitors in the pre- and post-samples were members of the same general population. In most cases, the response categories used in these statistical tests for were the same as those reported by visitors. However, at each location, the data for ethnicity and language included several outlier responses reported by less than 5 visitors. Based on this initial frequency analysis, categories were simplified for ethnicity (into White and Non-white) and language (English and Non-English) for the purposes of the statistical testing.

Some adjustments were also made to the categories used for age and income levels. Visitor ages were categorized into ranges which included Under 21, 21-29, 30-39, 40-49, and 50-59, 60+. Annual household income data were also categorized into ranges, which included Under \$20,000, \$20,000-\$39,999, \$40,000-\$59,999, \$60,000-\$79,999, \$80,000-\$99,999, \$100,000-\$149,999, and \$150,000+.

Greater detail about all the data reported in this section is available in Appendix F.

Short Programs

Mann-Whitney U tests performed on each of the demographic and psychographic indicators examined whether the pre- and post-samples were taken from the same general population. No statistically significant demographic differences were identified in gender, age, presence or absence of a disability, visits to the museum, visits to the nano exhibits in the museum, interest in science, or previous exposure to nano between the Short program pre- and post-samples.

Long Programs

As with the Short program samples, Mann-Whitney U tests performed on each of the demographic and psychographic indicators examined whether the pre- and post-samples for the Long programs were taken from the same general population. No statistically significant demographic differences were identified in education level, presence or absence of a disability, visits to the museum, visits to the nano exhibits in the museum, or use of science in daily work between the Long program pre- and post-samples.

However, statistically significant differences were identified in the Gender, Age, Income, and Previous Exposure to Nanoscience for pre- and post-sample Long program visitors. There were more males in the post-sample (U = 23,899.0; Z = -2.27; p = 0.02), and overall the sampled population appears to be younger than in the pre-sample (U = 22,156.5; Z = -2.96; p = 0.00). Visitors in post-sample for the Long programs also tended to make less annual income than those in the pre-sample (U = 16,685.5; Z = -4.03; p = 0.00). Finally, visitors in the post-sample reported higher levels of previous exposure to nanoscience, engineering, and technology than those in the pre-sample (U = 23,248.5; Z = -2.49; p = 0.01). On average, visitors in the Long program pre-sample reported lower levels of previous exposure to nanoscience (mean = 3.65, standard deviation = 2.535) than visitors in the post-program survey group (mean = 4.26, standard deviation = 2.738).

The differences in pre- and post-samples for the Long program must be considered when examining all Long program results unless otherwise accounted for within regression analysis. A summary of significant demographic differences in pre- and post-samples for both types of programs can be seen in Table 45.

Table 45: Summary of Significant Demographic Differences Between Pre- and Post-samples for Short and Long Programs

	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age	Education	Income	Ethnicity	Disability	Language	Museum Visits	Seen nano ISE
Short programs	N/A				√ **	N/A	N/A			N/A		
Long programs			√ *	√ *	√ **		√ **					

** p<0.01; *p<0.05 levels of significance. Note that not all demographic information was collected from Short program pre- and post-samples.

As noted in the introduction to this report, the Long programs were the element for which we recruited participants the most heavily, using social media outside of the museum itself as well as announcements within the museum. This recruitment brought an audience that was younger, more male, more diverse, lower income, and reported greater previous exposure to nano when compared with the group who had not seen the program.

Enjoyment and Interest: Programs

Evaluation Questions

- Do visitors find the programs interesting and enjoyable?
- What makes the programs interesting or enjoyable?
- Do the programs create additional interest in nanoscale science, engineering, and technology?

In this section, we present data that suggest visitors find these programs quite interesting and somewhat enjoyable, and most programs show higher levels of interest and enjoyment than seen in the formative evaluations. Generally, the programs score higher on interest than enjoyment.

Initial Levels of Interest

Visitors who had not seen a nano program were asked to rate kinds of programs they would be likely to attend on a scale of 1 to 10, with choices that included typical museum topics and one nano program (called Strange Matter). Table 46 shows the central tendencies from both surveys. Paralleling the exhibition pre-surveys, nanoscience received some of the lowest ratings. The only program receiving a lower mean rating was the “Life in the Cretaceous” for the Short program comparison group only.

Table 46: Central Tendencies of Visitor Responses to the Pre-Long Program Survey Asking "How Likely Are You to Attend a Museum Program About Each of the Following Topics?"

Topic	Mean / SD (Short Programs) (n=157)	Mean / SD (Long Programs) (n=197)
Journey to Space: Take a trip to the International Space Station. Investigate how low gravity will impact your muscles and how you will react to being in space.	8.0 / 1.92	7.8 / 2.28
Life in the Cretaceous: Travel back in time 65+ million years and be a dinosaur. Learn about dinosaurs' environment and the plants, animals and insects that shared it.	6.4 / 2.82	6.8 / 2.73
Biomechanics: Fish that project their jaws out to half their body lengths to capture prey? Spider webs stronger than steel? Discover the marvels of natural engineering.	7.0 / 2.37	6.9 / 2.59
CSI - The experience: Go from crime scenes to laboratories and autopsy rooms, bringing to life the most advanced scientific techniques used by today's crime scene investigators.	7.9 / 2.39	7.0 / 3.00
Strange Matter: Zoom to the nanoscale and explore the super small. Manipulated molecules and test new nanotechnologies, like the odor resistant socks and antibacterial teddy bears.	7.1 / 2.60	6.6 / 2.65

Levels of Interest and Enjoyment

Overall, visitors found NISE Net programs to be both interesting and enjoyable. Table 47 shows the percent of visitors' responses to the question, "How interesting was the program you just saw?" Response options included: *I was so interested I'd encourage others to see it, I was interested, but I wouldn't encourage others to see it, I wasn't really interested, I didn't find it interesting at all.* For all the programs, the majority of visitors gave the top rating.

Table 47: Percentage of Visitors Choosing Interest Levels for NISE Net Programs

Program title	Encourage others to see	Interested	I wasn't really interested	Not interesting at all
Intro to Nano (cart) (n=53)	89%	9%	2%	0%
Magic Sand (n=50)	88%	12%	0%	0%
Exploring Forces—Gravity (n=51)	78%	20%	2%	0%
Exploring Properties—Surface Area (n=50)	74%	22%	4%	0%
Exploring Products—Nano Fabric (n=55)	73%	25%	2%	0%
Electric Squeeze (n=50)	80%	16%	4%	0%
Attack of the Nanoscientist (n=100)	68%	21%	10%	1%
Intro to Nano (stage) (n=126)	61%	32%	6%	1%
Energy and Nanotechnology (n=105)	67%	29%	5%	0%
Treating Tumors with Gold (n=119)	85%	13%	2%	1%
Year 4 Overall Summative Program Evaluations	63%	35%	3%	<1%
All formative program evaluations (n=444)	45%	45%	10%	<1%

Two possible comparisons are offered in the last two lines of this table: the Year 4 Summative evaluation and the formative evaluations of all programs. The Year 4 summative evaluation looked at a smaller group of programs, using the same question. Almost all programs included in Year 5 were more highly ranked than the programs evaluated in the Year 4 summative evaluation – only Intro to Nanoscience (stage) was slightly less interesting to visitors. All programs outscored the baseline set by the formative evaluations of nano programs.

Higher ratings went to the Short programs and to the Treating Tumors with Gold Long program. Part of the difference in scores may lie in the design of the programs: Short programs were presented in a more intimate setting, and were more interactive than the lecture-style stage presentations. Attack of the Nanoscientist is an unusual program on this list; it is designed to engage children, and we were not surveying its primary audience and so the lower ratings might be ascribable to that. The high rating of Treating Tumors with Gold is an outlier that is harder to explain given our small sample of stage programs; it might be due to the subject matter (it is more medically focused than the others), the presenter's style, the use of props, or other factors.

Table 48 shows visitors' responses to the question, " How enjoyable was the program?" Response options included: *It was so enjoyable I'd encourage other to see it, It was enjoyable, I didn't really enjoy it, It didn't find it enjoyable at all.*

Table 48: Percentage of Visitors Choosing Enjoyment Levels for NISE Net Short Programs

	Encourage others to see	Enjoyable	Didn't enjoy	Not enjoyable at all
Intro to Nano (cart) (n=52)	63%	35%	2%	0%
Magic Sand (n=50)	74%	26%	0%	0%
Exploring Forces—Gravity (n=50)	64%	36%	0%	0%
Exploring Properties—Surface Area (n=50)	54%	44%	2%	0%
Exploring Materials—Nano Fabric (n=54)	43%	57%	0%	0%
Electric Squeeze (n=50)	48%	48%	4%	0%
Attack of the Nanoscientist (n=100)	44%	49%	5%	2%
Intro to Nano (stage) (n=126)	34%	52%	12%	2%
Energy and Nanotechnology (n=108)	30%	60%	10%	0%
Treating Tumors with Gold (n=119)	62%	37%	1%	0%
Year 4 Overall Summative Program Evaluations	54%	43%	3%	1%
All formative program evaluations (n=339)	40.7%	49.6%	8.6%	0.3%

The majority of visitors found the programs enjoyable in some way, but fewer programs show improvement in enjoyment than improvement in interest, and several show a lower level of enjoyment when compared to formative evaluation and to the group of programs evaluated in Year 4. Fewer visitors gave the highest ranking for enjoyment than for interest. The programs receiving the highest ratings for enjoyment overlap with those receiving the highest rating for interest: Intro to Nano (cart), Magic Sand, Exploring Forces—Gravity, Exploring Properties—Surface Area, and Treating Tumors with Gold. All score as high or higher in the top category as the group of programs evaluated for the Year 4 summative evaluation. With the exception of the Treating Tumors with Gold stage presentation, all are small group presentations, done by one person working closely with a small group of visitors.

Overall, there are still few negative responses (the bottom two categories): for most programs, the percentage giving negative rankings was at or below 4%. Exceptions are: Attack of the Nanoscientist, 7% negative, Intro to Nano (stage), 14%, and Energy and Nanotechnology, 10%. These three programs received lower interest ratings as well.

Answering the Evaluation Questions

- Do visitors find the programs interesting and enjoyable?
- What makes the programs interesting or enjoyable?
- Do the programs create additional interest in nanoscale science, engineering, and technology?

Visitors find these programs quite interesting and somewhat enjoyable, and most programs show higher levels of interest and enjoyment than seen in the formative evaluations. Generally, the programs score higher on interest than enjoyment, but a few visitors gave negative ratings for either interest or enjoyment.

Unlike the exhibits, where the survey and interview format allowed questions for visitors about what made the exhibits interesting or enjoyable, the program survey format did not allow for questions about individual elements of different programs. We can, though, look at the patterns of which scored highest, and note that the small-group programs across the board did better than all the large-group presentations except Treating Tumors with Gold. The small-group formats seem to be more effective for generating interest and enjoyment on this challenging topic. (Partners also prefer to implement the small-group format.) Comparing these formats solely on interest or enjoyment is not fair, but these different levels raise questions for how program formats differ on other aspects (awareness, understanding, and relevance).

The Minnesota programs audience, like the exhibition audiences in Boston, Portland, and Arkansas, had low expectations of interest or enjoyment for nano topics, so the levels of interest and enjoyment expressed here (generally equal or better than for exhibits) indicate that these programs likely outperformed peoples' expectations for nano topics. Visitors who had seen the Long programs indicated that they would be more likely to want to learn about nano or teach about nano in the future than museum visitors who had not learned about nano.

Awareness: Programs

Evaluation Questions

- How many museum visitors have heard of nano before visiting the exhibit or seeing the program? At what levels do these visitors show nanoawareness?
- Do visitors to the NISE Net exhibits or programs show increased nanoawareness, using the network's definition?

Evaluating different aspects of nanoawareness took many forms, as the definition of awareness utilized in this study is complex:

Awareness Part 1a: Nanometer-sized things are **very small.**
Awareness Part 1b: Nanometer-sized things often **behave differently than larger things do.**
Awareness Part 2: Nanotechnology is **manipulating matter with control at a small (size) scale.**
Awareness Part 3: Nanoscience and nanotechnology **lead to new applications.**
Awareness Part 4: Like any technology, nanotechnology has **risks and benefits.**

This definition was established and agreed upon by the NISE Network as appropriate for this study. It is crucial to note that any one of these (1a and 1b must be combined) constitutes nanoawareness; individual visitors are not expected to leave a program or exhibit having mastered all four kinds of nanoawareness.

In this section, we present data that suggest visitors to the museum have heard of nano a few times before, but their confidence in their ability to do things like name an application of nanotechnology is low. Importantly, visitors who saw NISE Net programs reported higher levels of confidence in each area of awareness than those who had not seen the programs.

Initial Levels of Nanoawareness

As with exhibits, all visitors were asked "Before today, how much have you heard about nanoscale science and technology?" using a scale from 0-10:

I have never heard about it		I have heard about it a few times					I hear about it often			I hear about it all the time
0	1	2	3	4	5	6	7	8	9	10

Means of all groups fell in the low to middle range of the scale. The pre-Short program survey group (M = 3.84, SD = 2.57), the pre-Long program survey group (M = 3.65, SD = 2.54), the post-Short program survey group (M = 3.60, SD = 2.77), and the post-Long program survey group (M = 4.26, SD = 2.74) indicate that Science Museum of Minnesota visitors, on average, have some familiarity with the concept of nano but that most do not rate themselves as hearing about it often. As noted in the demographic section, an independent sample *t*-test showed there was no significant difference between the mean of the pre-Short program survey group and the mean of post-Short program survey group. However, there was a significant difference between the post-Long program survey group and the pre-Long program survey group: $t(501) = -2.433$, $p = 0.16$. This finding suggests that differences found between the pre- and post-samples for the Long programs must be interpreted with extreme caution except in instances where regression analysis includes prior nano exposure as a covariate.

A recent survey (Hart Research Associates, 2009) asked a similar question of American adults, "How much have you heard about nanotechnology?," with a similar scale for responses: nothing, a little, some, a lot. By combining responses according to how they are positioned below to the anchors, a rough comparison with the scale used in this study is possible:

	NISE Net study				*Hart study*	
Rating scale	***Pre-Short visitors (n=197)***	***Post-Short visitors (n=407)***	***Pre-Long visitors (n=155)***	***Post-Long visitors (n=348)***	***American adults***	***Rating scale***
I hear about it all the time (9-10)	4.0%	4.9%	5.8%	6.0%	9%	A lot
I hear about it often (5.5-8)	30.3%	26.7%	20.1%	34.4%	22%	Some
I have heard about it a few times (2-5.5)	42.4%	41.1%	54.2%	40.4%	31%	A little
I have never heard about it (0-1)	23.2%	27.3%	20.0%	19.3%	37%	Nothing

The percentage of people giving the highest rating is similar across groups, but the museum audience appears to have more people who have heard some or a little about nano, and fewer people who have heard nothing about it, than the general public.

Changes in Nanoawareness

To assess nanoawareness of program visitors, the post-program survey included the same question as the exhibit survey, asking visitors to rate confidence in their ability to:

- name a nanoscale sized object,
- describe one way that nanoscale objects behave differently than other objects,
- name an application of nanoscale science,
- describe a process used to produce objects at the nanoscale, and
- explain some risks and benefits of nanotechnology.

The response scale for these items was, again, a 0-10 scale with four anchors:

Not at all confident				Somewhat confident			Confident			Extremely confident
0	1	2	3	4	5	6	7	8	9	10

For Long programs only, the final type of nanoawareness was separated into two items, on risks and on benefits, as time allowed for an extra question and the programs included more discussion of both risks and benefits than the exhibition or the other programs. The 6-item question was asked on the longer pre-program survey as well.

This question offers comparisons of visitor confidence in completing nanoawareness tasks between those who experience NISE Net programming and those who do not. Overall, the Short program post-survey scores were higher than the pre-survey scores, suggesting that experiencing even a short program increases visitor confidence in providing information about nanoscale science, engineering, and technology. As noted on p. 63, the pre- and post- samples for the Short programs show no significant difference in previous exposure to nano.

Table 49: Means From Each of the 5 Items Accompanying "How Confident Are You in Your Ability to Do Each of the Following?" on Short Program Surveys

Program title	Name nano object	Behave differently	Describe a nano process	App of nano-science	Explain benefits & risks
Intro to Nano (cart) (n=52)	5.37	5.23	3.86	5.12	4.29
Magic Sand (n=49)	4.96	5.63	4.45	5.90	3.55
Exploring Forces—Gravity (n=50)	5.66	6.38	3.88	5.02	3.48
Exploring Properties—Surface Area (n=49)	5.04	5.88	4.00	5.24	3.65
Exploring Products—Nano Fabric (n=51)	5.43	6.53	4.96	7.80	4.32
Electric Squeeze (n=48)	3.69	3.42	3.46	4.67	2.85
Attack of the Nanoscientist (n=96)	4.80	4.23	3.69	4.78	3.76
Pre-program surveys (n=195)	2.81	2.30	2.03	3.43	2.59

Individual differences between programs can be connected to the focus of the program. The Nano Fabric program stands out as scoring particularly well; Electric Squeeze shows the lowest scores across the board among the cart programs. The theater program, Attack of the Nanoscientist, is of a different type (a comedy aimed at children), and should not be compared directly with the other Short programs.

For the Long programs, those who saw the stage presentations also rated their confidence higher than those who did not; because of the statistically significant difference in previous exposure to nanoscience these numbers cannot be compared directly to the pre-sample in this format but are presented here for the interest of the reader.

Of particular note, this is the only sample that was queried separately about risks and benefits. For all programs, visitors felt they could speak with more confidence about the benefits of nano than about the risks of nano, and this was much more pronounced for the programs Energy and Nanotechnology and Treating Tumors with Gold.

Table 50: Means From Each of the 5 Items Accompanying "How Confident Are You in Your Ability to Do Each of the Following?" on Long Program Surveys

Program title	Name nano object	Behave different	Describe a nano process	App of nano-science	Explain benefits	Explain risks
Intro to Nano (stage) (n=124)	5.55	4.68	4.40	6.15	5.97	5.23
Energy and Nanotechnology (n=105)	4.20	4.15	3.50	5.36	5.56	3.11
Treating Tumors with Gold (n=116)	5.59	5.37	4.74	6.42	6.44	3.86
Stage Program Pre-Survey (n=148)	2.45	2.05	2.01	2.64	2.59	1.91

As with the Exhibits data, the program data were analyzed further using linear regression. We began once again by transforming the raw numbers from the 11-point scale in order to create a more normal distribution. The evaluation team felt that this compression balanced variability with meaningful responses; values in the middle of the scale were probably closer in meaning for respondents than those closer to the ends of the scale (e.g. 1 or 10). The scale was compressed using the following algorithm: 0=0, 1=1, 2=2, 3=3, 4=3, 5=3, 6=4, 7=4, 8=4, 9=5, 10=5. The transformed values for the confidence items were used as the outcome variables in the linear regressions, with each regression using one set of rescaled confidence ratings as the dependent variable.

For the Short programs, the covariates (or independent variables) included: program attendance, whether visitors used science in their daily work, gender, interest in science, age, and prior exposure to nano. The regressions for the Long programs included all of these covariates in addition to education level and income level. These variables differed in range, as seen in Table 51 below. As with the regressions conducted on the exhibition data, other factors, including ethnicity, languages spoken at home, and the presence or absence of a disability, were not included in the regression analyses due to lack of variability within visitor responses.

Table 51: Summary of Numerical Ranges for Variables Included in the Linear Regression of Confidence Items.

Variable	Numerical Range	Comments
Program attendance	0 or 1	0 = no attendance 1 = Program attendance
Science at work	0 or 1	0 = does not use science in daily work 1 = does use science in daily work
Interest in science	0 to 10	Scale
Previous exposure to nanoscience	0 to 10	Scale
Gender	0 or 1	0=female 1=male
Age	Varies	Number reported by visitor
Education	0 to 5	Closed-ended question with 5 increasing levels
Income	0 to 12	Closed-ended question with 12 increasing levels

Tables 52 and 53 provide a summary of the confidence item regressions for the Short and Long programs, identifying significant coefficients in the models and indicating whether the association was positive or negative. Once again, it is important to note that we did not focus heavily on the magnitude of the significant coefficients, but rather, just the general type of association – positive or negative – each had with the outcome variable. Our intent was to simply explore the presence or absence of these relationships and speak about their general nature, not to compare them to one another in order to make claims about one factor having more or less of an effect on the outcome than another factor.

Table 52: Summary of Significant Coefficients Within Linear Regressions Performed on Each Confidence Item – Short Programs

	Short Program Attendance	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age
Name a nanoscale sized object	√ (+)		√ (+)	√ (+)		
Describe one way that nanoscale objects behave differently than other objects	√ (+)		√ (+)	√ (+)		
Describe a process used to produce objects at the nanoscale	√ (+)		√ (+)	√ (+)		
Name an application of nanoscale science	√ (+)		√ (+)	√ (+)		
Explain some risks and benefits of nanotechnology	√ (+)		√ (+)	√ (+)		

For each of the confidence items, Short program attendance was associated with higher visitor confidence ratings. Other factors, including visitor interest in science, and prior nano exposure, also demonstrated associations with the confidence items in the regression analysis. Detailed information from the regression models can be seen in Appendix H.

Table 53: Summary of Significant Coefficients Within Linear Regressions Performed on Each Confidence Item - Long Programs

	Long Program Attendance	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age	Education	Income
Name a nanoscale sized object	√ (+)		√ (+)	√ (+)				
Describe one way that nanoscale objects behave differently than other objects	√ (+)		√ (+)	√ (+)				
Describe a process used to produce objects at the nanoscale	√ (+)		√ (+)	√ (+)				
Name an application of nanoscale science	√ (+)		√ (+)	√ (+)			√ (+)	
Explain some risks of nanotechnology	√ (+)		√ (+)	√ (+)				
Explain some benefits of nanotechnology	√ (+)			√ (+)		√ (+)		

For each of the confidence items, Long program attendance was associated with higher visitor confidence ratings. Other factors, including visitor interest in science, education level, age, and prior nano exposure, also demonstrated associations with various confidence items. Prior nano exposure was positively associated with each of the confidence items, and interest in science had a positive relationship with all items except explaining some benefits of nanotechnology. Education level was positively associated with visitor confidence in naming an application of nanoscale science, and age was negatively associated with explaining some benefits of nanoscale science. Detailed regression information can be seen in Appendix H.

Open-Ended Data on Nanoawareness

In order to gather additional data on nanoawareness, visitors were asked on the surveys how they would explain nanoscience to a friend. Visitor definitions from were coded for the absence or presence of all the nanoawareness categories. In coding these responses the evaluation team was strict but not restrictive. For instance:

- For "small," responses needed to indicate that items were small, but a specific definition using metric measurements was not required.
- For "different," some indication of different behavior was required, but examples (e.g., different effects of gravity) were not needed.

Table 54: Percentage of Total Responses in Each Category Answering the Question "If a Friend Asked You to Describe Nanoscience, What Would You Say?" (As Asked on Short Program Surveys) or "If a Friend Asked You to Explain Nanoscale Science, How Would You Explain It?" (As Asked on Long Program Surveys)

	Program pre-surveys	Program post-surveys
1a: Nano is small.		
Short	75% (n=163)	77% (n=388)
Long	64% (n=124)	69% (n=255)
1b: Nano is different.		
Short	2% (n=163)	18% (n=388)
Long	6% (n=124)	12% (n=255)
2: Nano is manipulating matter with control.		
Short	8% (n=163)	11% (n=388)
Long	6% (n=124)	8% (n=255)
3: Nano appears in new applications and technologies.		
Short	28% (n=163)	14% (n=388)
Long	16% (n=124)	18% (n=255)
4: Risks and Benefits		
Short	3% (n=163)	2% (n=388)
Long	2% (n=124)	4% (n=255)
Don't know		
Short	15% (n=163)	8% (n=388)
Long	29% (n=124)	7% (n=255)
Other		
Short	9% (n=163)	9% (n=388)
Long	4% (n=124)	22% (n=255)

*Visitors' responses may have been placed in more than one category, therefore percentages may not add to 100%.

Both Long and Short programs appeared to inform visitors about different aspects of nano. The percentage of respondents who could not define or explain nanoscience was lower for both Long and Short programs as compared to their respective pre-samples. As with the exhibition data, the program data suggest that most visitors associated nano with small both before and after engaging with a program – the “cultural definition” of nano meaning small holds for many in these groups. Both the Long and Short programs appeared to improve visitor understanding of general idea that “nano is different.” Visitors who saw both programs included ideas about manipulation at slightly higher rates than the respective groups who had not seen the programs. Interestingly, visitors who saw the Short programs discussed the applications of nano at a lower rate than those who did not. The Short programs included in this study have a greater focus on phenomena than applications, perhaps reorienting visitors to think about nano less in terms of products and applications, and perhaps more in terms of phenomena.

Further analysis, using binary logistic regression, was performed on this data to get a better sense of the different relationships between visitor nanoawareness and factors that might affect that awareness. For the Short programs, the covariates (or independent variables) included program attendance, whether visitors used science in their daily work, gender, interest in science, age, and prior exposure to nano. In addition, the regressions for the Long programs also included education level and income level as covariates. Tables 55 and 56 provide a summary of the confidence item regressions for the Short and Long programs, identifying significant odds ratios in the models and indicating whether the outcome was more or less likely to occur given the presence of a specific factor. As with the logistic regressions performed on the exhibition data, regressions were performed for all nano awareness objects that were present in 15% or greater of the visitor responses, and the magnitude of the odds ratio for a given factor was not the primary focus of the analysis – but rather, the overall relationship of the factor to the outcome variable. For the Short programs, this meant conducting regressions for the “Nano is small,” “Nano is different,” and “Nano is about applications” awareness indicators. For the Long programs, regressions were performed on Nano is small” and “Nano is about applications.” In addition, regressions for the “I don’t know” code were also conducted for both Short and Long programs.

Table 55: Summary of Significant Odds Ratios Within Logistic Regressions Performed on Nano Awareness Items for the Short Programs

	Short Program Attendance	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age
Nano is small				√ (+)		
Nano is different	√ (+)					
Nano is about applications	√ (-)		√ (+)			
I don't know	√ (-)		√ (-)	√ (-)		

For the Short program data, the regression models suggested that Short program attendance was positively associated with an increase in the "Nano is different" outcome, which suggests that visitors were more likely to touch on the "nano is different" aspect of nanoawareness after viewing a Short program. Short program attendance was also negatively associated with the "I don't know" outcome, which suggests visitors were less likely to say "I don't know" after having seen a Short program.

The regressions do indicate that Short program attendance is negatively associated with the "Nano is about applications" outcome, meaning it is less likely that visitors would mention this nanoawareness indicator after viewing a program. This may be potentially be explained by the content of the Short programs: generally, they focus on the different properties of nano and introducing nano concepts to visitors, but spend little time explaining applications of nano. These results are consistent with the messages emphasized in these programs, which were focused on the "small and different" kinds of messages much more than applications.

Other factors, such as prior exposure to nano and visitor interest in science, were negatively associated with the "I don't know" outcome. More details about the logistic regression models for the Short programs can be found in Appendix H.

Table 56: Summary of significant odds ratios within logistic regressions performed on nano awareness items for the Long programs

	Long Program Attendance	Science at Work	Interest in Science	Prior nano	Gender	Age	Education	Income
Nano is small				√ (+)		√ (-)		
Nano is about applications								
I don't know	√ (-)			√ (-)		√ (+)	√ (-)	

For the Long program data, the regression models suggested that stage presentation attendance was negatively associated with the "I don't know" outcome, suggesting that visitors who view a Long program are less likely to say "I don't know" in response to "If a friend asked you to define nanotechnology, what would you say?" Prior nano exposure was also negatively associated with the "I don't know" outcome, while being positively associated with the "Nano is small" outcome. Interestingly, visitor age was positively associated with the "I don't know" outcome, and negatively associated with the "Nano is small" outcome. Additional details about the regression models can be found in Appendix H.

Answering Evaluation Questions

- How many museum visitors have heard of nano before visiting the exhibit or seeing the program? At what levels do these visitors show nanoawareness?
- Do visitors to the NISE exhibits or programs show higher nanoawareness, using the NISE Net definition?

Visitors to the museum, on average, say that they have heard of nano a few times before, but their confidence in their ability to do things like name an application of nanotechnology is low.

Visitors who saw both kinds of programs reported higher levels of confidence in each area of awareness than those who had not seen the programs; regression analysis supports the connection between program attendance and confidence in these areas of nanoawareness. Visitors who have seen the programs give definitions of nano that show higher rates of use of appropriate ideas about nanotechnology (and one significant and unexpected decrease); they also retain the cultural definition of 'nano=small'. Regression analysis shows that both visitors to both programs reply "I don't know" less frequently; Short program visitors are more likely to talk about nano being different, but less likely to talk about applications of nano.

Understanding: Programs

Evaluation Questions

- How well do general museum visitors understand nanoscale science, engineering, and technology?
- How do these understandings differ for visitors who have seen the exhibit or program?
- How do these understandings connect to the specific exhibits or program seen?

In this section, we present data that suggest most visitors tend to share the cultural definition of “nano is small.” However, visitors who had seen NISE Net programs tend to have a more sophisticated understanding of nano as compared to those who did not.

Program Intent: Short programs

The survey for Short programs included a question that asked visitors “In your own words, what would you say the program you just saw was trying to show visitors?” Responses to the question were coded for themes. The wide variety of program goals resulted in 25 themes. The four or five most prominent themes for each program are discussed below.

Magic Sand

The Magic Sand cart demonstration showed visitors how sand with a nanocoating is not attracted to water the same way that natural sand is. Visitors generalized the focus of this program—26% stated that the program showed applications of nanotechnology in everyday life, another 18% talked about cool new science. The main message of the program was given by 14% of the survey respondents and general science concepts were stated by 12%.

Program title	Everyday nanotech	Cool new science	Coated sand different	Science concepts
Magic Sand (n=50)	26.0%	18.0%	14.0%	12.0%

Exploring Forces—Gravity

The Exploring Forces—Gravity activity aimed to show visitors that different physical forces can dominate at the nanoscale,. Almost a third of the visitors (29.4%) took away this idea. About a quarter (23.5%) of the visitors stated more general science concepts. Fifteen percent of the visitors stated that small (nanoscale) objects behave differently, a main message of nanoawareness. Everyday applications of nanotechnology was the most important message for 10% of the visitors responding to the survey.

Program title	Gravity is different at nanoscale	Science concepts	Small behaves differently	Everyday nanotech
Exploring Forces—Gravity (n=51)	29.4%	23.5%	15.7%	9.8%

Exploring Properties—Surface Area

Exploring Properties—Surface Area is a facilitated activity showing that crushed effervescent antacid tablets react more quickly with water than whole tablets, because they have a greater surface area to volume ration. It was successful in conveying this message. Twenty-eight percent of the visitors responding to the survey stated that surface area was related to the speed of reaction. Fourteen percent stated a related idea, that size was related to speed of reaction, for a total of 42% stating the main message of the program. Another 24% said the program was about an everyday example of nano. A slightly smaller group, 18%, stated science concepts such as the relationship between surface area and volume (not including anything about nano or reaction rate). Ten percent of the visitors attending this program were able to summarize that small particles behave differently, realizing another main message.

Program title	SA: volume vs. speed of reaction	Everyday nanotech	Science concepts	Size vs. speed of reaction	Small behaves differently
Should be Exploring Properties—Surface Area (n=50)	28.0%	24.0%	18.0%	14.0%	10.0%

Exploring Products—Nano Fabric

Exploring Products—Nano Fabric is a facilitated activity focusing on the science and behavior of an accessible and commonly available application of nano, stain resistant pants. A majority of the visitors, 58.2%, said it showed how nanotechnology was being used in everyday life. Fourteen and a half percent were more specific, naming fabric with nanotechnology as the focus of the program. Another 12.7% focused on the stain or water repellency rather than the nanotechnology. A small group thought the water repellency came from a coating.

Program title	Everyday nanotech	Nanotech fabric	Stain repellent	Nanotech coatings
Exploring Products–Nano Fabric (n=55)	58.2%	14,5%	12.7%	3.6%

Electric Squeeze

The Electric Squeeze cart demonstration focuses on how rearranging molecules through the application of force can produce a piezoelectric current. Cards with musical inserts are used to demonstrate the principle. Many of the visitors (22%) were able to relate the idea that electricity was produced. Another 20% focused on how quartz or carbon was involved in the process. A smaller group (12.0%) of visitors generalized the message as an example of nanotechnology in everyday life. Other visitors (12%) took away basic science concepts.

Program title	Electricity concepts	Quartz or carbon in process	Everyday nanotech	Other science concepts
Electric Squeeze (n=50)	22.0%	20.0%	12.0%	12.0%

Intro to Nano (cart)

The Intro to Nano cart demonstration provides an overview of nanoscience and technology, incorporating numerous other short activities and demonstrations (which can also be presented as stand-alone programs): Exploring Products—Nano Fabric, Exploring Forces—Gravity, and Exploring Properties—Surface Area. Visitors had a variety of ideas about what the program was supposed to show – any science concepts that were not nano-related were coded as “science concepts – not nano.” For instance, if a visitor wrote they thought the program was about learning a concept from chemistry or physics (without using the word nano) their response was coded as science concept. This was the most common response category, with a frequency of 18.9%. The next most common category (at 17%) reflected the goals of the surface area portion of the program, showing how crushed antacid tablets reacted more quickly because they have a greater surface area to volume ratio. Fifteen percent of visitors clearly stated one of the main messages for nano programming, that nanoscale objects can behave differently. The next category of responses, given by 11% of visitors, generalized the program content by stating that they saw cool new science or interesting science. Another 9.4% were more specific, stating that the program was about nanotechnology in everyday life.

Program title	Science concepts (not nano)	SA:volume vs. speed of reaction	Small behaves differently	Cool new science	Everyday nanotech
Intro to Nano (cart) (n=53)	18.9%	17.0%	15.1%	11.3%	9.4%

Attack of the Nanoscientist

The Attack of the Nanoscientist theatre presentation was different from the rest of the Short programs: it was presented on the Atrium Stage on the main exhibit hall floor by professional actors rather than in the Experiment Gallery by volunteers. A majority of the visitors (40%) came away understanding what is and is not nanoscience. The program is a conversation between two scientists, one an evil villain wearing a cape who claims to be a nanoscientist and the other a lab-coated, more reasonable practitioner who explains to the villain and the audience what nanoscience really is — new research and technology that may already be part of our lives. Twenty eight percent of survey respondents focused on the everyday technology aspect of the program. Another 10% more generally stated they were learning cool, new or interesting science.

Program title	What nanoscience is	Everyday nanotech	Cool science
Attack of the Nanoscienctist (n=100)	40.0%	28.0%	10.0%

If a Friend Asked You to Define Nanotechnology . . .

The pre- and post-exhibit interviews asked visitors to complete the sentence "Nanoscale science is the study of . . . " The post-program survey asked visitors an open-ended question, "If a friend asked you to define nanotechnology, what would you say?" The open-ended definitions of nano were recoded to account for detail and for differentiated understanding of nano within and beyond the broader nanoawareness categories.

As with the exhibition data, some open-ended definitions of nano were recoded within the program data to account for detail and for differentiated understanding of nano within and beyond the broader nanoawareness categories. Any nanoawareness category that was present in more than 10% of a pre- or post-sample was reexamined with a more differentiated and nuanced coding scheme. For both the Short and Long program data, nanoawareness items 1A (small), 1B (different), and 3 (applications) appeared often enough to meet this criterion.

Within the "small" nanoawareness categories, we coded to differentiate between generic descriptions (for instance, nano is "small"), alternative conceptions (for instance, nano is "Cellular sized machines"), and specific and/or scientific explanations ("A billionth of a meter, a nanometer"). Coding results for the nuanced coding of "nano is small" for both the Short and Long programs can be seen in Table 57 and 58 below.

Table 57: Nuanced Coding for Visitor Understanding of "Nano is Small," Short Programs

	Pre-survey			*Post-survey*		
		Overall n=	***163***	***Overall n=***	***388***	
	n	**% of NA code**	**% of Pre-surveys**	**n**	**% of NA code**	**% of Post-surveys**
SMALL	***122***		***75%***	***298***		***77%***
Generic	69	57%	42%	191	64%	49%
Alternative Conceptions	27	22%	17%	28	9%	7%
Scientific Understanding	26	21%	16%	78	26%	20%

Table 58: Nuanced Coding for Visitor Understanding of "Nano is small," Long Programs

	Pre-survey			*Post-survey*		
	Overall n=		124	Overall n=	255	
	n	% of NA code	% of Pre-surveys	n	% of NA code	% of Post-surveys
SMALL	79		64%	177		69%
Generic	46	58%	37%	93	53%	36%
Alternative Conceptions	19	24%	15%	19	11%	7%
Scientific Understanding	14	18%	11%	65	37%	25%

The post-samples for both the Long and Short programs show a higher percentage of visitors who articulated a more sophisticated and scientifically appropriate understanding of "nano is small" relative to the pre-sample. For the Short programs, 20% of visitors had such a response in the post-sample, as compared to only 16% in the pre-sample. The post-sample for Long program visitors found 25% with a scientifically appropriate definition of small, as compared to only 11% in the pre-sample.

When compared to the appropriate pre-samples, people who saw the Long and Short programs shared fewer alternative conceptions of the "nano is small" relationship. In the pre-samples, 17% of Short program respondents and 15% of Long program respondents stated an alternative conception, while in post-samples, only 7% of both the Short and Long program respondents made such comments.

Within the "different" nanoawareness categories, we coded to differentiate between generic descriptions (for instance, "how things react differently on a smaller scale"), alternative conceptions (for instance, nano is "less movement for gravity"), and specific and/or scientific explanations (for instance, "very small area can create surface tension to oppose gravity"). Coding results for the nuanced coding of "nano is small" for both the Short and Long programs can be seen in Table 59 and 60 below.

Table 59: Nuanced Coding for Visitor Understanding of "Nano is Different," Short Programs

	Pre-survey			Post-survey		
	Overall n=		163		Overall n=	388
	n	% of NA code	% of Pre-surveys	n	% of NA code	% of Post-surveys
DIFFERENT	***3***		***2%***	***68***		***18%***
Generic	3	100%	2%	49	87%	13%
Alternative Conceptions	0	0%	0%	2	4%	0%
Specific, identified behaviors	0	0%	0%	5	9%	1%

Table 60: Nuanced Coding for Visitor Understanding of "Nano is Different," Long Programs

	Pre-survey			Post-survey		
	Overall n=		124		Overall n=	255
	n	% of NA code	% of Pre-surveys	n	% of NA code	% of Post-surveys
DIFFERENT	7		6%	30		12%
Generic	7	100%	6%	17	57%	7%
Alternative Conceptions	0	0%	0%	3	10%	1%
Specific, viable examples	0	0%	0%	10	33%	4%

Though the overall percentages for "nano is different" are quite small, higher percentages of people mentioning this aspect of nanoawareness – and in particular, general and specific examples of "nano is different – do appear between pre- and post-sample for both Short and Long programs.

Within the "applications" nanoawareness categories, we coded to differentiate between generic descriptions (for instance, nano is "about applications"), alternative conceptions (for instance, nano "can make a thing have a strong power"), and specific and/or scientific applications (nano is used in "creating a material that is impervious to water"). Coding results can be seen in Tables 61 and 62 below.

Table 61: Nuanced Coding for Visitor Understanding of "Nano is About Applications," Short Programs

	Pre-survey			Post-survey		
		Overall n=	163		Overall n=	388
	n	% of NA code	% of Pre-surveys	n	% of NA code	% of Post-surveys
APPLICATION	45		28%	55		14%
Generic	17	38%	10%	18	33%	5%
Alternative Conceptions	9	20%	6%	3	5%	1%
Specific, viable examples	11	24%	7%	20	36%	5%

Table 62: Nuanced Coding for Visitor Understanding of "Nano is About Applications," Long Programs

	Pre-survey			Post-survey		
		Overall n=	124		Overall n=	255
	n	% of NA code	% of Pre-surveys	n	% of NA code	% of Post-surveys
APPLICATION	20		16%	46		18%
Generic	13	65%	10%	19	41%	7%
Alternative Conceptions	2	10%	2%	0	0%	0%
Specific, viable examples	5	25%	4%	27	59%	11%

For the "applications" category, the post-sample for the Long programs show a higher percentage of visitors (11%) who articulated a more sophisticated and scientifically appropriate understanding of "nano is about applications" relative to the pre-sample (4%). For the Short programs, the post-sample actually found a lower percentage of visitors articulating a scientific understanding than the pre-sample, with 5% of visitors providing such a response in the post-sample, as compared to 7% in the pre-sample. However, both Short and Long programs saw lower levels of alternative conceptions about nano and applications in the post-samples as compared to the pre-samples.

The general category of "other" responses was also dissected to separate responses which simply repeated words from the question ("nanotechnology"), showed misconceptions that did not fit into the above categories (nano is "gold/laser"), repeated general words about science (nano is "new technology"), referred to the future ("nano is the future"), or responded in some other way ("I would tell them to Google it").

Table 63: Nuanced Coding for Visitor Nano Awareness Responses Initially Coded as "Other," Short Programs*

	Pre-survey			Post-survey		
		Overall n=	*163*	*Overall n=*	*388*	
	n	% of NA code	% of Pre-surveys	n	% of NA code	% of Post-surveys
OTHER	*14*		*9%*	*33*		*9%*
isolated nano vocabulary	1	7%	1%	2	6%	1%
alternative conceptions	4	29%	2%	16	48%	4%
general science/tech	4	29%	2%	0	0%	0%
related to the future	1	7%	1%	0	0%	0%
not related to nano	8	57%	5%	15	45%	4%

* Visitors could be coded for more than one nuanced response category.

Table 64: Nuanced Coding of Visitor Nano Awareness Responses Initially Coded as "Other," Long Programs*

	Pre-survey			Post-survey		
		Overall n=	*124*	*Overall n=*	*255*	
	n	% of NA code	% of Pre-surveys	n	% of NA code	% of Post-surveys
OTHER	5		4%	56		22%
isolated nano vocabulary	0	0%	0%	1	2%	0%
alternative conceptions	1	20%	1%	23	41%	9%
general science/tech	2	40%	2%	10	18%	4%
related to the future	0	0%	0%	8	14%	3%
not related to nano	2	40%	2%	18	32%	7%

*Visitors could be coded for more than one nuanced response category.

Answering Evaluation Questions

- How well do general museum visitors understand nanoscale science, engineering, and technology?
- How do these understandings differ for visitors who have seen the exhibit or program?
- How do these understandings connect to the specific exhibits or program seen?

Visitors who have not seen the programs generally share the cultural definition of nano meaning small, mostly with generic explanations of what that means. Detailed analysis of definitions of nano show that visitors to the programs can share more accurate knowledge and offer fewer alternative conceptions in some areas than those who have not.

Visitors respond to prompts about the subject matter of the programs they saw in ways that suggest they understood the intent of the program, and in some cases learned important scientific content.

Relevance: Programs

Evaluation Questions

- Does the general museum visitor think of nano as relevant?
- Do visitors find the exhibition/programs relevant to their everyday lives?
- What elements make the exhibits or programs relevant to visitors? (Topics, approaches, etc.)
- Do the exhibits or programs make nanoscale science, engineering, and technology seem more relevant to visitors' lives?
- How do visitors envision interacting with nano in the future?

In this section, we present data that suggest visitors who had seen NISE Net programs tended to see a stronger connection between nano and their everyday lives than visitors who had not.

Nanotopics vs. Non-Nanotopics

For the Long programs, vistors were asked on both pre- and post-survey, "How well do each of the following topics connect to things in your everyday life that you know or wonder about: nanoscience, alternative energy, cancer treatments, nanotechnology, purifying water, and nanomedicine." Respondents assigned relevance scores to nano and non-nano topics on an 11 point scale from 0-10. All these topics were covered by the programming (some only by one program, though nanoscale science, engineering, and technology were covered by all three). According to the raw numbers (see Table 65), all visitors rate their connection to nano topics lower than to non-nano topics, but the difference is greater for those who have not seen nano programming than those who have seen the programming.

Table 65: Mean of Visitor Responses to "How Well Do Each of the Following Topics Connect to Things in Your Everyday Life That You Know or Wonder About?" – Long Programs

Topic	Pre-Long program survey (n=148)	Post-Long program survey (n=328)
Alternative Energy	6.32	6.42
Cancer Treatments	6.11	6.03
Purifying Water	6.78	6.22
Nanoscience	3.84	5.29
Nanotechnology	4.18	5.51
Nanomedicine	4.88	5.24

Further analysis using linear regression was performed on this data to get a better sense of the different relationships between visitor connection to nano topics, Long program attendance, and other demographic and psychographic information such as age, gender, education level, income level, prior nano exposure, whether visitors used science in their daily work, and visitor interest in science. As with the exhibition data, visitor ratings for individual topics were first pooled together into two comparison groups. Ratings for nanoscience, nanotechnology, and nanomedicine were added together to form a total score for nano topics, and ratings for alternative energy, cancer treatments, and purifying water were added together to form a total score for non-nano topics. Pooling the data in this way reflected our desire to examine how visitors connected to nano topics generally at the aggregate level, instead of focusing on each specific nano topic at the individual level.

The outcome variable for the linear regression was the *difference* between the pooled ratings for the nano topics and the non-nano topics. In other words, for a given visitor who answered this question, the visitor's pooled ratings for the three non-nano topics were subtracted from the same visitor's pooled ratings for the three nano topics, as seen in Equation 1:

$$Y = (\text{Pooled ratings for nano topics}) - (\text{Pooled ratings for non-nano topics}). \quad [1]$$

Because we used the difference between the pooled ratings as the outcome variable for the linear regression, any significant coefficients in the model would point to a relationship between this difference and a given factor.

Once the outcome variable was computed, a linear regression was performed. The resulting model is summarized in Table X below.

Table 66: Summary of Significant Coefficients Ratios Within a Linear Regression Model Exploring Relationships Between Factors and the Relevance of Nano for Long Programs

	Long Program Attendance	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age	Education	Income
Difference between connection ratings for non-nano and nano topics	√ (+)							√ (+)

The regression models suggest that Long program attendance was positively associated with a difference in visitor connection to nano topics. In addition, visitor income level also demonstrated a positive relationship with visitor connection to nano-related topics. Detailed regression model information can be seen in Appendix H.

Answering Evaluation Questions

- Does the general museum visitor think of nano as relevant?
- Do the exhibits or programs make nanoscale science, engineering, and technology seem more relevant to visitors' lives?
- How do visitors envision interacting with nano in the future?

Questions about relevance were not included on the abbreviated surveys used for Short program visitors. Visitors who had not seen nano programming ranked their connection to nano topics as lower than other topics they were queried about; those who saw the Long, stage programs ranked nano higher than the comparison group, with no corresponding shift in other topics covered by the programming.

Information about intent to interact with nano in the future is found in the following section.

Learning About Nano Beyond the Museum

Both interest and relevance, as constructs, imply the possibility that visitors might learn about and use information about nano beyond the museum. Ideally museum exhibits and programs capitalize on previous experiences and increase the likelihood and power of future experiences. Information about these experiences is combined in this section, incorporating data collected from exhibition viewers in Boston, Little Rock, and Portland and also, where possible, from program viewers in Minnesota. This data is combined to present a more complete picture of visitors' past and hypothetical future interactions.

Sources of Information About Nano

In addition to the 0-10 ranking question about **how much visitors had heard** about nano in the past (used both to compare samples with each other and with the American public), interviewers asked both pre- and post-exhibition visitors about **how they had learned** about nanoscience before coming the museum. First, they checked with visitors about whether they had learned about it before; this yes/no response was quickly given and intended just to give interviewers a go-ahead to ask the following question (it is not intended as a confirmation of the question about how much visitors had heard), but the answers are interesting (Table 67). In all locations, over half of visitors said they had not learned about nano before.

Table 67: Frequency of Interviewee Responses to "Learned About Nano Before?" (in Percent)

	Boston, MOS (n=111)*	Little Rock, MOD (n=91)*	Portland, OMSI (n=111)*
Not learned	55.0%	50.5%	53.5%
Learned before	40.5%	42.9%	42.3%

*Not all interviews included this question.

Visitors who said they had learned about nanoscience before were queried about how they had learned what they knew. The responses varied by location; in Boston, work or school were the most common sources; in Little Rock, television was by far the most frequent source; in Portland, television and non-fiction were most prevalent (Table 68).

Table 68: Frequency Interviewee Responses for Those Who Have Learned About Nano Previously

	Boston, MOS (n=45)*	Little Rock, MOD (n=39)*	Portland, OMSI (n=47)*
Television non-fiction	11.1%	43.6%	27.7%
Radio	2.2%	2.6%	8.5%
Read non-fiction	20.0%	20.5%	40.4%
Read/view fiction	4.4%	15.4%	6.4%
School or class	22.2%	12.8%	19.1%
Tech related job	26.7%	15.4	15.4%
Other	4.4%	5.1%	5.1%

*Not all interviews included this question.

When asked if they wanted to learn more, most visitors said yes (Table 69). From 73% to 100% were interested in learning more. Of note, in Boston and Little Rock, higher proportions of the pre-exhibit group than the post-exhibit group were interested in learning more. These differences may be due to a range of factors beyond the exhibition itself (ways the question was answered, for instance) so cannot be taken as definitive evidence of a difference in interest; it may also mean that visitor interest in nano is not enormous and the exhibition was sufficient to answer their questions.

Table 69: Frequency of Responses in Each Category to "Would You Want to Learn More About Nano?"

	Pre-exhibit Boston, MOS (n=56)*	Post-exhibit Boston, MOS (n=55)*	Pre-exhibit Little Rock, MOD (n=25)*	Post-exhibit Little Rock, MOD (n=66)*	Pre-exhibit Portland, OMSI (n=51)*	Post-exhibit Portland, OMSI (n=56)*
Yes	92.9%	78.2%	76.0%	57.6%	66.7%	92.9%
No	3.6%	7.3%	0.0%	18.2%	0.0%	3.6%

*Not all interviews included this question.

Visitors who replied that they wanted to learn more were asked why. Their responses are tallied in Table 70. General interest or curiosity was the most common reason cited for wanting to learn more about nanoscience.

Table 70: Frequency of Interviewee Responses in Each Category for Those Answering Yes to "Why Would You Want to Learn More?"

	Pre-exhibit Boston, MOS (n=52)*	Post-exhibit Boston, MOS (n=43)*	Pre-Exhibit Little Rock, (n=19)*	Post-Exhibit Little Rock, MOD (n=38)*	Pre-exhibit Portland, OMSI (n=34)	Post-exhibit Portland, OMSI (n=41)
General Interest	59.6%	67.4%	78.9%	52.6%	50.0%	61.0%
Societal Interest	1.9%	2.3%	5.3%	7.9%	11.8%	9.8%
Medical Applications	17.3%	14.0%	5.3%	23.7%	14.7%	12.2%
Nano products	3.8%	7.0%	5.3%	2.6%	14.7%	14.6%
Career related	11.5%	16.3%	5.3%	7.9%	8.8%	7.3%
Parenting	3.8%	4.7%	0.0%	0.0%	2.9%	2.4%
Other	1.9	0.0%	0.0%	5.3%	0.0%	2.4%

*Responses were coded in more than one category if applicable, so total may exceed 100%.

Nano in Visitors' Future—Pre-Exhibition

To better understand how pre-exhibit visitors might interact with nanoscience and technology beyond the museum, the pre-exhibit survey and the pre- and post-long program surveys asked visitors how interested they were in doing five different tasks if the opportunity presented itself: informally teach about nanoscale science, read a newspaper or magazine article about nanoscale science, learn more about the use of nanotechnology in medical treatments, learn more about the use of nanoscale technology in personal care products, or change purchasing habits based on knowledge of nanotechnology. The first two items were taken from the Dyehouse et al. (2008) nanomotivation scale.

Visitors' responses suggest that learning more about nano is moderately interesting to people; that educating others is a lower priority; and that changing behavior is a possibility. Due to space limitations, this question was not asked of post-exhibit viewers.

Table 71: Central Tendencies of Pre-Exhibit Visitors' Responses to "Assuming the Opportunity Presented Itself, How Interested Would You Be in Doing Each of the Following . . . "

Way to teach or learn about nano	Mean	Standard Deviation
Informally/casually teach someone something about nanoscale science (n=243)	3.23	2.94
Read a news story or popular magazine article about nanoscale science (n=243)	5.23	2.99
Learn more about the use of nanotechnology in medical treatments (n=242)	6.06	2.96
Learn more about the use of nanotechnology in a personal care product (n=242)	5.12	3.3
Change what products I buy based on what I know or learn about nanotechnology (n=244)	5.22	2.91

Table 72: Mean of Pre- and Post-Long Survey Visitors' Responses to "Assuming the Opportunity Presented Itself, How Interested Would You Be in Doing Each of the Following . . . "

Way to teach or learn about nano	Long pre-surveys (n=148)	Intro to nano (Long)(n=119)	Energy and nano (n=101)	Treating Tumors (n=113)
Informally/casually teach someone something about nanoscale science	2.81	4.09	3.70	4.58
Read a news story or popular magazine article about nanoscale science	5.01	6.26	6.00	6.66
Learn more about the use of nanotechnology in medical treatments	5.83	6.78	6.23	7.16
Learn more about the use of nanotechnology in a personal care product	5.09	6.28	5.70	5.97
Change what products I buy based on what I know or learn about nanotechnology	5.10	5.93	6.04	5.64

The pre-Long program surveys show similar numbers to the pre-exhibit group, with lowest interest in teaching someone else, however informally or casually, and greater interest in various ways of learning about nano or in changing consumer behavior around nano. The post-Long program surveys show higher scores across the board, providing a contrasting view to the post-exhibit groups expressing lower levels of interest in learning more about nano (Table 72).

Main findings and discussion

In consolidating the main findings of this study and examining implications, it's useful first to review a few methodological points.

As is the case for many studies in museums, we compared separate groups for the pre- and post-samples in each setting. Overall these groups were not statistically different across a wide range of demographic and psychographic measures (including things like interest in science, previous exposure to nano, and other self-ratings that might be thought to influence the constructs studied here), but a few differences were found for each group. Most importantly, the comparison sample for the Long programs differed significantly from the group who saw stage programs on how much they had heard about nano before, with the group who saw the programs rating their previous knowledge higher than the group that did not. In all cases we presented the raw data for differences in how these groups answered questions, and in cases where these numbers seemed to present particularly intriguing differences (or similarities) between groups, and where the differences were particularly important to know about, we used regression analysis to control for demographic and psychographic factors. Both the descriptive comparisons and the regressions offer useful information to the reader, but the regressions speak more directly to the differences related to seeing the exhibition or the program in question.

Though the same or similar instruments were used across exhibits and programs, direct comparisons of data on any point across groups is rarely appropriate in this study. Exhibits and programs (and indeed, different types of programs) attract visitors who are looking for different kinds of experiences, have different possibilities and constraints, and cannot and should not be compared directly. Comparisons within groups are designed to highlight particular successes or struggles, and can be used to improve the development of exhibits or programs in the future.

The constructs examined here can be consolidated within the interest-development model presented by Hidi and Renninger (2006). Our measure of interest examines how well the exhibits and programs work to trigger and sustain interest in the museum setting; our measures of awareness and understanding provide insight into how visitors are (or are not) developing further content knowledge about the topic, knowledge that can help them move along in the stages of interest; our construct of relevance looks at how the exhibition or program worked to provide the visitor with ways to connect with the subject matter that might also facilitate future connections. Our examination of the ways visitors might engage with nano beyond the museum is a hypothetical exploration of future encounters with nano, not a definitive study of that engagement, but provides some insight into what that might look like. Overall, the NISE Network goal is to engage visitors effectively within the museum (stage 2, maintained situational interest), and perhaps to provide them with tools that might allow for stage 3 and 4 outside of the museum, or a deeper, differently triggered stage 2. There is no expectation that every visitor (or even most visitors) will achieve stage 4 – rather, the hope is that people will leave with more ways to engage with nano than they entered with.

The exhibition and programs were successful at engaging visitors, educating them about nano content, and providing avenues for visitors to connect nano to their lives both in the context of the museum and potentially in the future. The nature of that success and its limitations are explored below.

Exhibits and programs effectively engage visitors with nano content

Visitors enter the museum doors with lower expectations for a hypothetical nano offering than for most or all other topics suggested to them. Those who see the exhibition or programming rate them as reasonably enjoyable and interesting, at rates higher than seen in formative assessment of nano programming; a majority who see the exhibition rate it as equally or more interesting indicating than other exhibits they have seen that day. These strong rankings of interest and enjoyment, combined with the low expectations held by those entering, suggest that the Network has risen to meet a key challenge – creating interest in this less-than-appealing topic.

For adults, descriptions of engagement center most frequently on the nano subject matter itself and the ways it is treated in the exhibition. For children, the descriptions center on the interactive elements in particular exhibit elements. This information, while not surprising, is worth remembering when designing future public products for a broad audience.

Visitors who see exhibits and programs show higher levels of nanoawareness

Recent assessment of public awareness of nano (Hart, 2009) shows that over a third of adults say they have heard nothing about nano, about a third rank their awareness low, and under a third rank their awareness as medium or high. Museum visitors rate their awareness of nano somewhat higher than the general public rates its awareness of nano – the proportion giving the highest rank is similar, but there are more ranking themselves in the medium and low categories and fewer in the "heard nothing" category. Visitors who see the nano exhibits and programs express higher confidence in their general nano knowledge than those who don't see the exhibits or programs; regression analysis suggests this difference is related to their time at the exhibition or program.

Our examination of children's levels of awareness doesn't offer specific information about what they learned from the exhibition, but it's worth noting that after the exhibition, 46% report that the exhibition was about nano (some with details about 'small' or particles) and 14% describe content from the exhibition, suggesting that the exhibition conveyed information and awareness of nano to the children surveyed.

Many visitors associate "nano" with small, even before seeing nano in the museum

The rate at which visitors in all locations, including those who had seen the Network products and those had not, defined nanoscale science as being the study of small things was a surprise to the evaluation team and to others in the network. At least 60% of visitors included the idea of "small" in their definition. This number was higher than anticipated, and only increased slightly among those who saw exhibits or programs – both of which are important and unanticipated findings. The high rate suggests that the general public, or at least the museum-going public, has developed a new definition of nano as meaning small, perhaps because of the iPod Nano and other consumer products that use the term “nano” to label a smaller version of an existing product (e.g., a small vacuum called a Nano Light).

The durability of this definition is also striking. Even though many visitors who saw exhibits or programs expressed a higher level of confidence in doing other things associated with nano knowledge, their definitions did not reflect this higher level of knowledge to as great an extent as might be hoped for. While this might reflect over-rating of their own knowledge, it seems also possible that this reflects the ways that visitors are defining nano: that “small” is the most important thing to know about it, and additional knowledge (including things like “behave differently” or “allows for new applications”) that is important to the Network is less important to the general public, currently.

All this gives Network staff an important series of decisions to make as they develop new educational products. Since fewer resources need to be devoted to introducing the idea that nano means “small,” new possibilities arise. Is it important to develop more scientifically accurate definitions of small? Or is the generic idea of “small” sufficient, and more time should be devoted to developing understanding of other content areas? (The latter is more likely, given current work underway in the Network.)

Exhibits and programs offer ways for visitors to deepen their nano knowledge

This topic was investigated in two ways: first, by parsing out visitor definitions of nano in more depth by analyzing their definitions for scientific accuracy or alternative conceptions, and second, by observing how they operationalized those definitions in sorting everyday objects into nano and non-nano groups. The definitions offered by exhibition visitors did not change in significant ways, but those offered by program visitors were more appropriate: for some visitors, definitions of “small” and of nano as being about new applications included more scientific accuracy and showed fewer alternative conceptions.

Exhibition visitors were asked by interviewers to sort everyday objects into nano and non-nano groups and explain their process. In doing so, visitors who had seen the exhibition showed more sophisticated understanding of nano than non-exhibition-visitors as they sorted everyday objects. Their schema for sorting , showed a better understanding of the diversity of nano, and also its connection to new and improved items. While this activity asked visitors questions beyond what the exhibition itself was designed to convey, it suggests ways that visitors might be able to use their nano knowledge beyond the museum.

Visitors find relevance in the exhibits and programs, and may find more ways to connect their everyday lives to nano when they encounter it in the future

Anecdotal perception by members of the Network that many visitors may not enter the museum with a clear vision of how nano connects to their lives was supported by the data. Visitors entering the museum ranked their connection to nano as average or below average. For both exhibits and programs, visitors who saw nano products showed a difference in their connection to nano (with no corresponding difference in other topics presented in the exhibition or program). We asked visitors to the exhibition about what they connected to, and the medical topics were most effective in what was offered there. That group also participated in the interview segment about the possible use of nano objects, which can suggest ways that visitors might use nano knowledge in the future. Visitor concerns centered on safety and effectiveness, and those who saw the exhibition displayed more knowledge in their questioning.

A set of questions exploring visitors' interactions (past and future) with nano outside of the museum offers possible further information about ways that visitors might engage with content and interact more with nano in the future. Visitors were asked about where they've learned about nano in the past; the most common answers reflect sources that are likely to be reasonably reliable (work, school, television, and non-fiction), though less common answers (like reading fiction) might be more likely to lead to alternative conceptions of nano. Adults and children generally say they would want to learn more about nano in the future, though in some cases, adults who had seen a nano exhibition said so at a lower rate than their comparison sample. We also asked visitors in the Long program and their comparison sample about a range of ways that they might interact with nano in the future (including ways to learn, talk about, and teach others about nano). Those who saw the program answered positively more frequently than those who had not seen the program.

This information – both the hypothetical question about using nano knowledge in everyday life as a consumer, and the data about how visitors might learn about nano outside the museum – might be useful in development of future products, as Network developers consider additional ways to help create relevance and encourage visitors to create new connections, connections that might allow for more meaningful interactions with nano in the future.

As the Network continues to grow, this successful work on public products (and the process used to produce it) provides a firm footing for further development of those products. This evaluation has highlighted those successes, but it also draws attention to important challenges for Year 6 and beyond. These include:

- Paying greater attention to the ways that children can be engaged in nano content – a challenge that has already been embraced by the Network, and which needs to be reflected in future Evaluations as well.

- Determining how to capitalize on the public's identification of nano with small size.

- Exploring appropriate ways to discuss costs, risks, and benefits in more depth – this evaluation showed that visitors have some understanding that these risks and benefits exist, but showed little evidence of sophistication in understanding. The Network has committed to exploring these in more depth and future Evaluations should look more closely at what results.

- Discussing the role of alterations to the products, and how those are developed, deployed, and evaluated across institutions.

- Considering possible avenues for museum visitors to engage with nano beyond the museum, and how public products can help visitors prepare for those during their visit.

When the NISE Network began, appropriate approaches for engaging the general public in this emerging area of science and technology had not been established, and success was not a given. After five years, it's clear that the Network has found successful approaches to initially engage the public on the museum floor, communicate important content, and help visitors connect nano with their everyday lives. According to the Hidi and Renninger (2006) model, these developments may allow those visitors to have more meaningful and sustained encounters with nano when they come across it in the future. This success should be lauded, but also built on, as the Network enters the second phase of work.

References

Dyehouse, M., Diefes-Dux, H., Bennett, D. and Imbrie, P.K. (2008) Development of an Instrument to Measure Undergraduates' Nanotechnology Awareness, Exposure, Motivation, and Knowledge. *Journal of Science Education and Technology* 17:500–510.

Hidi, S., and Renninger, K.A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist* 41(2): 111-127.

National Research Council. (1996). *National Science Education Standards*. National Academy Press: Washington, DC.

National Research Council. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. National Academy Press: Washington, DC.

Peponis, J., & Wineman, J. (2002). The spatial structure of environment and behavior. In R. Betchel & A. Churchman (Eds.), Handbook
of environmental psychology (pp. 271-291). New York: John Wiley and Sons.

Spencer, D., Phillips, T., Angelotti, T. & Murphy, S. (2007). Too Small to See. Summative evaluation report**:** For a Science museum exhibition on nanotechnology education. Edited by Fred Conner of Edu, Inc. Ithaca, NY. http://www.exhibitfiles.org/too_ small_to_see__zoom_into_nanotechnology

Strauss, A. & Corbin, J. (1998). Basics of qualitative research (2nd ed.) Thousand Oaks, CA: Sage

Appendix A: Development of Exhibits

Nanomedicine Explorer (Museum of Science & OMSI)

Big Idea
The field of nanomedicine is rapidly expanding and may soon bring us long-hoped for improvements in areas such as cancer detection and treatment. Researchers from different fields bring together their expertise to develop novel and sometimes revolutionary approaches to the detection and treatment of disease. All new approaches must go through rigorous safety and efficacy testing procedures in vitro, in animal models, and in clinical trials before being approved.

Learning Goals

- Nanomedicine is the application of nanotechnology to medicine.
- Nanotechnology is the science of the small and the engineering and applications of very small structures.
- Nanomedicine researchers develop tiny materials, tools and devices that can work with extreme precision at the nanoscale, the scale of the molecules and cells that make up our bodies.
- Nanotechnology has created many materials and devices with unique and distinctive features - providing a new "toolbox" to try to address many medical needs.
- Experts from a variety of backgrounds and in a range of different science and engineering disciplines are coming together to address these challenges.
- Research involves creativity, discipline, teamwork and inspiration; it is often rewarding in personal as well as professional ways.
- What cancer is, and how it grows and metastasizes.
- All new techniques must go through years of testing to ensure that they will work and that they will be safe.

Nanomedicine: Treating Disease (OMSI)

Big Idea
Nanotechnology is changing the way we treat disease. Cutting-edge treatments will use materials that are as small (or even smaller!) as the tiniest parts of cells in the body. Researchers think that nanomedicine will work only on targeted cells, and will have fewer side effects on the rest of the body.

Learning Objectives

- When gold nanoshells are injected into the bloodstream, they travel through healthy blood vessels but easily slip through the leaks found in tumor blood vessels and collect in the tumors.
- A laser shines light through skin and tissue (without damaging them!) and into each tumor, where the nanoshells absorb the energy and heat up.
- The heat from the nanoshells destroys the tumor cells.

OR

Nanomedicine treatments use materials that are as small (or even smaller!) as the tiniest parts of cells in the body.
New nano treatments may work better and have fewer side effects than current medical treatments
One example of nanomedicine is the use of gold nanoshells to kill cancerous cells without harming healthy cells.

Nanomedicine: Detecting Disease (OMSI)

Big Idea
Researchers are working to better detect disease with nanotechnology.

Learning Objectives
- Diseases can be detected before a patient has any noticeable symptoms.
- A patient has a better chance of beating a disease if treatment starts very early in the disease's progression.
- The GreeneChip tests for many different diseases at the same time using genetic material from a pathogen "library" and a sample from the patient.

OR
- Nanotechnology is being used to develop new diagnostic tools that work better than traditional methods.

Nanomedicine: Regenerating Tissues (OMSI)

Big Idea
Researchers are working on ways to repair tissues with nanotechnology.

Learning Objectives
Nerve tissue injuries are typically permanent because scar tissue prevents injured nerve cells from reconnecting.
Researchers have created a fluid that can be injected into an injured brain that self-assembles into a nanoscaffold that actually helps the brain heal.
The nanoscaffold enables neurons to grow towards one another, "knitting" the wounded brain back together.
OR
Researchers are working on ways to repair tissues with nanotechnology

Nanomedicine: Intro to Nanomedicine Video (OMSI)

Big Idea
Researchers in nanomedicine work in interdisciplinary teams to develop novel and much improved techniques of diagnosis, treatment, and repair through the application of nanotechnology, the science and engineering of tiny materials and devices that can work on the scale of the molecules and cells that make up our bodies. All these new nanomedicine materials, devices and techniques need to go through years of testing to prove that they are safe as well as effective.

Learning Objectives

Nanomedicine is the application of nanotechnology to medicine.
Nanotechnology is the science of the small and the engineering and applications of very small structures.
The building blocks are molecules and atoms.
Most of the components of our cells are nanoscale objects.
Nanomedicine researchers develop tiny tools that can work with extreme precision at the nanoscale.
Nanotechnology has created many materials with unique and distinctive features - providing a new "toolbox" to try to address many medical needs. These include delivering drugs to the right place and avoiding biological barriers.
These challenges require the coordinated efforts of interdisciplinary teams - many such teams are already at work.
Each technique will need to go through years of testing to ensure that it will work and that it will be safe.

OR

Nanomedicine is the application of nanotechnology to medicine
New medical treatments are being developed with the tools provided by nanotechnology
New treatments will need to be tested before they are available to the general public

Intro to Nanotechnology: Creating Nano Materials (OMSI)

Big Idea

Scientists are figuring out how to create and manipulate materials as the nanoscale through self-assembly.

Intro to Nanotechnology: At the Nanoscale (OMSI)

Big Idea

Things at the nanoscale are super small.

Intro to Nanotechnology: Introductory Video (OMSI)

Learning Objectives

Things at the nanoscale are super small
Super small nanoparticles can have very unexpected properties
Nanotechnology is being used to create consumer goods with new and/or improved properties
Nanotechnology is being used in medical applications, such as the treatment of cancer
There may be risks associated with nanotechnology that include human health and the environment

Intro to Nanotechnology: Unexpected Properties (OMSI)

Big Idea

Super small nanoparticles can have very unexpected properties.

Bump and Roll (SMM)

Big Idea
Nanoscience is harnessing nanoscale phenomena seen in nature to create new techniques, materials, and products.

Learning Objectives

Tiny, micro, and nanoscale bumps can make surfaces water-repellent and self-cleaning.
It's fun to play with water on a superhydrophobic surface, but there are lots of practical applications of the technology.

Changing Colors (also known as Way to Glow) (SMM)

Big Idea
Nanoscience is harnessing nanoscale phenomena seen in nature to create new techniques, materials, and products.

Learning Objectives

The butterfly scales and thin films contain no pigment.
The butterfly scales and thin films are made up of layers of super thin, transparent materials. The spacing between the layers causes only certain light waves to bounce back to our eyes as colors.
When you change the angle of the light, you change the color.

NanoLab (Sciencenter)

Big Idea
Some nanoscientists work in labs called clean rooms, where they learn about and make things that are too small to see.

Learning Objectives

In nano labs, scientists learn about and make things that are too small to see.
Many different scientists work in nano labs.
Some nano labs are clean rooms.
In clean rooms, scientists build with atoms.
Scientists who work in clean rooms use special tools and equipment.
Scientists who work in clean rooms wear special clothes.
Nano is very, very small.

Nanotechnology: Fact or Fiction? (Sciencenter)

Big Idea
Many real examples of nanotechnology do exist, but others (such as nanobots) are imaginary.

Learning Objectives

Nano is very, very small.

Nanotechnology is real and can be found in applications such as clothing and sports equipment

Nanobots are not real and do not currently exist.

There are many challenges related to creating a nano-sized robot.

In the future, nanobots might exist and might be able to do useful things. Future examples of nanobots include applications in medicine.

There might be unintended consequences to creating nanobots.

Appendix B: Content of Programs

Theatre Presentation: Attack of the Nanoscientist

Developed by SMM
Presented by public programs staff, SMM

Description

A ten minute play in which a supervillain from the future attempts to conquer the audience using...Nanoscience? Nano is now; it's not bizarre and only of the future, it involves manipulating tiny objects to make things in different ways.

Big Idea

Nanoscience is not one thing, it has many possible applications in many fields, like medicine, computing, materials, defense, environment, and consumer products.

Learning Objectives

To introduce the visitor to the field of nanoscale science and technology
To encourage the visitor to learn more about nanoscale science and technology.

Audience

Seven and up

Stage Presentation: Intro to Nano (Stage)

Developed by MOS
Presented by public programs staff, SMM

Description

This is a stage presentation, designed for audiences of 11 and up, intended to give a broad overview and introduction to the subject of nanotechnology. The talk attempts to answer three basic questions about nanotech: How is It New, What Can It Do, and Do You Care?

Big Idea

Nanotechnology is a new field of science, and can have some potentially huge applications.

Learning Objectives

Nano has allowed us to create some new materials.
Nano has been enabled by some new tools.
Nano has been prompted by, and is prompting, some new ideas.
Nano has all sorts of cool applications, that may help us address some of the most pressing problems the world faces.
The biggest discoveries in nano are still ahead of us. Ultimately, we can learn a lot from living things.

Audience

11 and up

Stage Presentation: Energy and Nanotechnology

Developed by MOS
Presented by public programs staff, SMM

Description
Energy & Nanotechnology is a slide show presentation, designed for medium-to-large audiences, exploring the potential of nanotechnology to contribute to improved sources of energy. The program consists mostly of a lecture, with a few live demonstrations and audience interactions.

Big Idea
Nanotechnology can have a big impact on the future of energy.

Learning Objectives

- Identify a few potential applications where nano might impact alternative and renewable energies.
- Nanoscale effects occur in many places. Some are natural, everyday occurrences; others are the result of cutting-edge research.

Audience
11 and up

Stage Presentation: Treating Tumors With Gold

Developed by MOS
Presented by public programs staff, SMM

Description
"Treating Tumors with Gold" presents promising research being conducted at Rice University in Texas. Through videos and demonstrations, the program considers the following questions: What is a tumor and what causes it to spread? What is a gold nanoshell and how does it kill tumor cells? What does the future hold for targeted cancer therapies?

Big Idea
Certain properties at the nanoscale allow researchers to exploit materials for new targeted cancer therapies.

Learning Objectives

- Scientists in nanotechnology bridge the gap between disciplines to try and solve research problems.
- The size of a material (like gold) determines its properties and its interaction with light.
- Gold nanoshells can be fabricated to absorb infrared light and produce heat.
- The size of the nanoshell enables it to enter the tumor site.
- Certain properties at the nanoscale allow researchers to exploit materials for new, targeted cancer therapies.

Audience
11 and up

Cart Demonstration: Intro to Nano (cart)

Developed by OMSI
Presented by public programs volunteers, SMM

Description
This cart demonstration reviews the basics about nanotechnology. Visitors learn that nanoscale objects are very small and have surprising properties because of their size. They also learn about some of the possible technologies that may lead to. They mix chemicals, turn potatoes black, generate electricity, and see invisible light in their exploration.

Big Idea
Nanotechnology takes small things that act differently to do something useful.

Learning Objectives
Know that self-assembly is a process for creating nanomaterials.

Audience
11 and up

Cart Demonstration: Electric Squeeze

Developed by OMSI
Presented by public programs volunteers, SMM

Description
Visitors learn how some crystals produce electricity when you squeeze them. They also learn about the history of piezoelectricity, how it's used, and how it's applied in nanotechnology. They make electric sparks, handle models and listen to cheesy music.

Big Idea
Certain crystals have structures that change shape on the nanoscale.

Learning Objectives
The nanostructure of a material determines its properties. Small changes in structure can mean big changes in property.
Piezoelectricity is a property of crystals with a certain shape. Squeeze them and they generate electricity. Apply a current to them and they change shape.
Scientists use piezoelectricity to explore and transform the nanoscale world.

Audience
All ages

Cart Demonstration: Magic Sand

Developed by UW MRSEC
Presented by public programs volunteers, SMM

Description
"Magic Sand" is a cart demo that demonstrates how changing nanoscale changes in a material can affect how that material behaves at the macroscale. Visitors learn that hydrophobic surfaces repel water and that "magic" sand repels water because of a nanoscale hydrophobic coating on the grains of sand. During the program, compare how magic sand and regular sand interact with water.

Big Idea
Nanoscale changes to the surface of sand make it repel water.

Learning Objectives
- See how nanotechnology can change everyday materials
- Learn that magic sand is "afraid" of water because it is covered with a nanoscale monolayer of oil-like molecules.
- Many materials exhibit startling properties at the nanoscale.

Audience
7 and up

NanoDays Activity: Exploring Forces—Gravity
Developed by Sciencenter
Presented by public programs volunteers, SMM

Description
"Exploring Forces - Gravity" is a hands on activity in which visitors discover that it's easy to pour water out of a regular-sized cup, but not out of a miniature cup. They learn that size can affect the way materials like water behave.

Big Idea
A material can act differently when it's nanometer-sized.

Learning Objectives
- A material can act differently when it's nanometer-sized.
- Different physical forces dominate when things get very, very small. For example, gravity is very apparent to us on the macroscale, but it's hardly noticeable on the nanoscale.

Audience
All ages

NanoDays Activity: Exploring Properties—Surface Area
Developed by Sciencenter
Presented by public programs volunteers, SMM

Description

"Exploring Properties - Surface Area" is a hands-on activity demonstrating how a material can act differently when it's nanometer-sized. Visitors compare the reaction rate of an effervescent antacid tablet that is broken in half with one that is broken into many pieces.

Big Idea
A material can act differently when it's nano-sized.

Learning Objectives
Things on the nanoscale have a lot of surface area, so they react much more easily and quickly than they would if they were larger.

NanoDays Activity: Exploring Products—Nano Fabric

Developed by Sciencenter
Presented by public programs volunteers, SMM

Description
"Exploring Products: Nano Fabric" is a hands-on activity exploring how the application of nano-sized whiskers can protect clothing from stains. Visitors investigate the hydrophobic properties of pants made from nano fabric and ordinary fabric.

Big Idea
The way a material behaves on the macroscale is affected by its structure on the nanoscale.

Learning Objectives
The way a material behaves on the macroscale is affected by its structure on the nanoscale.
Special fabrics are coated with nanometer-sized "whiskers" that protect them from stains.

Audience
All ages

Appendix C: Description of Objects Used for Interview

Sorting Items

Short descriptions are provided for each item. Online sources are provided as additional informational materials.

Nano-Tex Fabric Pants / Stain Resistant Pants
(Nano) Stain resistant pants are made by treating fabric with acid and hydrophobic polymers to create a surface that repels liquids. The chemicals are baked into the fabric resulting in hairs that become part of the fabric and repel liquid making them stain resistant.

Sources:
http://www.nanooze.org/english/articles/article17_stainresistantpants.html
http://science.howstuffworks.com/nanotechnology3.htm

iPod Nano
(Not Nano) A handheld, portable media player put out by Apple. The first iPod Nano came out in 2005. The iPod Nano has gone through multiple upgrades with later generations offering more capabilities.

Source:
http://www.ipodhistory.com

CVS Pharmacy Zinc Oxide Skin Protectant Ointment / Generic Rub-on Sunscreen with Zinc Oxide
(Not Nano) Older versions of zinc oxide use large particles of zinc-oxide which are visible. This is what makes many zinc oxide ointments whitish in color.

Source:
http://science.howstuffworks.com/nanotechnology3.htm

Coppertone Kids Continuous Spray Sunscreen / Spray-on Sunscreen with Zinc Oxide
(Nano) This product contains nano-sized particles of zinc oxide. Unlike the zinc oxide in older sunblocks, the smaller particles of zinc oxide are so small that they do not reflect visible light, making the product appear clear.

Source:
http://science.howstuffworks.com/nanotechnology3.htm

Silver Works Ionic Colloidal Silver / Colloidal Silver
(Nano) A suspension of nano-sized silver particles (colloidal silver) in water. It is believed to have medicinal and antimicrobial properties.

A Cabbage Leaf
(Exhibits Nano properties) The leaves on a cabbage have waxy, nanoscale structures that repel water and cause it to bead up and roll off the leaves.

Source:
http://www.nisenet.org/catalog/exhibits/bump_roll

L'Oreal Paris Infallible Never Fail Powder / Makeup with Sunscreen
(Nano) This makeup contains sunscreen with nanoparticles of zinc oxide. Nanoparticles of zinc oxide are less visible than larger particles of zinc oxide and do not affect the pigmentation in the makeup.

FlexPower Joint and Muscle Pain Cream: Topical Cream for Sore Muscles
(Nano) This cream is used to alleviate sore muscles and joints. It contains nanoscale liposomes, FlexSomes ™, that penetrate deep into the skin and reach muscles.

Source:
http://www.flexpower.com/flex_work.html

"Would you use this product?" Questions

3M ESPE Adper Single Bond Plus / Tooth Repair Resin
(Nano) Part of an adhesive kit used for porcelain and composite dental repair. The bonding agent contains nano-scale particles

Source:
http://solutions.3m.com/wps/portal/3M/en_US/3M-ESPE/dental-professionals/products/catalog/online/?PC_7_RJH9U5230GE3E02LECFTDQO5H0_nid=7RRJMKWR70gsGWD35HDG5PglH9543DMWPPbl&PC_7_RJH9U5230GE3E02LECFTDQO5H0_c=LongDescOutlink

Two products from this kit were used; one was used with all visitors; another resin was used as a follow-up with visitors in Little Rock, only.

Location
Oregon Museum of Science & Industry
Museum of Science, Boston
Museum of Discovery, Little Rock

L'Oreal Paris Revitalift Double Lifting Day Treatment / Face Lotion with Nanoparticles
(Nano) A facial cream marketed for fighting wrinkles and retightening skin. It is "unique" in that it combines two "nano-treatments": a "lifting gel" and an "anti-wrinkle" cream.

Sources:

http://webcache.googleusercontent.com/search?q=cache:29cf70GdLYMJ:www.totalbeauty.com/reviews/product/511771/loreal-paris-revitalift-double-eye-lift+L
http://www.lorealparisusa.com/_us/_en/default.aspx#/?page=top{userdata//d+d//|diagnostic|main:pdp//objectid+SK3_8//{pdp_tab:pdp_overview//objectid+SK3_8//}|media:_blank|nav|overlay:_blank}

Locations

Oregon Museum of Science & Industry
Museum of Science, Boston

Appendix D: NISE Network Content Map

Nanoscale Science Informal Learning Experiences: NISE Network Content Map

Version 1, November 19, 2010

The NISE Network content map presents key science content ideas for informal science education in nanoscale science, engineering and technology. NISE Net programs, exhibits, media, and other educational experiences engage the public in these ideas.

The content map is organized around four main ideas:

1. *Nanometer-sized things are very small, and often behave differently than larger things do.*
2. *Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.*
3. *Nanoscience, nanotechnology, and nanoengineering lead to new knowledge and innovations that weren't possible before.*
4. *Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.*

These four statements represent a basic understanding of nanoscale science, technology, and engineering ("nano awareness"). For each of the four main ideas, the content map articulates key supporting information, allowing learners to connect different concepts and explore single ideas more deeply ("nano understanding"). Additionally, the content map includes specific examples that illustrate or demonstrate the supporting knowledge concepts. Each educational experience developed by the network focuses on different parts of the content map, as appropriate for its target audience, format, and topic.

The content map is a working document, and will be updated in coming months and years.

Developed by Marjorie Bequette, Rae Ostman, Kirsten Ellenbogen, Greta Zenner Petersen, Darrell Porcello, Troy Livingston, Marilyn Johnson, and Paul Martin for the NISE Network.

This project was supported by the National Science Foundation under Award Nos. ESI-0532536 and 0940143. Any opinions, findings, and conclusions or recommendations expressed in this program are those of the authors and do not necessarily reflect the views of the Foundation.

IDEA 1:
Nanometer-sized things are very small and often behave differently than larger things do.

Nanoscience is an emerging field in which scientists study and research the novel properties and behaviors of systems operating at the nanoscale.

The prefix "nano" means one thousand millionth, or one billionth. So a "nano" of something is one billionth of the whole—a very, very small fraction. A nanometer is a billionth of a meter.

Scientists and engineers think about, experiment with, and try to explain the properties of materials.

> Physical properties are a way for scientists to describe matter. They can also use these properties to predict a material's behavior. Physical properties include size, conductivity, melting point, and density.
>
> Scientists use chemical properties to describe the ways a material interacts with other matter during a chemical reaction. For example, materials react differently in the presence of oxygen or acid.

Some materials behave in a different way at a small scale than they do at a larger scale. At the nanoscale, a material may exhibit different properties that may lead to new uses.

> For instance, materials on the nanoscale have significantly more surface area per unit of volume than things on the micro- or macroscale. Thus, nanoscale materials often react much more quickly than they would if they were larger.
>
> - For example, aluminum is extremely reactive, but macroscale aluminum objects—like soda cans—generally remain stable unless in a severe environment, like a fire. However, nanoscale particles of aluminum can spontaneously combust and explode because the surface-area-to-volume ratio is so much greater than with a soda can. A much larger percentage of atoms lie on the surface of a nanoparticle, and surface atoms are where reactions take place.
>
> Intermolecular forces cause atoms and molecules to form temporary bonds (to be "sticky"). These forces become more pronounced at the nanoscale and can also influence a material's macroscale properties (and thus how we can use it).
>
> - An example of this from nature is the gecko's foot. When humans touch a wall, the atoms in our hand bond with the atoms in the wall. But those bonds are far too few and too weak to support our weight, which means we can easily pull away. Not so with a gecko. When a gecko puts its foot on a wall, it sticks—not because of a sticky substance, but rather because of intermolecular forces. The feet of a gecko have thousands of extremely fine "hairs" called setae about 200 nanometers thick. This vastly increases the surface area of the lizard's foot. Molecules in the setae are attracted to the molecules in the wall. Because there is so much surface area, enough bonds form to overcome the force of gravity.

Some commonly-used materials can act in unexpected ways at the nanoscale.

A material's color can change when the particles are nanometer-sized. Light interacts differently with very small particles, and can cause them to appear a different color. Examples include titanium dioxide, zinc oxide, and gold.

- Titanium dioxide in its macroscale form is the white sunblock that lifeguards used to put on their noses: great at UV protection, but not very attractive. Nanoscale particles of titanium dioxide offer the same UV protection, but the sunblock appears clear because the particles interact differently with light. This makes for a much more appealing sunblock. Nanoscale titanium dioxide is frequently used in cosmetics with SPF (such as foundation and powders) and sunscreens. Zinc oxide has similar properties and is used the same way.

- Similarly, nanoscale particles of gold look nothing like the yellowish, shiny material used in jewelry. Nanoparticles of gold are so small that they interact differently with light. Thus, solutions of nanoscale gold can appear red, blue, purple, or other colors, depending on the size of the particle and the amount of space between them. The color change that results from the spacing of the gold nanoparticles can be helpful in detecting DNA. When researchers and investigators are testing for the presence of a specific disease or investigating DNA samples from a crime scene, they can attach nanoparticles of gold to strands of DNA that complement the DNA in question. If that DNA is indeed present, the strands of DNA will combine. This brings the particles of gold closer together and consequently changes the color of the solution, indicating the presence of the DNA in question.

IDEA 2:
Scientists and engineers have formed the interdisciplinary field of nanotechnology by investigating properties and manipulating matter at the nanoscale.

All matter consists of atoms, which are particles much too small to see even with light microscopes. Atoms can link together to make molecules. The arrangement of atoms and molecules is a major factor in determining the properties of a material.

Carbon and its different forms are a clear example of the relationship between the properties of a material on the macroscale and the arrangement of its atoms.

- Two familiar forms of carbon atoms are diamond and graphite. Both consist solely of carbon atoms, yet they have very different properties. Diamonds are clear, extremely hard, and electrically insulating. In contrast, graphite is black, soft, slippery, and electrically conductive. The very different properties of diamond and graphite result from the ways in which the carbon atoms are put together. The carbon atoms in diamond are arranged in a very strong tetrahedral shape, making the material hard. In graphite, the carbon atoms are arranged in layers of hexagons, which look like sheets of chicken wire stacked on top of one another. The layers can slip past each other, making the material soft.

- Scientists have recently discovered two new forms of carbon that we didn't know about before: carbon nanotubes and buckyballs (also called fullerenes or C_{60}). Again, these materials have very different properties because of their atomic structure. Carbon nanotubes are hollow, tubular molecules that look like sheets of rolled-up chicken wire. They have very high tensile strength (the strength of something when pulled at both ends), and they can be conducting or semi-conducting. Buckyballs are hollow soccer-ball shaped molecules. They are slippery (they roll easily over one another), and attractive for drug delivery (drugs or other molecules can be put inside the spheres).

Nano researchers have developed new ways to manipulate matter at the nanoscale. These techniques fall into two broad categories, known as "bottom-up" and "top-down" approaches.

"Bottom-up" approaches involve building structures from smaller building blocks, similar to building things out of Lego bricks. The building blocks for nanoscale materials include individual atoms and molecules. An important bottom-up approach is self-assembly, a process by which certain materials, under a certain set of conditions, spontaneously assemble themselves into organized structures.

- A snowflake is a familiar, naturally-occurring example of self-assembly. The complex structure of snowflakes results from the nanoscale arrangement of water molecules in an ice crystal. Under the right conditions, water molecules form an ice crystal, and as additional water molecules join on the crystal grows into a snowflake. Snowflakes have six sides because molecules of water freeze into a hexagonal shape. The spontaneous self-assembly of seemingly perfect snowflakes can happen because each snowflake is so small. The larger something self-assembled is, the more chance there is for something to go wrong in the process. (In nature, you would never expect to see a human-size snowflake: before it could grow that large, it would fall to the ground.)

- Another example of self-assembly at the nanoscale is the bilipid cell membrane. A bilipid membrane consists of two layers of molecules. The hydrophobic ("water-hating") ends of the molecules point toward each other, while the hydrophilic ("water-loving") parts of the molecules line the two sides of the membrane, on the outside of the cell and the inside.

"Top-down" approaches involve paring down larger blocks of material into smaller, nanoscale structures. A macroscale analogy to the top-down down approach is sculpture or carving. When artists create sculptures, they start with a large piece of stone or wood and cut away the extra material to create the figure or shape they want. A benefit of this approach is that it's well-known and understood. A drawback is that it wastes material and isn't extremely precise.

- A technical example of this is creating a computer chip out of a chunk of silicon. Technicians (and others) accomplish this through lithography, a process frequently used in electronics manufacturing. There are several different lithographic techniques, but the general idea is similar to sculpting: take a relatively large sample of silicon and etch it away to create small features and components.

Nanoscale effects occur in a wide range of materials and objects.

Nanoscale effects can be found in nature, such as the super-hydrophobic properties of some leaves, including lotus leaves and the iridescence on some insect wings or bird feathers.

- The lotus effect, first observed in the leaves of the lotus plant, is a dirt- and water-repelling property of some plants. Despite constant exposure to dust, dirt, and rain, the leaves of the lotus plant remain clean and dry. Scientists have learned that this is because the surface of each leaf contains waxy, nanoscale bumps that prevent dirt and water from adhering.

- Similarly, the iridescence on some butterflies, insects, and birds also results from nanoscale structures. For example, the beautiful colors you see in a peacock feather or a blue morpho butterfly wing do not come from pigments, but rather from the size and spacing of nanoscale structures.

Scientists and engineers have recreated some of these effects in commercial products. Stain- and water-resistant fabrics mimic the lotus effect. Security images on currency, credit cards, sensors, and fabrics mimic naturally occurring iridescence.

The dramatic growth of the fields of nanoscience and nanotechnology has been made possible by the recent development of specialized tools by scientists and engineers.

A group of microscopes called scanning probe microscopes (SPMs) illustrates the importance of tools to nanoscience and nanotechnology. Nanoscale objects, including atoms, are smaller than the wavelengths of visible light. Thus, light does not bounce off them; it is literally impossible to see something so small. This means that we can't use traditional light microscopes to see things at the nanoscale.

- A scanning probe microscope gathers information about a surface by detecting different kinds of information. You can think about the tool as "feeling" the topography of a material's surface—its hills, valleys, and contours. Similar to a person running their finger over a page of Braille, an SPM gathers information by running the tip of a probe back and forth over a sample. And, just like the nerve stimulation in the person's finger that must be processed by the brain, the SPM sends the information about the tip movement to a computer, which turns the information into an image. Before the development of scanning probe microscopy, researchers were limited in their ability to learn what is happening in the nanoscale and atomic world. SPMs changed that, opening up new areas for more thorough exploration.

IDEA 3:
Nanoscience, nanotechnology, and nanoengineering lead to new knowledge and innovations that weren't possible before.

In the field of nanotechnology, researchers and engineers take advantage of the change in properties at the nanoscale to produce new and/or improved materials and devices in areas such as computing, medicine, energy, the environment, and manufacturing.

The interdisciplinary nature of the field of nanotechnology has helped scientists and engineers develop new innovations. People from a diverse disciplines work together and share their knowledge and approaches with each other. By approaching scientific and engineering questions from new, interdisciplinary angles, researchers can come up with and pursue new ideas.

Nanotechnology includes a wide range of research and applications. It's important that everyone—scientists, citizens, media, government officials—be specific when talking about each kind of nanotechnology and not assume they are all the same.

The products enabled by nanotechnology include applications that are on our shelves every day.

There are likely many more applications ahead of us, but several current examples include:

- The glue in McDonald's food packaging: http://www.nanotechproject.org/inventories/consumer/browse/products/6806/. Starch-based adhesives are commonly used to laminate graphics onto cardboard packaging, but traditional starch-based adhesives need high temperatures and lots of water to hold the cardboard layers together. A company called EcoSynthetix has made a new adhesive that they claim uses nanoparticles of starch between 50 and 150nm across. The smaller particles have more surface area per volume than larger starch molecules, which means they need less heat and water—and therefore less energy—to activate the adhesive and laminate graphics onto cardboard. McDonald's was the first major company to take advantage of this technology in their cardboard packaging.

- Burt's Bees Chemical-Free Sunscreen SPF 15: http://www.nanotechproject.org/inventories/consumer/browse/products/chemical-free_sunscreen_spf_15/.Titanium dioxide (TiO_2) has long been used as a sunscreen because it reflects, refracts, and absorbs the sun's rays and therefore prevents them from reaching your skin. However, naturally occurring titanium dioxide is opaque white and, when used in a sunscreen, leaves a visible white film on the skin. Nanoscale titanium dioxide, in contrast, is transparent because light interacts differently with particles that small, but it is still effective at protecting skin from UV rays. This Burt's Bees sunscreen, as well as many other skin products, takes advantage of this property of nanoscale titanium dioxide.

- Health and diet supplements, such as NanoTrim http://www.nanotechproject.org/inventories/consumer/browse/products/nanotrim/ and Revive Health supplements http://www.nanotechproject.org/inventories/consumer/browse/products/revive_health_glycemic_supplement/. These companies claim that they have "nanoized" certain nutrients (made them smaller), thereby increasing their reactivity and efficacy within the body (because of the increased surface area), as well as the body's likelihood of accepting the synthetic nutrients.

- Plastic beer bottles, including Corona, Miller Lite, Miller Genuine Draft, and Ice House: http://www.nanotechproject.org/inventories/consumer/browse/products/beer_bottle_plastics/. "Imperm" technology, used by Miller Brewing, is a plastic composite that includes nanoparticles of clay. The clay nanoparticles make the plastic stronger than glass and help prevent air exchange between the inside and outside of the bottle, keeping the beer fresher longer.

All of these examples were found on the Project for Emerging Nanotechnologies (PEN) Consumer Products Inventory website, http://www.nanotechproject.org/inventories/consumer/.

- Disclaimer: It is important to recognize that the PEN inventory does not verify the manufacturers' claims: it's only a repository of products that companies claim to be enabled by nanotechnology. In addition, the list of products enabled by nanotechnology is constantly changing, and the PEN inventory (as well as this content map) can make no claims about the degree to which the listed products are current and accurate.

Nanotechnology allows us to rework existing applications, making things work in new ways as those products are reengineered at the nanoscale. Nano-based research into areas like food supply, clean water, energy, climate change, and disease detection, prevention and treatment may also lead to unprecedented developments and entirely new applications.

Examples of potential applications include targeted cancer treatments; inexpensive and easy-to-use drinking water filters; and more efficient and less expensive solar cells.

- Detecting and fighting cancer: Much of the current research in nanotechnology is dedicated to the ultimate goal of detecting or curing cancer. Current methods of cancer screening have trouble detecting tumors smaller than one million cells. Diagnostics based on nanotechnology research, however, have much higher specificity and are more sensitive, holding the promise of detecting tumors smaller than 1,000 cells. The earlier a doctor can detect cancer, the higher the person's chance of survival. Furthermore, current cancer treatments take a systemic approach: radiation and chemotherapy treatments are directed at a person's entire body, and often the treatment side effects can be as debilitating as the cancer itself. With the extremely small size and increased specificity offered by nanotechnology-enabled approaches, researchers hope to change this. Targeted drug delivery and targeted attacks on tumors would make cancer treatment much easier on the patient. Professor Naomi Halas at Rice University conducts promising research on using gold nanoshells to fight cancer. This targeted therapy focuses only on the tumors, rather than the entire body. An interview with Naomi Halas is online at http://www.pbs.org/wgbh/nova/body/halas-nanoshell.html. The company Nanopartz, based in Colorado, produces and sells the 5-100nm gold nanoshells scientists might use in their research http://www.nanopartz.com/. In addition, a good nanotech/cancer overview article is available at http://www.wired.com/medtech/health/news/2005/11/69206?currentPage=1, Brandon Kleim, "A Nanotech Cure for Cancer?", *Wired*, 11/07/05.

- Filtering drinking water: Nanofilters offer hope for a cheaper and more effective method of cleaning water to make it safe for drinking. These filters have extremely small pores, or holes, some even as small as 15nm across. In comparison, the smallest water-borne poliovirus is 25 nm. Filters with such small pores allow water to pass through, while unwanted bacteria, chemicals, and viruses stay on the other side. No single type filter has yet emerged as a clear success, but scientists and engineers are experimenting with ceramic filters, carbon nanotube filters, and more. Many companies are developing nano-based water treatments. Dais Analytic Corporation in Florida has developed a reverse-osmosis treatment using the "NanoClear" process http://www.daisanalytic.com/nanoclear.htm, while Seldon Technologies in Vermont has created the Seldon WaterBox, a carbon-nanotube-membrane based filter that cleans drinking water http://www.seldontechnologies.com/products.htm. A good review article about filters is J. Theron, J.A. Walker, T.E. Cloete (2008). "Nanotechnology and Water Treatment: Applications and Emerging Opportunities." *Critical Reviews in Microbiology*; 34(1), 43-69.

- Harnessing the sun's energy: Solar cells hold great potential for capturing the sun's energy and transforming it into electricity that we can use to fulfill our various energy needs. However, current solar cells are expensive, bulky, and not very efficient, making them unrealistic for widespread use. Researchers hope that nanotechnology can help address these issues by making thinner, less-expensive, flexible, and/or higher efficiency solar panels. Current research focuses on a range of approaches, including zinc oxide (ZnO), titanium dioxide (TiO_2), carbon nanotubes, buckyballs, and quantum dots. Professor Bob Hamers from the University of Wisconsin-Madison conducts research on the use of carbon nanofibers, titanium dioxide, and zinc oxide for renewable energy purposes. More information about Hamers' research group is available at http://hamers.chem.wisc.edu/. InnovaLight is a California-based company that specializes in silicon nanoparticle-based inks, which they hope to modify and use to design novel solar cells. http://www.innovalight.com/technology_solarink.htm

IDEA 4:
Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict.

Through our choices as consumers and citizens, we affect the development of nanotechnologies.

> People play an important role in governing new technologies, exerting their influence in many ways. Consumers influence the market through purchases. Citizens help choose the political leaders who invest in and regulate new knowledge and technologies. Scientists and engineers choose what knowledge gets pursued, elaborated, and translated into practice. Activists seek to assure that knowledge is pursued and applied in accordance with their agendas.

Governments, companies, and individuals can all be involved in guiding the development and regulation of nanotechnologies.

> Some nanomaterials may interact in surprising new ways with complex biological systems, both in nature and in our bodies, creating new environmental and health impacts (both positive and negative). At the moment, there are few, if any, processes in place to monitor either the presence of nanoparticles or their effects in 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, dangers, and benefits of nanotechnology is matched by uncertainty about how to manage such impacts.

While regulations and safety standards exist for other chemicals, most existing governmental regulations do not seem to apply to nanoscale materials. Even where nanomaterials do fall under existing regulations, the question remains as to whether officials need to reevaluate those regulations.

- 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. It is unclear whether regulations can and should treat nanoparticles in the same way as their larger scale versions.

  In 2009, the USDA National Organics Standards Board (NOSB) materials committee recommended that nanoparticles be excluded from organic production, processing, and packaging, except when required by law. Public comment responding to a previously published NOSB Materials Committee discussion document on nanotechnology overwhelmingly called for the total prohibition of nanotechnology in certified organic products. http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5083223

Non-profits, interest groups, and other coalitions can have an impact on the regulatory regimes that govern nanotechnology.

  In 2006, Friends of the Earth and the International Center for Technology Assessment organized a broad coalition of consumer, health, and environmental groups in submitting the first-ever legal petition to the Food and Drug Administration, charging that the agency has failed to address the human health and environmental risks of nanomaterials in consumer products. http://www.foe.org/groups-challenge-fda-nanotechnology-risks-consumers-and-environmentalists-warn-risks-current-uses-un and http://www.icta.org/press/release.cfm?news_id=19

A nanotechnology that benefits one person or group may put others at risk.

Using nanotechnologies can represent tradeoffs across many dimensions in society. The presence of nanotechnologies in new materials could have secondary environmental, economic, and political impacts across the globe.

  Nanoparticle silver is increasingly common in fabrics as an antibacterial agent. Research shows that silver nanoparticles leach out of the fabrics and into laundry wash water, which could become a concern for water sources, aquatic animals, and perhaps people. http://www.nanowerk.com/news/newsid=5208.php

- As with any technological innovation, new approaches can make old processes obsolete. If new materials reduce the need for catalysts like platinum, the mining industry in South Africa could decline. Similarly, replacing copper in electronics with new conductive nanomaterials could impact the economy of Brazil, a major copper producer.

- Manufacturers of thin film photovoltaics, the next generation of solar technologies, will likely have a market advantage over companies that produce older solar energy technologies.

Technologies and society are closely interconnected. Change in one influences change in the other.

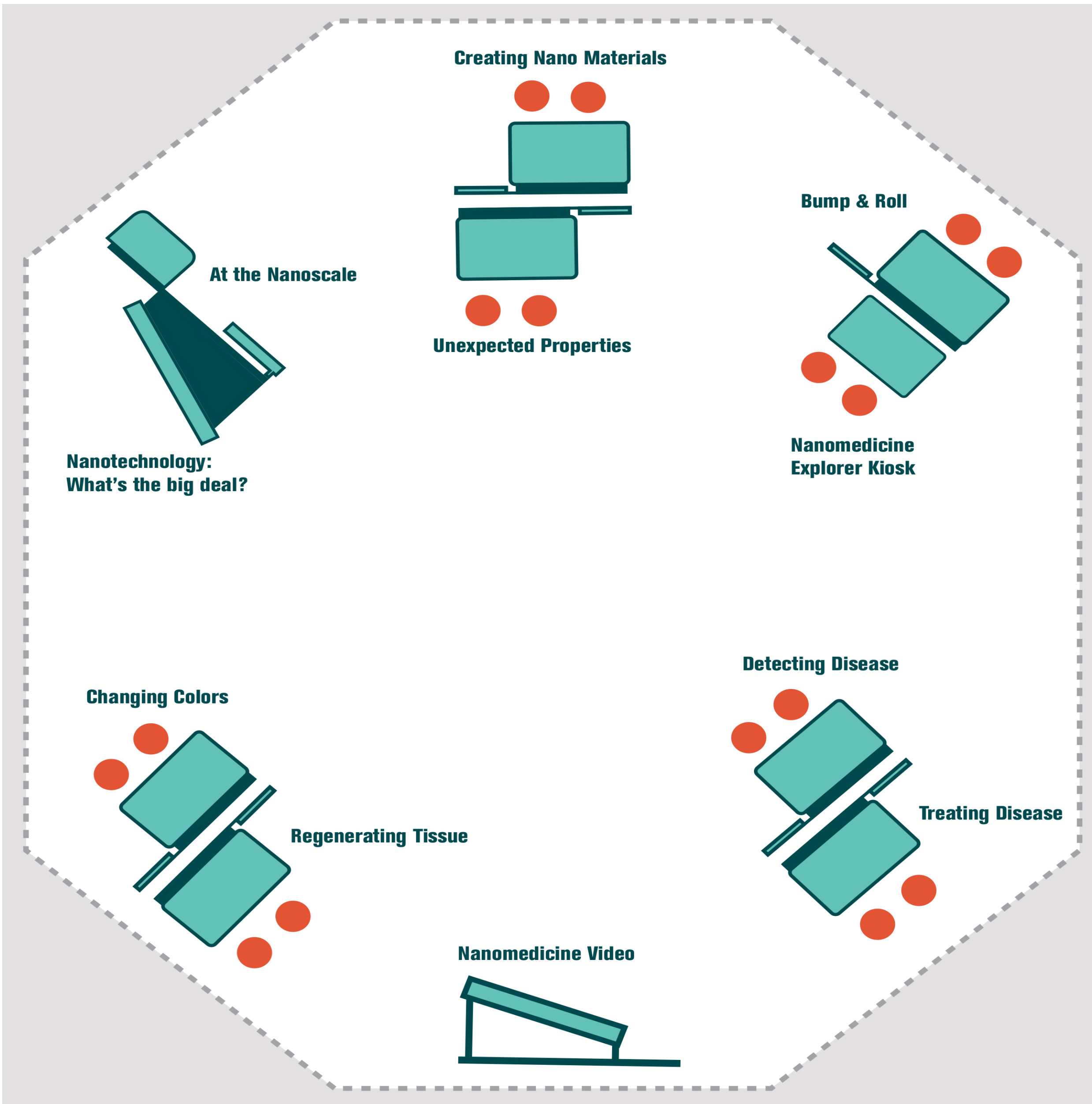
Throughout history, changes in technologies have gone hand-in-hand with changes in the broad organization of society.

- The Industrial Revolution radically changed people's lives. Instead of working at home on the family farm, most people now commute to offices and factories, and structure their lives around 9-to-5 business hours, weekends and two-week vacations. Societies also changed dramatically with the widespread use of the automobile, and again with the adoption of the personal computer and the Internet.

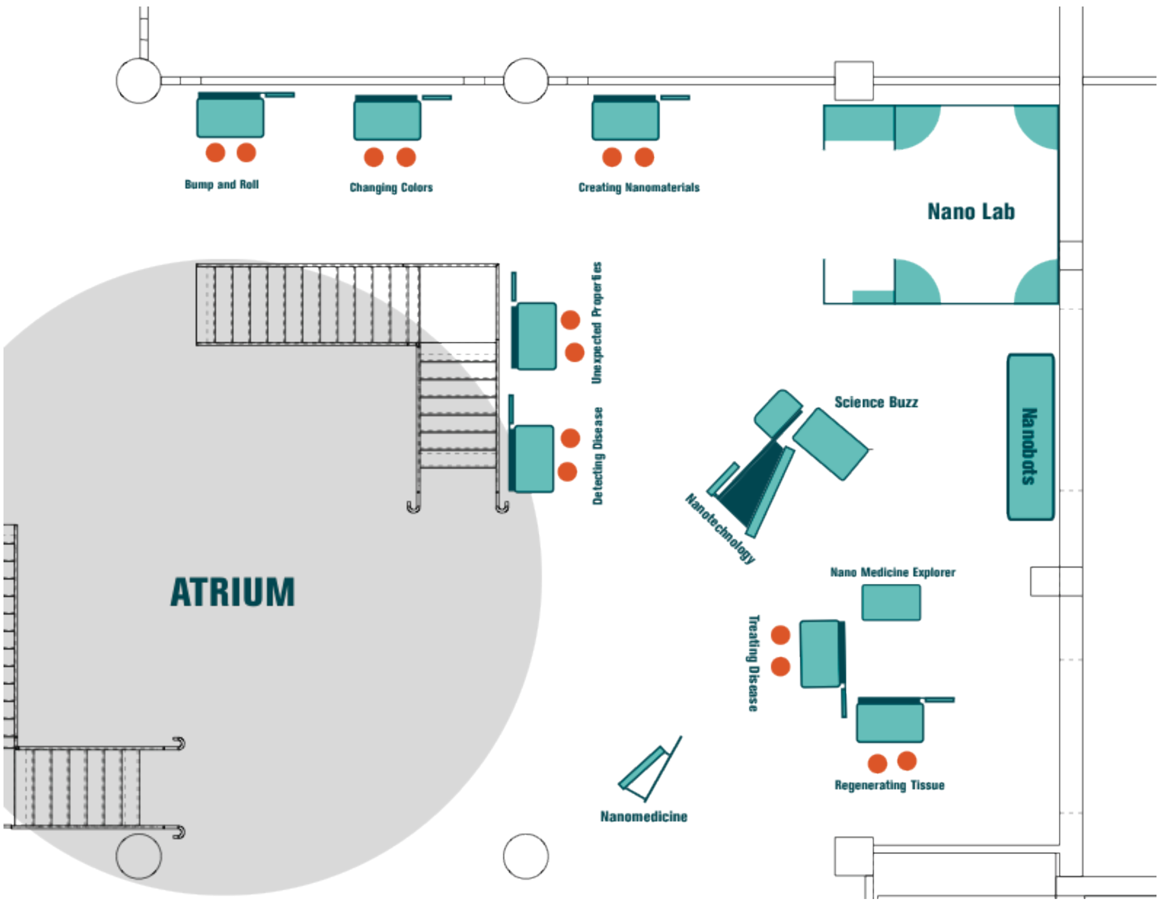
  Similarly, nanotechnologies could also have dramatic effects on our society. For example, researchers are testing a new device designed for public spaces like malls, airports, and even public schools to signal the presence of flu viruses, including swine flu and influenza A (H1N1), and perhaps even HIV.
  http://www.azonano.com/nanotechnology-video-details.asp?VidID=413
  Some sensors could be sophisticated enough to detect illness even before an individual shows symptoms. These kinds of sensors could be vital to preventing broad outbreaks of deadly illnesses in schools and workplaces. However, we currently have strict protections on individual health records, which these sensor data could violate.
  http://216.117.216.152/biosensors.html

Appendix E: Exhibition Maps

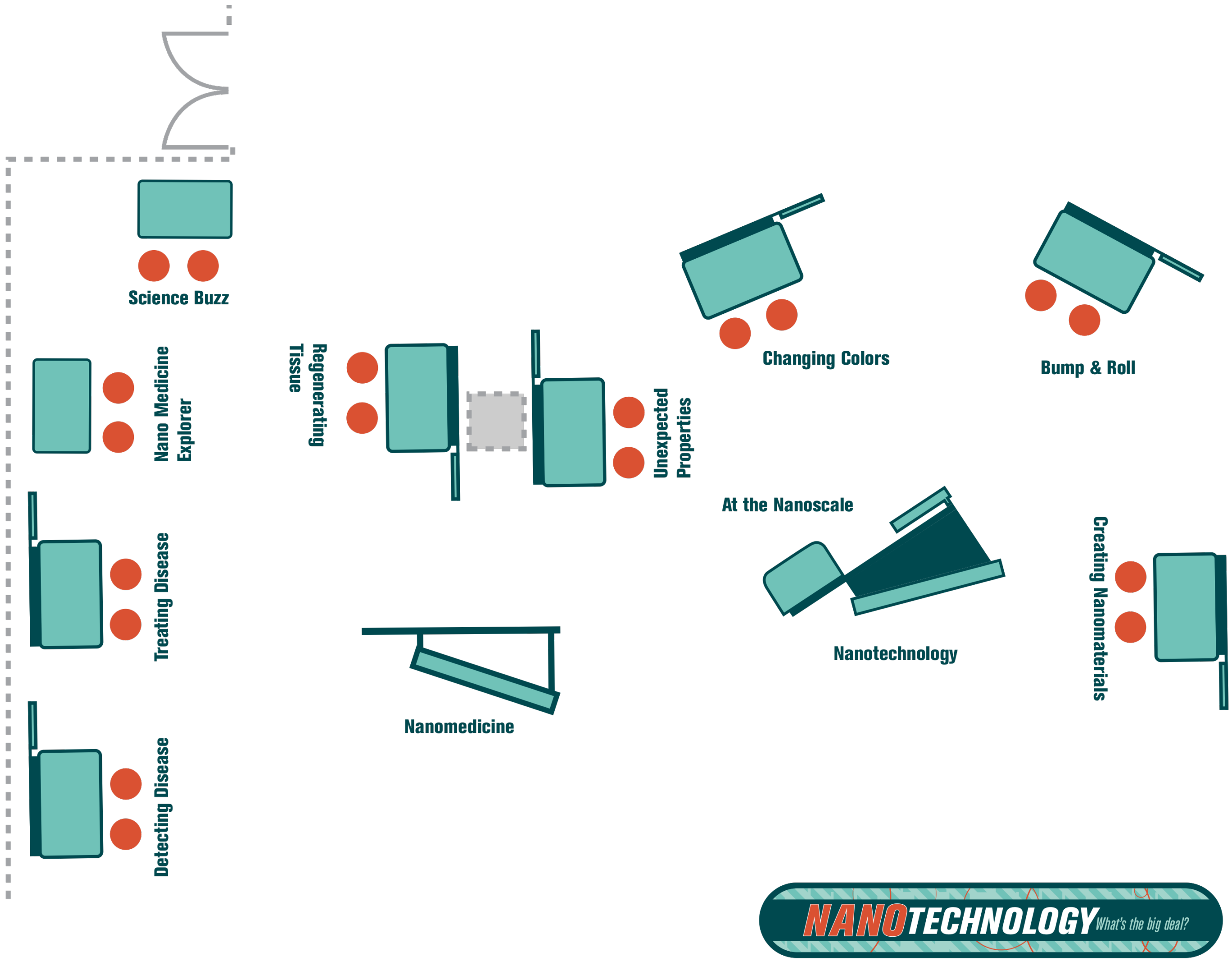
Boston:



Little Rock:


Bump and Roll
Changing Colors
Creating Nanomaterials
Nano Lab
Unexpected Properties
Detecting Disease
Science Buzz
Nanobots
Nanotechnology
ATRIUM
Nano Medicine Explorer
Treating Disease
Regenerating Tissue
Nanomedicine

Portland:



Science Buzz
Nano Medicine Explorer
Regenerating Tissue
Unexpected Properties
Changing Colors
Bump & Roll
Treating Disease
At the Nanoscale
Nanotechnology
Creating Nanomaterials
Nanomedicine
Detecting Disease
NANOTECHNOLOGY What's the big deal?

Appendix F: Exhibit Demographics

Detailed tables with data on all measures used to compare the visitors who saw the exhibits and those who did not are included here.

Demographic data is presented on visitor Gender, Age, Ethnicity, Languages Spoken at Home, Education, Income, Disability, Science in Daily Work, Previous Visits to the Museum, Previously Seen Nano ISE, Interest in Science, and Previous Exposure to Nano.

Boston

GENDER	Male	Female
Pre-exhibit Boston, MOS (n=126)	42.1	57.9
Post-exhibit Boston, MOS (n=125)	32.8	67.2

AGE	Under 21	21-29	30-39	40-49	50-59	60+
Pre-exhibit Boston, MOS (n=125)	6.4	31.2	24.0	16.8	15.2	6.4
Post-exhibit Boston, MOS (n=125)	8.0	26.4	22.4	29.6	10.4	3.2
Comparison data	4.2	9.7	21.6	30.9	15.7	9.9

ETHNICITY	African-American	White	Hispanic	Native American	South Asian	Asian	Other
Pre-exhibit Boston, MOS (n=126)	2.4	82.5	4.8	0.0	1.6	7.9	4.8
Post-exhibit Boston, MOS (n=125)	0.8	85.6	2.4	0.8	2.4	6.4	3.2
Comparison data		78.4					

LANGUAGES SPOKEN AT HOME	English	Spanish	German	French
Pre-exhibit Boston, MOS (n=121)	92.6	4.1	3.3	2.5
Post-exhibit Boston, MOS (n=120)	93.3	3.3	1.7	2.5

Languages spoken at home by 1% or less of visitors were Albanian, Arabic, Catalan, Chinese, Dutch, Filipino, Hindi, Italian, Japanese, Marathi, Nepali, Polish, and Vietnamese.

EDUCATION LEVEL	Less than high school	Completed high school	Some college or technical ed.	College degree	Post-graduate degree
Pre-exhibit Boston, MOS (n=126)	0.8	11.1	23.0	34.1	31.0
Post-exhibit Boston, MOS (n=124)	1.6	5.6	20.2	44.4	28.2
Boston comp (n=235)	NA	5.5	13.6	30.6	47.7 (+Post-grad work)

INCOME	Under $20,000	$20,000 -$39,999	$40,000 -$59,999	$60,000 -$79,999	$80,000 -$99,999	$100,000 -$149,999	$150,000 +
Boston Pre-Exhibit (n=111)	11.7	11.7	18.0	9.9	14.4	23.4	10.8
Boston Post-Exhibit (n=112)	11.6	9.8	14.3	11.6	17.0	19.6	16.1
Boston Comparison Data	Under $25,000 3.8	$25,000-$49,999 11.5	$50,000-$74,999 18.3	$75,000-$99,999 13.6	$100,000-$149,999 22.1	$200,000+ 6.7	$100,000-$149,999 22.1

DISABILITY	Yes	No
Pre-exhibit Boston, MOS (n=123)	2.4	97.6
Post-exhibit Boston, MOS (n=124)	6.5	93.5
Boston comparison data (n=232)	10.3	89.7

"DO YOU USE SCIENCE IN YOUR DAILY WORK?"	Yes	No
Pre-exhibit Boston, MOS (n=125)	49.6	50.4
Post-exhibit Boston, MOS (n=125)	49.6	50.4

VISITS TO THE MUSEUM IN THE LAST TWO YEARS	None	1-2 times	3-4 times	5 or more times
Pre-exhibit Boston, MOS (n=126)	43.7	27.0	13.5	15.9
Post-exhibit Boston, MOS (n=124)	52.4	25.0	11.3	11.3

SEEN NANO ISE BEFORE	Yes	No
Pre-exhibit Boston, MOS (n=54)	7.4	92.6
Post-exhibit Boston, MOS (n=55)	9.1	90.9

This question was asked in the interview.

Boston, Scale questions regarding interest in science and previous exposure to nanoscience

	Stage	N	Mean	*SD*
Interest in Science (on a scale of 0-10)	Pre	125	8.06	1.958
	Post	125	7.64	2.259
Previous Exposure to Nanoscience (on a scale of 0-10)	Pre	128	4.68	3.137
	Post	124	4.49	2.943

Boston, Mann-Whitney U Tests to examine demographic differences in pre- and post-samples

	U	*Z*	*p*	Pre-sample n	Post-sample n
Gender	7145.50	-1.51	0.13	126	125
Age	7794.50	-0.03	0.97	125	125
Education	7625.50	-0.46	0.65	126	125
Income	5870.50	-0.73	0.47	111	112
Ethnicity (White/Non-White)	8138.00	-0.61	0.54	130	129
Language (English/Non-English)	8329.50	-0.15	0.88	130	129
Disability (Y/N)	7444.50	-1.40	0.16	124	125
Science at work (Y/N)	7812.50	0.00	1.00	125	125
Visits to the museum	7008.50	-1.62	0.11	126	125
Seen nano exhibits/programs before (Y/N)	1460.00	-0.32	0.75	54	55
Interest in Science	7053.50	-1.36	0.18	125	125
Previous exposure to nano ISE	7690.00	-0.43	0.67	128	124

*Significant at the $p < .05$ level.

Non-parametric Mann-Whitney U tests were performed on each of the demographic and psychographic indicators to determine whether the pre- and post-samples were taken from the same general population. The categories used in these tests for Gender, Age, Education, Income, and Visits to the Museum were the same as those reported in the tables above. Based on initial frequency analysis, categories were simplified for Ethnicity (into White and Non-white) and Language (English and Non-English). No statistically significant demographic differences were identified between the pre- and post-samples for the Boston data.

Little Rock

GENDER	Male	Female

Pre-Exhibit Little Rock, MOD (n=44)	59.1	40.9
Post-Exhibit Little Rock, MOD (n= 74)	51.4	48.6

AGE	Under 21	21-29	30-39	40-49	50-59	60+
Pre-exhibit Little Rock, MOS (n=44)	2.3	13.6	54.5	18.2	2.3	9.1
Post-exhibit Little Rock, MOS (n=74)	0.0	14.9	43.2	24.3	14.9	2.7

ETHNICITY	African-American	White	Hispanic	Native American	South Asian	Asian	Other
Pre-Exhibit Little Rock, MOD (n=44)	9.1	90.9	0.0	4.5	0.0	2.3	0.0
Post-Exhibit Little Rock, MOD (n= 73)	11.0	87.7	1.4	0.0	0.0	0.0	0.0

LANGUAGES SPOKEN AT HOME	English	Spanish	German	Gujarati
Pre-Exhibit Little Rock, (n=43)	100.0	0.0	2.3	2.3
Post-Exhibit Little Rock, MOD (n=74)	100.0	2.7	0.0	0.0

EDUCATION	Less than high school	Completed high school	Some college or technical ed.	College degree	Post-graduate degree
Pre-Exhibit Little Rock, MOD (n=43)	0.0	11.6	25.6	44.2	18.6
Post-Exhibit Little Rock, MOD (n= 75)	0.0	13.3	34.7	36.0	16.0

INCOME	Under $20,000	$20,000-$39,999	$40,000-$59,999	$60,000-$79,999	$80,000-$99,999	$100,000-$149,999	$150,000+
Little Rock Pre-Exhibit (n=39)	10.3	20.5	15.4	12.8	15.4	15.4	10.3
Little Rock Post-Exhibit (n=71)	5.6	19.7	22.5	8.5	19.7	11.3	12.7
Little Rock Comparison Data							

DISABILITY	Yes	No
Pre-Exhibit Little Rock, (n=43)	7.0	93.0
Post-Exhibit Little Rock, MOD (n=75)	14.7	85.3

"DO YOU USE SCIENCE IN YOUR DAILY WORK?"	Yes	No
Pre-Exhibit Little Rock, (n=44)	47.7	52.3

Post-Exhibit Little Rock, MOD (n=72)	37.5	62.5

NO. OF VISITS IN LAST TWO YEARS	None	1-2 times	3-4 times	5 or more times
Pre-Exhibit Little Rock, MOD (n=43)	60.5	14.0	9.3	16.3
Post-Exhibit Little Rock, MOD (n=75)	65.3	21.3	5.3	8.0

PREVIOUS NANO ISE	Yes	No
Little Rock Pre-Exhibit (n=25)	0.0	100.0
Little Rock Post-Exhibit (n=53)	1.9	98.1

This question was asked in the interview.

LITTLE ROCK SCALE QUESTIONS	Stage	N	Mean	*SD*
Interest in Science (on a scale of 0-10)	Pre	43	7.65	2.181
	Post	74	6.43	2.527
Previous Exposure to Nanoscience (on a scale of 0-10)	Pre	44	3.34	2.869
	Post	72	4.01	2.464

LITTLE ROCK MANN-WHITNEY U TESTS	*U*	*Z*	*p*	Pre-sample n	Post-sample n
Gender	1502.00	-0.81	0.42	44	74
Age	1453.50	-1.04	0.30	44	74
Education	1454.50	-0.93	0.35	43	75
Income	1333.00	-0.33	0.74	39	71
Ethnicity (White/Non-White)	1522.00	-1.43	0.15	44	76
Language (English/Non-English)	1666.00	-0.12	0.90	44	76
Disability (Y/N)	1488.50	-1.24	0.22	43	75
Science at work (Y/N)	1422.00	-1.08	0.28	44	72
Visits to museum	1474.00	-0.90	0.37	43	75
Seen nano exhibits/programs before (Y/N)	650.00	-0.69	0.49	25	53
Interest in Science	1149.50	-2.52	**0.01***	43	74
Previous exposure to nano ISE	1291.50	-1.69	0.09	44	72

*Significant at the $p < .05$ level.

Non-parametric Mann-Whitney U tests were performed on each of the demographic and psychographic indicators to determine whether the pre- and post-samples were taken from the same general population. The categories used in these tests for Gender, Age, Education, Income, and Visits to the Museum were the same as those reported in the tables above. Based on initial frequency analysis, categories were simplified for Ethnicity (into White and Non-white) and Language (English and Non-English). A statistically significant difference was identified in the levels of interest in science for pre- and post-sample visitors; as seen in means reported in the table above, the pre-sample visitors appeared to have higher levels of interest in science than the visitors in the Post-sample. However, no other statistically significant differences were found for the Little Rock data.

Portland

GENDER	Male	Female
Pre-exhibit Portland, OMSI (n=75)	54.7	45.3
Post-exhibit Portland, OMSI (n=101)	56.4	43.6

AGE	Under 21	21-29	30-39	40-49	50-59	60+
Pre-exhibit Portland, MOS (n=75)	4.0	25.3	32.0	28.0	4.0	6.7
Post-exhibit Portland MOS (n=101)	5.0	37.6	22.8	20.8	11.9	2.0

ETHNICITY	African-American	White	Hispanic	Native American	South Asian	Asian	Other
Pre-exhibit Portland, OMSI (n=75)	1.3	86.7	5.3	0.0	0.0	5.3	5.3
Post-exhibit Portland, OMSI (n=101)	3.0	83.2	6.9	2.0	1.0	3.0	4.0

LANGUAGES SPOKEN AT HOME	English	Spanish
Pre-exhibit Portland, OMSI (n=75)	98.7	5.3
Post-exhibit Portland, OMSI (n=100)	98.0	7.0

Languages spoken at home by 1% or less of visitors were Cantonese, Czech, Danish, German, Gujarati, Hindi, Korean, Marathi, Russian, and Swedish.

EDUCATION LEVEL	Less than high school	Completed high school	Some college or technical ed.	College degree	Post-graduate degree
Pre-exhibit Portland, OMSI (n=75)	0.0	9.3	30.7	37.3	22.7
Post-exhibit Portland, OMSI (n= 101)	3.0	16.8	23.8	39.6	16.8

INCOME	Under $20,000	$20,000-$39,999	$40,000-$59,999	$60,000-$79,999	$80,000-$99,999	$100,000-$149,999	$150,000+
Portland Pre-Exhibit (n=71)	11.3	18.3	14.1	15.5	8.5	15.5	16.9
Portland Post-Exhibit (n=96)	19.8	16.7	16.7	11.5	10.4	13.5	11.5

DISABILITY	Yes	No
Pre-exhibit Portland, OMSI (n=75)	5.3	94.7
Post-exhibit Portland, OMSI (n=101)	7.9	92.1

"DO YOU USE SCIENCE IN YOUR DAILY WORK?"	Yes	No
Pre-exhibit Portland, OMSI (n=74)	47.3	52.7
Post-exhibit Portland, OMSI (n=99)	49.5	50.5

NO. OF VISITS IN LAST TWO YEARS	None	1-2 times	3-4 times	5 or more times
Pre-exhibit Portland, OMSI (n=75)	37.3	17.3	22.7	22.7
Post-exhibit Portland, OMSI (n=101)	53.5	22.8	9.9	13.9

PREVIOUS NANO ISE	Yes	No
Pre-exhibit Portland, OMSI (n=50)	6.0	94.0
Post-exhibit Portland, OMSI (n=59)	6.8	93.2

This question was asked in the interview.

PORTLAND SCALE QUESTIONS	Stage	N	Mean	*SD*
Interest in Science (on a scale of 0-10)	Pre	75	7.88	1.945
	Post	100	7.85	2.124
Previous Exposure to Nanoscience (on a scale of 0-10)	Pre	75	4.31	2.477
	Post	98	4.33	2.651

PORTLAND MANN-WHITNEY U TESTS	*U*	*Z*	*p*	No. of visitors-pre	No. of visitors-post
Gender	3720.50	-0.23	0.82	75	101
Age	3373.50	-1.28	0.20	75	101
Education	3394.00	-1.23	0.22	75	101
Income	2986.00	-1.38	0.17	71	96
Ethnicity (White/Non-White)	3617.50	-0.80	0.42	75	101
Language (English/Non-English)	3725.50	-0.72	0.47	75	101
Disability (Y/N)	3689.50	-0.67	0.50	75	101
Science at work (Y/N)	3582.50	-0.29	0.78	74	99
Visits to museum	2975.50	-2.59	0.01*	75	101
Seen nano exhibits/programs before (Y/N)	1353.50	-1.41	0.16	50	59
Interest in Science	3671.50	-0.24	0.81	75	100
Previous exposure to nano ISE	3651.00	-0.07	0.94	75	98

*Significant at the $p < .05$ level.

Non-parametric Mann-Whitney U tests were performed on each of the demographic and psychographic indicators to determine whether the pre- and post-samples were taken from the same general population. The categories used in these tests for Gender, Age, Education, Income, and Visits to the Museum were the same as those reported in the tables above. Based on initial frequency analysis, categories were simplified for Ethnicity (into White and Non-white) and Language (English and Non-English). A statistically significant difference was identified in the numbers of visits to the museum for pre- and post-sample visitors; as reported in the table above, over half of the post-sample visitors had not been to the museum in the past two years, while almost half of the Pre-sample visitors had been three or more times over the same period. However, no other statistically significant differences were found for the Portland data.

Pine Bluff

The data collected at the Pine Bluff location focused on a sample of children.

GENDER	Male	Female
Pine Bluff (n=73)	53.4	46.6

AGE	5 and under	6-8	9-12	Over 12
Pine Bluff (n=71)	2.8	33.8	62.0	1.4

ETHNICITY	African-American	White	Hispanic	Native American	South Asian	Asian	Other
Pine Bluff (n= 80)	77.8	5.6	9.7	9.7	1.4	4.2	2.8

LANGUAGES SPOKEN AT HOME	English	Spanish
Pine Bluff (n=60)	100.0	0.0

DISABILITY	Yes	No
Pine Bluff (n=73)	11.0	89.0

	Mean	Standard Deviation
Interest in Science, on a scale of 0-10 (n=68)	7.54	2.99

Appendix G: Program Demographics

GENDER	Male	Female
Pre-Short programs (n=196)	40.8	59.2
Post-Short programs (n=391)	39.6	60.4
Pre-Long programs (n=150)	37.3	62.7
Post-Long programs (n=358)	48.3	51.7

AGE	Under 21	21-29	30-39	40-49	50-59	60+
Pre-Short programs (n=192)	4.2	19.8	29.7	20.8	13.0	12.5
Post-Short programs (n=390)	4.4	14.6	35.1	31.8	9.0	4.9
Pre-Long programs (n=149)	2.7	9.4	25.5	34.9	13.4	14.1
Post-Long programs (n=355)	5.1	15.2	30.1	28.5	13.5	7.6

ETHNICITY	African-American	White	Hispanic	Native American	South Asian	Asian	Other
Pre-Short programs (n=193)	4.1	90.2	0.0	1.6	1.0	2.6	3.1
Post-Short programs (n=388)	1.8	88.4	2.6	1.8	1.3	5.2	2.1
Pre-Long programs (n= 358)	3.2	89.8	0.3	0.6	0.9	2.2	2.6
Post-Long program (n=356)	2.8	80.3	2.0	2.2	1.7	8.7	3.9

EDUCATION	Less than high school	Completed high school	Some college or technical ed.	College degree	Post-graduate degree
Pre-Long programs (n=150)	0.7	6.0	22.7	42.7	28.0
Post-Long programs (n=357)	1.7	11.2	20.7	40.1	26.3

LANGUAGES SPOKEN AT HOME	English	Spanish
Pre-Long programs (n=144)	95.8	1.4
Post-Long programs (n=350)	95.1	2.0

Languages spoken at home by 1% or less of visitors were American Sign Language (ASL), Arabic, Bengali, Chinese, Finnish, French, German, Hindi, Hmong, Italian, Japanese, Kannada, Korean, Marathi, Malay, Malayalam, Multiple (Unspecified), Other, Portuguese, Russian, Swedish, Tagalog, Tamil, Telugu, Ukranian, and Urdu.

DISABILITY	Yes	No
Pre-Short programs (n=194)	7.2	92.8
Post-Short programs (n=390)	4.4	95.6
Pre-Long programs (n=151)	4.6	95.4
Post-Long programs (n=361)	6.1	93.9

INCOME	Under $20,000	$20,000-$39,999	$40,000-$59,999	$60,000-$79,999	$80,000-$99,999	$100,000-$149,999	$150,000+
Pre-Long programs (n=134)	2.2	10.4	13.4	17.9	14.9	29.1	11.9
Post-Long programs (n=326)	12.0	15.0	14.7	19.6	13.8	16.0	8.9

"D O YOU USE SCIENCE IN YOUR DAILY WORK?"	Yes	No
Pre-Short programs (n=192)	50.0	50.0
Post-Short programs (n=382)	49.0	51.0
Pre-Long programs (n=156)	57.1	42.9
Post-Long programs (n=350)	51.1	48.9

NO. OF VISITS IN THE LAST 2 YEARS	None	1-2 times	3-4 times	5 or more times
Pre-Long programs (n=150)	31.3	31.3	24.0	13.3
Post-Long programs (n=356)	41.6	21.6	18.3	18.5

Programs, Scale questions regarding interest in science and previous exposure to nanoscience

	Length	Stage	N	Mean	*SD*
Interest in Science (on a scale of 0-10)	Short	Pre	191	7.55	1.972
		Post	393	7.64	2.113
	Long	Pre	154	8.01	1.667
		Post	354	7.86	1.894
Previous Exposure to Nanoscience (on a scale of 0-10)	Short	Pre	197	3.84	2.574
		Post	407	3.60	2.769
	Long	Pre	155	3.65	2.535
		Post	348	4.26	2.738

SHORT PROGRAMS MANN-WHITNEY U TESTS	*U*	*Z*	*p*	Pre-sample n	Post-sample n
Gender	37868.00	-0.27	0.78	196	391
Age	35928.00	-0.82	0.41	192	390
Ethnicity (White/Non-White)	39517.00	-1.24	0.22	201	409
Disability (Y/N)	36935.50	-1.18	0.24	194	390
Science at work (Y/N)	36432.00	-0.15	0.88	192	382
Interest in Science	35711.50	-0.97	0.33	191	393
Previous exposure to nano ISE	37373.00	-1.36	0.17	197	407

*Significant at the $p < .05$ level.

Non-parametric Mann-Whitney U tests were performed on each of the demographic and psychographic indicators to determine whether the pre- and post-samples were taken from the same general population. The categories used in these tests for Gender and Age were the same as those reported in the tables above. Based on initial frequency analysis, categories were simplified for Ethnicity, into White and Non-white groups. No statistically significant differences were found for the Short program data.

LONG PROGRAMS MANN-WHITNEY U TESTS	*U*	*Z*	*p*	Pre-sample n	Post-sample n
Gender	23899.00	-2.27	0.02*	150	358
Age	22156.50	-2.96	0.00**	149	355
Education	25215.00	-1.09	0.28	150	357
Income	16685.50	-4.03	0.00**	134	326
Ethnicity (White/Non-White)	26201.00	-1.85	0.06	156	361
Language (English/Non-English)	27517.50	-0.83	0.41	156	361
Disability (Y/N)	26858.00	-0.65	0.52	151	361
Science at work (Y/N)	25687.00	-1.23	0.22	156	350
Visits to museum	25426.50	-0.89	0.38	150	356
Interest in Science	26559.50	-0.47	0.64	154	354
Previous exposure to nano ISE	23248.50	-2.49	0.01*	155	348

*Significant at the $p < .05$ level; **Significant at the $p < .01$ level.

Non-parametric Mann-Whitney U tests were performed on each of the demographic and psychographic indicators to determine whether the pre- and post-samples were taken from the same general population. The categories used in these tests for Gender, Age, Education, Income, and Visits to the Museum were the same as those reported in the tables above. Based on initial frequency analysis, categories were simplified for Ethnicity (into White and Non-white) and Language (English and Non-English). Statistically significant differences were identified in the Gender, Age, Income, and Previous Exposure to Nanoscience for pre- and post-sample Long program visitors. As reported in the tables above, there are a higher percentage of males in the post-sample, and overall the sampled population appears to be younger than in the pre-sample. Visitors in post-sample for the Long programs also tended to make less annual income than those in the pre-sample. Finally, visitors in the post-sample reported higher levels of prior exposure to nanoscience and technology than those in the pre-sample. No other statistically significant differences were found for the Long program data.

Appendix H: Regression Analysis

Regression analysis can be a useful tool for examining the relationships between specific project outcomes, project activities, and characteristics of study participants. In this study, we used regression to more deeply explore the associations between visitor contact with NISE products (the exhibition or programs), demographic and psychographic information, and three specific outcomes of interest: visitor confidence around nanoawareness items, visitor references to nanoawareness items when asked to define nano, and visitor connection to nano topics. These three outcomes were chosen after an initial analysis of the survey and interview data revealed interesting patterns that could be more effectively explored with regression techniques.

In this study, two types of regression were implemented: linear regression, used in cases where the outcome variable was a rating on an multi-point scale, and logistics regression, used in cases where the outcome variable was dichotomous (with values of either "0" or "1," depending on the presence or absence of a certain coding category). When the regression results were interpreted, significant coefficients or odds ratios (depending on the type of regression) were identified and became the basis for claims about relationships between the different factors and the outcome variables. It is important to note that we did not focus heavily on the magnitude of the significant coefficients or odds ratios, but rather, just the general type of association – positive or negative – each had with the outcome variable. Our intent was to simply explore the presence or absence of these relationships and speak about their general nature, not to compare them to one another in order to make claims about one factor having more or less of an effect on the outcome than another factor.

The covariates, or independent variables, included in the regression models varied, depending on what information was gathered during data collection within a given context. However, through the use of common demographics and psychographic questions on each survey instrument, the manner in which specific pieces of information were collected from visitors did not vary across contexts. The most commonly included covariates in the regression models were whether visitors used science in their daily work, gender, interest in science, age, prior exposure to nano, education level, and income level. These variables differed in range, as seen in Table H1 below.

Table H1: Summary of numerical ranges for variables included in the linear regression of confidence items.

Variable	Numerical Range	Comments
Exhibition/program attendance	0 or 1	0 = no attendance 1 = exhibit/program attendance
Science at work	0 or 1	0 = does not use science daily 1 = does use science daily
Interest in science	0 to 10	Scale
Previous exposure to nanoscience	0 to 10	Scale
Gender	0 or 1	0=female 1=male
Age	Varies	Number reported by visitor
Education	0 to 5	Closed-ended question with 5 increasing levels
Income	0 to 12	Closed-ended question with 12 increasing levels

The essential elements of the linear and logistic regression models produced during the data analysis for this study are described in the sections that follow. The models are presented in the order their summary tables appear in the body of the report, beginning with the regressions on the exhibition data and following with those from the program data.

Regressions Performed on Exhibition Data

Visitor confidence in performing nano-related tasks

The first set of regressions performed on the exhibition data correspond to the survey question that asked visitors to rate their confidence in doing certain tasks related to the key nanoawareness indicators. Visitors rated their confidence in performing each task on an 11-point scale of 0-10, and then these ratings were transformed into a 0-5 point scale using the compression algorithm described in the body of the report. A set of five linear regressions, each with one task's confidence ratings as its outcome variable, were performed, and the resulting models can be seen in Tables H2-H6 below.

Table H2: Linear regression model for "Name a nanoscale sized object" outcome using pooled exhibit data.

	Coefficient, B	Std. Error, B	Std. Coefficient, β
Exhibition attendance	0.646	0.127	0.192**
Science at work	0.006	0.006	0.040
Interest in science	0.177	0.033	0.233**
Previous exposure to nanoscience	0.233	0.026	0.390**
Gender	0.019	0.015	0.052
Age	-0.008	0.006	-0.060

Education	0.059	0.070	0.034
Income	0.027	0.020	0.058
Constant	-0.710	0.381	

**p<0.01; *p<0.05 as observed within the model; R^2=0.339.

By calculating significant standard coefficient values greater than zero for exhibit attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in naming a nanoscale sized object.

Table H3: Linear regression model for "Describe one way that nanoscale objects behave differently than other objects" outcome using pooled data.

	B	Std. Error B	β
Exhibition attendance	0.977	0.122	0.289**
Science at work	0.009	0.006	0.065
Interest in science	0.147	0.031	0.193**
Previous exposure to nanoscience	0.266	0.024	0.444**
Gender	-0.003	0.015	-0.007
Age	0.002	0.006	0.015
Education	0.081	0.067	0.046
Income	0.011	0.019	0.022
Constant	-1.176	0.365	

**p<0.01; *p<0.05 as observed within the model; R^2=0.400.

By calculating significant standard coefficient values greater than zero for exhibit attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in describing a way that nanoscale objects behave differently than other objects.

Table H4: Linear regression model for "Describe a process used to produce objects at the nanoscale" outcome using pooled data.

	B	Std. Error B	β
Exhibition attendance	0.762	0.125	0.234**
Science at work	0.015	0.006	0.112**
Interest in science	0.114	0.032	0.156**
Previous exposure to nanoscience	0.238	0.025	0.412**
Gender	-0.008	0.015	-0.024
Age	0.002	0.006	0.019
Education	0.032	0.069	0.019
Income	0.005	0.020	0.012

Constant	-0.770	0.375	

**p<0.01; *p<0.05 as observed within the model; R^2=0.313.

By calculating significant standard coefficient values greater than zero for exhibit attendance, use of science in daily work, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in describing a process used to create objects at the nanoscale.

Table H5: Linear regression model for "Name an application of nanoscale science" outcome using pooled data.

	B	Std. Error B	β
Exhibition attendance	1.235	0.116	0.348**
Science at work	0.009	0.005	0.059
Interest in science	0.187	0.030	0.233**
Previous exposure to nanoscience	0.285	0.023	0.454**
Gender	-0.010	0.014	-0.026
Age	0.002	0.005	0.017
Education	0.187	0.064	0.101**
Income	0.021	0.018	0.042
Constant	-1.662	0.349	

**p<0.01; *p<0.05 as observed within the model; R^2=0.501.

By calculating significant standard coefficient values greater than zero for exhibit attendance, visitor interest in science, prior nano exposure, and education level, this linear regression model identifies these factors as having a positive association with visitor confidence in naming an application of nanoscale science.

Table H6: Linear regression model for "Explain some risks and benefits of nanotechnology" outcome using pooled data.

	B	Std. Error B	β
Exhibition attendance	1.004	0.119	0.297**
Science at work	0.015	0.005	0.106**
Interest in science	0.197	0.030	0.258**
Previous exposure to nanoscience	0.249	0.024	0.415**
Gender	-0.014	0.014	-0.038
Age	0.008	0.005	0.059
Education	0.114	0.065	0.065

Income	-0.003	0.019	-0.006
Constant	-1.675	0.356	

**p<0.01; *p<0.05 as observed within the model; R^2=0.431.

By calculating significant standard coefficient values greater than zero for exhibit attendance, use of science in daily work, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in explaining some risks and benefits of nanotechnology.

A summary of significant associations determined by this set of regressions can be seen in Table H7 below.

Table H7: Summary of significant coefficients within linear regressions performed on each confidence item (3 locations pooled)

Topic	Exhibition Attendance	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age	Education	Income
Name a nanoscale sized object	√ (+)		√ (+)	√ (+)				
Describe one way that nanoscale objects behave differently than other objects	√ (+)	√ (+)	√ (+)	√ (+)				
Describe a process used to produce objects at the nanoscale	√ (+)	√ (+)	√ (+)	√ (+)				
Name an application of nanoscale science	√ (+)		√ (+)	√ (+)				
Explain some risks and benefits of nanotechnology	√ (+)	√ (+)	√ (+)	√ (+)				

Open-ended nanoawareness questions

The next regression performed on exhibit data corresponds to the interview question that asked visitors to complete the statement "Nanoscale science is the study of . . .?" A high percentage of visitors in both the pre- and post-exhibition samples gave responses to this question that touched on the "Nano is small" aspect of nanoawarenss, and therefore we conducted a logistic regression to better understand the relationships between this outcome, exhibit attendance, and other demographic and psychographic factors. Visitor responses coded as having a reference to "Nano is small" were assigned the value of "1," and all other cases were assigned the value of "0." These codes became the outcome variable for the logistic regression. The covariates included exhibit attendance, use of science in daily work, gender, interest in science, age, and prior nano exposure. The results of the regression model can be seen in Table G8 below.

Table H8: Logistic regression model for "Nano is small" outcome using pooled data.

	B	Std. Error B	β
Exhibition attendance	0.059	0.270	1.061
Science at work	0.010	0.012	1.010
Interest in science	0.101	0.062	1.107
Previous exposure to nanoscience	0.187	0.055	1.205**
Gender	-0.045	0.043	0.956
Age	-0.004	0.011	0.996
Constant	-0.470	0.656	0.625

**p<0.01; *p<0.05 as observed within the model; Cox & Snell R^2=0.079; Nagelkerke R^2=0.112.

The regression model only produced one significant odds ratio, which suggests there is a positive association between the "Nano is small" outcome and prior nano exposure. Exhibit attendance does not appear to have any significant relationship with the outcome.

Visitor connection to nano topics

The final regression conducted on the exhibition data corresponds to the set of survey questions that explored visitors' level of connection to nano and non-nano topics. Visitors rated their connection to six topics on an 11-point scale from 0-10. The topics included nanoscience, nanotechnology, nanomedicine, butterfly wings, cancer treatments, and repairing bone and nerve tissue.

Because we wanted to compare how well visitors connected to nano topics in comparison to non-nano topics, we pooled visitor ratings into two corresponding comparison groups: nano topics (nanoscience, nanotechnology, and nanomedicine) and non-nano topics (butterfly wings, cancer treatments, and repairing bone and nerve tissue). Ratings for the three topics in one group were added together to get a new score, potentially adding to 30 if each topic within a group was rated by the visitor as a 10. Pooling the data in this way reflected our desire to examine how visitors connected to nano topics generally at the aggregate level, instead of focusing on each specific nano topic at the individual level.

Means were calculated for the nano and non-nano topic groups and reported. However, in order to get a richer understanding of the relationships between visitor connection to these topics, exhibit attendance, and other demographic and psychographic data, a linear regression was performed. The outcome variable for this regression was the *difference* between the pooled ratings for the nano topics and the non-nano topics. In other words, for a given visitor who answered this question, the visitor's pooled ratings for the three non-nano topics were subtracted from the same visitor's pooled ratings for the three nano topics, as seen in Equation 1:

$$Y = \text{(Pooled ratings for nano topics)} - \text{(Pooled ratings for non-nano topics)} \quad . [1]$$

Because we used the difference between the pooled ratings as the outcome variable for the linear regression, any significant coefficients in the model would point to a relationship between this difference and a given factor.

Once the outcome variable was computed, a linear regression that included exhibit attendance, use of science in daily work, gender, interest in science, age, prior nano exposure, education level, and income level was performed. A summary of the model can be seen in Table H9 below.

Table H9: Linear regression model for visitor connection to nano and non-nano topics using pooled data.

	B	Std. Error B	β
Exhibition attendance	1.283	0.550	0.102*
Science at work	-0.011	0.029	-0.018
Interest in science	0.227	0.144	0.078
Previous exposure to nanoscience	0.826	0.112	0.365**
Gender	0.098	0.066	0.073
Age	-0.045	0.025	-0.087
Education	-0.051	0.298	-0.008
Income	0.219	0.085	0.124*
Constant	-5.849	1.661	

**p<0.01; *p<0.05 as observed within the model; R^2=0.201.

The regression model produced three significant standardized coefficients. Each of these was greater than zero, suggesting that exhibit attendance, income level, and prior nano exposure have positive associations with the outcome variable, and ultimately, a positive difference in visitor connection to nano topics.

Regressions Performed on Program Data

The regression analyses performed on the Short and Long program data mirrored the structure of the regressions performed on the exhibition data and are described below.

Visitor confidence in performing nano-related tasks

The first set of regressions performed on the program data correspond to the survey question that asked visitors to rate their confidence in doing certain tasks related to the key nanoawareness indicators. Visitors rated their confidence in performing each task on an 11-point scale of 0-10, and then these ratings were transformed into a 0-5 point scale using the compression algorithm described in the body of the report.

A set of five linear regressions, each with one task's confidence ratings as its outcome variable, were performed on the Short program data, and the resulting models can be seen in Tables H10-H14 below.

Table H10: Linear regression model for "Name a nanoscale sized object" outcome using Short program data.

	B	Std. Error B	β
Program attendance	1.129	0.118	0.345**
Science at work	0.059	0.120	0.019

Interest in science	0.139	0.031	0.186**
Previous exposure to nanoscience	0.185	0.024	0.326**
Gender	0.074	0.119	0.024
Age	0.000	0.004	0.002
Constant	0.213	0.293	

**p<0.01 as observed within the model; R^2=0.313.

By calculating significant standard coefficient values greater than zero for Short program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in naming a nanoscale sized object.

Table H11: Linear regression model for "Describe one way that nanoscale objects behave differently than other objects" outcome using Short program data.

	B	Std. Error B	β
Program attendance	1.521	0.117	0.457**
Science at work	0.065	0.118	0.021
Interest in science	0.120	0.031	0.158**
Previous exposure to nanoscience	0.143	0.023	0.250**
Gender	0.190	0.118	0.060
Age	-0.001	0.004	-0.006
Constant	0.212	0.290	

**p<0.01 as observed within the model; R^2=0.341.

By calculating significant standard coefficient values greater than zero for Short program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in describing a way that nanoscale objects behave differently than other objects.

Table H12: Linear regression model for "Describe a process used to produce objects at the nanoscale" outcome using Short program data.

	B	Std. Error B	β
Program attendance	1.147	0.131	0.340**
Science at work	0.019	0.133	0.006
Interest in science	0.097	0.035	0.125**
Previous exposure to nanoscience	0.116	0.026	0.200**
Gender	0.144	0.132	0.045
Age	0.002	0.005	0.018
Constant	0.189	0.326	

**p<0.01 as observed within the model; R^2=0.196.

By calculating significant standard coefficient values greater than zero for Short program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in describing a process used to produce objects at the nanoscale.

Table H13: Linear regression model for "Name an application of nanoscale science" outcome using Short program data.

	B	Std. Error B	β
Program attendance	1.003	0.121	0.298**
Science at work	0.020	0.123	0.006
Interest in science	0.160	0.032	0.208**
Previous exposure to nanoscience	0.191	0.024	0.328**
Gender	0.197	0.122	0.061
Age	-0.005	0.005	-0.040
Constant	0.471	0.301	

**$p<0.01$ as observed within the model; R^2=0.313.

By calculating significant standard coefficient values greater than zero for Short program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in naming an application of nanoscale science.

Table H14: Linear regression model for "Explain some risks and benefits of nanotechnology" outcome using Short program data.

	B	Std. Error B	β
Program attendance	0.648	0.126	0.195**
Science at work	-0.013	0.128	-0.004
Interest in science	0.142	0.033	0.187**
Previous exposure to nanoscience	0.178	0.025	0.312**
Gender	0.180	0.126	0.057
Age	-0.004	0.005	-0.035
Constant	0.247	0.312	

**$p<0.01$; *$p<0.05$ as observed within the model; R^2=0.234.

By calculating significant standard coefficient values greater than zero for Short program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in explaining some risks and benefits of nanotechnology.

A summary of significant associations determined by this set of regressions on the Short program data can be seen in Table H15 below.

Table H15: Summary of significant coefficients within linear regressions performed on each confidence item – Short programs

	Program Attendance	Science at Work	Interest in Science	Previous Exposure to Nanoscience	Gender	Age
Name a nanoscale sized object	√ (+)		√ (+)	√ (+)		
Describe one way that nanoscale objects behave differently than other objects	√ (+)		√ (+)	√ (+)		
Describe a process used to produce objects at the nanoscale	√ (+)		√ (+)	√ (+)		
Name an application of nanoscale science	√ (+)		√ (+)	√ (+)		
Explain some risks and benefits of nanotechnology	√ (+)		√ (+)	√ (+)		

For the Long programs, a set of six linear regressions, each with one task's confidence ratings as its outcome variable, was performed on the data. The survey for the Long program separated the last confidence item into two parts, thus resulting in a sixth regression. The resulting models can be seen in Tables H16-H21 below.

Table H16: Linear regression model for "Name a nanoscale sized object" outcome using Long program data.

	B	Std. Error B	β
Program attendance	1.289	0.145	0.347**
Science at work	0.131	0.137	0.039
Interest in science	0.208	0.040	0.226**
Previous exposure to nanoscience	0.215	0.028	0.343**
Gender	0.029	0.137	0.009
Age	-0.007	0.005	-0.054
Education	0.100	0.075	0.058
Income	0.010	0.021	0.021
Constant	-0.986*	0.398	

**p<0.01; *p<0.05 as observed within the model; R^2=0.419.

By calculating significant standard coefficient values greater than zero for Long program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in naming a nanoscale sized object.

Table H17: Linear regression model for "Describe one way that nanoscale objects behave differently than other objects" outcome using Long program data.

	B	Std. Error B	β
Program attendance	1.322	0.139	0.376**
Science at work	0.103	0.132	0.032
Interest in science	0.148	0.039	0.171**
Previous exposure to nanoscience	0.207	0.027	0.350**
Gender	0.139	0.131	0.044
Age	-0.006	0.005	-0.054
Education	0.030	0.071	0.019
Income	0.006	0.020	0.013
Constant	-0.427	0.380	

**p<0.01 as observed within the model; R^2=0.406.

By calculating significant standard coefficient values greater than zero for Long program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in describing a way that nanoscale objects behave differently than other objects.

Table H18: Linear regression model for "Describe a process used to produce objects at the nanoscale" outcome using Long program data.

	B	Std. Error B	β
Program attendance	1.187	0.147	0.332**
Science at work	0.072	0.139	0.022
Interest in science	0.168	0.041	0.190**
Previous exposure to nanoscience	0.198	0.028	0.329**
Gender	0.022	0.138	0.007
Age	-0.004	0.005	-0.029
Education	0.086	0.075	0.052
Income	0.026	0.022	0.055
Constant	-1.074**	0.403	

**p<0.01 as observed within the model; R^2=0.355.

By calculating significant standard coefficient values greater than zero for Long program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in describing a process used to produce objects at nanoscale.

Table H19: Linear regression model for "Name an application of nanoscale science" outcome using Long program data.

	B	Std. Error B	β
Program attendance	1.519	0.141	0.408**

Science at work	0.046	0.134	0.014
Interest in science	0.154	0.039	0.169**
Previous exposure to nanoscience	0.215	0.027	0.344**
Gender	0.080	0.133	0.024
Age	-0.007	0.005	-0.054
Education	0.174	0.072	0.101*
Income	0.036	0.021	0.073
Constant	-0.912*	0.386	

**p<0.01; *p<0.05 as observed within the model; R^2=0.451.

By calculating significant standard coefficient values greater than zero for Long program attendance, visitor interest in science, prior nano exposure, and education level, this linear regression model identifies these factors as having a positive association with visitor confidence in naming an application of nanoscale science.

Table H20: Linear regression model for "Explain some risks of nanotechnology" outcome using Long program data.

	B	Std. Error B	β
Program attendance	1.164	0.152	0.323**
Science at work	0.120	0.144	0.037
Interest in science	0.096	0.042	0.108*
Previous exposure to nanoscience	0.227	0.029	0.374**
Gender	0.003	0.143	0.001
Age	0.002	0.005	0.016
Education	-0.002	0.078	-0.001
Income	-0.005	0.022	-0.010
Constant	-0.341	0.418	

**p<0.01; *p<0.05 as observed within the model; R^2=0.318.

By calculating significant standard coefficient values greater than zero for Long program attendance, visitor interest in science, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in explaining some risks of nanotechnology.

Table H21: Linear regression model for "Explain some benefits of nanotechnology" outcome using Long program data.

	B	Std. Error B	β
Program attendance	1.571	0.141	0.440**
Science at work	0.109	0.133	0.034
Interest in science	0.075	0.039	0.085

Previous exposure to nanoscience	0.194	0.027	0.323**
Gender	0.112	0.132	0.035
Age	-0.011	0.005	-0.086*
Education	0.124	0.072	0.075
Income	0.029	0.021	0.061
Constant	0.092	0.386	

**p<0.01; *p<0.05 as observed within the model; R^2=0.411.

By calculating significant standard coefficient values greater than zero for Long program attendance, age, and prior nano exposure, this linear regression model identifies these factors as having a positive association with visitor confidence in explaining some benefits of nanotechnology.

A summary of significant associations determined by this set of regressions on the Long program data can be seen in Table H22 below.

Table H22: Summary of significant coefficients within linear regressions performed on each confidence item - Long programs

	Long Program Attendance	Science at Work	Interest in Science	Prior Exposure to Nanoscience	Gender	Age	Education	Income
Name a nanoscale sized object	√ (+)		√ (+)	√ (+)				
Describe one way that nanoscale objects behave differently than other objects	√ (+)		√ (+)	√ (+)				
Describe a process used to produce objects at the nanoscale	√ (+)		√ (+)	√ (+)				
Name an application of nanoscale science	√ (+)		√ (+)	√ (+)			√ (+)	
Explain some risks of nanotechnology	√ (+)		√ (+)	√ (+)				
Explain some benefits of nanotechnology	√ (+)			√ (+)		√ (+)		

Open-ended nanoawareness questions

The next set of regressions performed on program data corresponds to the interview question that asked visitors to provide a definition of nanotechnology. As in the exhibition data, a high percentage of visitors in both the pre- and post-samples for the Short programs gave responses to this question that touched on the "Nano is small" aspect of nanoawarenss. We therefore conducted a logistic regression to better understand the relationships between this outcome, program attendance, and other demographic and psychographic factors. Visitor responses coded as having a reference to "Nano is small" were assigned the value of "1," and all other cases were assigned the value of "0." These codes became the outcome variable for the logistic regression. The covariates included

Short program attendance, gender, interest in science, age, and prior nano exposure. The results of the regression model can be seen in Table H23 below.

Table H23: Logistic regression model for "Nano is small" outcome using Short program data.

	B	Std. Error B	β
Program attendance	0.333	0.244	1.396
Science at work	0.205	0.239	1.227
Interest in science	0.040	0.058	1.041
Previous exposure to nanoscience	0.262	0.051	1.300**
Gender	0.172	0.240	1.188
Age	-0.007	0.009	0.993
Constant	-0.083	0.561	0.920

**p<0.01 as observed within the model; Cox & Snell R^2=0.089; Nagelkerke R^2=0.135.

The regression model only produced one significant odds ratio, which suggests there is a positive association between the "Nano is small" outcome and prior nano exposure. Short program attendance does not appear to have any significant relationship with the outcome.

Regressions were performed for all nano awareness objects that were present in 15% or greater of the visitor responses. For the Short programs, this meant also conducting regressions for the "Nano is different" and "Nano is about applications" aspects of nanoawareness. For the first of these regressions, visitor responses coded as having a reference to "Nano is different" were assigned the value of "1," and all other cases were assigned the value of "0." These codes became the outcome variable for the logistic regression. The covariates included Short program attendance, gender, interest in science, age, and prior nano exposure. The results of the regression model can be seen in Table H24 below.

Table H24: Logistic regression model for "Nano is different" outcome using Short program data.

	B	Std. Error B	β
Program attendance	2.684	0.728	14.645**
Science at work	0.072	0.302	1.075
Interest in science	0.010	0.072	1.010
Previous exposure to nanoscience	-0.096	0.059	0.909
Gender	-0.450	0.311	0.638
Age	0.006	0.012	1.006
Constant	-4.114	1.000	0.016**

**p<0.01 as observed within the model; Cox & Snell R^2=0.077; Nagelkerke R^2=0.145.

The regression model produced a significant odds ratio for Short program attendance.

Because this odds ratio is greater than 1, it suggests that Short program attendance is positively associated with the "Nano is different" outcome.

For the next regression, visitor responses coded as having a reference to "Nano is about applications" were assigned the value of "1," and all other cases were assigned the value of "0." These codes became the outcome variable for the logistic regression. The covariates included Short program attendance, gender, interest in science, age, and prior nano exposure. The results of the regression model can be seen in Table H25 below.

Table H25: Logistic regression model for "Nano is about applications" outcome using Short program data.

	B	Std. Error B	β
Program attendance	-0.772	0.242	0.462**
Science at work	-0.063	0.254	0.939
Interest in science	0.151	0.075	1.163*
Previous exposure to nanoscience	0.076	0.049	1.079
Gender	-0.280	0.251	0.756
Age	-0.010	0.009	0.990
Constant	-1.941	0.684	0.144**

**p<0.01; *p<0.05 as observed within the model; Cox & Snell R^2=0.046; Nagelkerke R^2=0.075.

The regression model produced two significant odds ratios for model covariates, including Short program attendance and interest in science. Because the odds ratio for Short program attendance is less than 1, it suggests that Short program attendance is actually negatively associated with the "Nano is about applications" outcome. Visitor interest in science, however, has an odds ratio greater than 1, which suggests interest in science is positively associated with the "Nano is about applications" outcome.

Finally, a logistic regression for the "I don't know" visitor response was conducted on Short program data. Visitor responses coded as "I don't know" were assigned the value of "1," and all other cases were assigned the value of "0." These codes became the outcome variable for the logistic regression. The covariates included Short program attendance, gender, interest in science, age, and prior nano exposure. The results of the regression model can be seen in Table H26 below.

Table H26: Logistic regression model for "I don't know" outcome using Short program data.

	B	Std. Error B	β
Program attendance	-1.342	0.358	0.261**
Science at work	-0.145	0.373	0.865
Interest in science	-0.269	0.084	0.764**
Previous exposure to nanoscience	-0.357	0.091	0.700**
Gender	-0.670	0.407	0.512

Age	0.007	0.013	1.007
Constant	1.377	0.789	3.962

**p<0.01; *p<0.05 as observed within the model; Cox & Snell R^2=0.121; Nagelkerke R^2=0.262.

The regression model produced three significant odds ratios for model covariates, including Short program attendance, interest in science, and prior nano exposure. Because all three of these odds ratios were less than 1, the model suggests that Short program attendance, interest in science, and prior nano exposure are all negatively associated with the "I don't know" visitor response.

For the Long programs, regressions were also conducted on the "Nano is small" and "Nano is about applications" aspects of nanoawareness. For the first of these regressions, visitor responses coded as having a reference to "Nano is small" were assigned the value of "1," and all other cases were assigned the value of "0." These codes became the outcome variable for the logistic regression. The covariates included Long program attendance, interest in science, use of science in daily work, age, gender, education level, income level, and prior nano exposure. The results of the regression model can be seen in Table H27 below.

Table H27: Logistic regression model for "Nano is small" outcome using Long program data.

	B	Std. Error B	β
Program attendance	0.304	0.279	1.355
Science at work	0.370	0.274	1.448
Interest in science	0.100	0.079	1.105
Previous exposure to nanoscience	0.137	0.059	1.147*
Gender	0.049	0.277	1.050
Age	-0.042	0.010	0.959**
Education	0.282	0.150	1.326
Income	0.078	0.043	1.081
Constant	-0.845	0.750	0.429

**p<0.01; *p<0.05 as observed within the model; Cox & Snell R^2=0.144; Nagelkerke R^2=0.201.

The regression model produced two significant odds ratios for age and prior nano exposure. Because the odds ratio for age is less than one, the model suggests a negative relationship between age and the "Nano is small" outcome. In contrast, odds ratio greater than one suggests there is a positive association between the "Nano is small" outcome and prior nano exposure. Long program attendance does not appear to have any significant relationship with the outcome.

For the next regression, visitor responses coded as having a reference to "Nano is about applications" were assigned the value of "1," and all other cases were assigned the value of "0." These codes became the outcome variable for the logistic regression. These codes became the outcome variable for the logistic regression. The covariates included Long program attendance, interest in science, use of science in daily work, age, gender, education level, income level, and prior nano exposure. The results of the regression model can be seen in Table H28 below.

Table H28: Logistic regression model for "Nano is about applications" outcome using Long program data.

	B	Std. Error B	β
Program attendance	0.004	0.324	1.004
Science at work	-0.086	0.320	0.918
Interest in science	-0.145	0.094	0.865
Previous exposure to nanoscience	0.108	0.063	1.114
Gender	0.560	0.323	1.751
Age	-0.015	0.013	0.985
Education	0.352	0.185	1.422
Income	0.026	0.051	1.026
Constant	-2.046	0.914	0.129*

*p<0.05 as observed within the model; Cox & Snell R^2=0.042; Nagelkerke R^2=0.068.

The regression model produced no significant odds ratios for model covariates, suggesting that none of these factors have a significant association with the "Nano is about applications" outcome.

Finally, a logistic regression for the "I don't know" visitor response was conducted on Long program data. Visitor responses coded as "I don't know" were assigned the value of "1," and all other cases were assigned the value of "0." These codes became the outcome variable for the logistic regression. The covariates included Long program attendance, interest in science, use of science in daily work, age, gender, education level, income level, and prior nano exposure. The results of the regression model can be seen in Table H29 below.

Table H29: Logistic regression model for "I don't know" outcome using Long program data.

	B	Std. Error B	β
Program attendance	-2.172	0.415	0.114**
Science at work	-0.355	0.395	0.701
Interest in science	0.021	0.113	1.021
Previous exposure to nanoscience	-0.256	0.099	0.774**
Gender	-0.119	0.398	0.888
Age	0.042	0.013	1.043**
Education	-0.647	0.211	0.524**
Income	-0.075	0.063	0.928

Constant	1.285	1.038	3.616

**p<0.01; *p<0.05 as observed within the model; Cox & Snell R^2=0.191; Nagelkerke R^2=0.344.

The regression model produced four significant odds ratios for model covariates, including Long program attendance, age, education level, and prior nano exposure. Because the odds ratios for program attendance, education level, and prior nano exposure were all less than one, the model suggests that Short program attendance, interest in science, and prior nano exposure are all negatively associated with the "I don't know" visitor response. The odds ratio for age was greater than one, suggesting age was positively associated with the "I don't know" outcome.

Visitor connection to nano topics

The final regression conducted on the Long program data corresponds to the set of survey questions that explored visitors' level of connection to nano and non-nano topics. As with was the case for the exhibition data, visitors rated their connection to six topics on an 11-point scale from 0-10. The topics on the Long program survey included nanoscience, nanotechnology, nanomedicine, alternative energy, cancer treatments, and purifying water.

The outcome variable for the linear regression was computed in the same way as the exhibition data. We began by pooling visitor ratings into two comparison groups: nano topics (nanoscience, nanotechnology, and nanomedicine) and non-nano topics (alternative energy, cancer treatments, and purifying water). Thus, the outcome variable was once again the *difference* between the pooled ratings for the nano topics and the non-nano topics. In other words, for a given visitor who answered this question, the visitor's pooled ratings for the three non-nano topics were subtracted from the same visitor's pooled ratings for the three nano topics, as seen in Equation 1:

$$Y = (\text{Pooled ratings for nano topics}) - (\text{Pooled ratings for non-nano topics}) \quad . [1]$$

Once the outcome variable was computed, a linear regression that included exhibit attendance, use of science in daily work, gender, interest in science, age, prior nano exposure, education level, and income level was performed. A summary of the model can be seen in Table H30 below.

Table H30: Linear regression model for visitor connection to nano and non-nano topics using pooled data from the Long programs

	B	Std. Error B	β
Program attendance	2.614	0.838	0.156**
Science at work	-0.145	0.796	-0.009
Interest in science	0.065	0.233	0.016
Previous exposure to nanoscience	-0.222	0.432	-0.028
Gender	-1.032	0.802	-0.067
Age	0.045	0.031	0.075
Education	-0.158	0.124	-0.070

Income	0.759	0.160	0.265**
Constant	-8.620**	2.331	

**p<0.01; *p<0.05 as observed within the model; R^2=0.096.

The regression model produced two significant standardized coefficients. Because both were greater than zero, the model suggests that Long program attendance and income level have positive associations with the outcome variable, and ultimately, a positive difference in visitor connection to nano topics.