Windows on Research

Promoting Public Awareness of Research in Nanotechnology through Informal Science Education in a Science Museum Exhibition

Findings from a Summative Study

Douglas Spencer

Mike Timms
Cathy Ringstaff
This material is based upon work supported by the National Science Foundation under Grant Number 0206377.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

© 2005 Edu, Inc. All Rights Reserved.
# Table of Comments

**Abstract**

**Executive Summary**

**Introduction to Windows on Research Project**

**Background**

**Project Goals**

**Exhibition Description**

- NanoZone Walk Through
- Descriptions of the Exhibits and Computer Interactives
- Description of Programs

**Coverage of Content Goals**

**Evaluation Methodology**

**Evaluation Team**

**Evaluation Stages**

- Front-end Research
- Formative Evaluation

**Summative Evaluation Study**

- Summative Instruments
- Validity
- Sample
- Challenges

**Findings**

**Evaluation Questions**

- Does the Exhibition Attract?
- Does the Exhibition Educate?
- Relative Effectiveness of Different Exhibits
- Experimentation

**Collaboration**

- Internal Collaboration – Conversations with the Windows on Research Teams

**Appendices**

**Appendix A Evaluation Instruments**

- Pre-visit and Post-visit Survey
- Scientist Interview
- Unobtrusive Observation and Mediated Interview
- Programs Instruments
- Staff Interviews on Internal Collaboration

**References**
List of Figures
Figure 1 Layout of the NanoZone Exhibition ................................................................. 9
Figure 2 The Evaluation Stages and Timeline .............................................................. 15
Figure 3 Pre-Visit Responses to "What does nano mean?" ............................................ 29
Figure 4 Pre-Visit Response to “Have you heard of nanotechnology?” ......................... 29
Figure 5 Post-Visit Response to “Describe nanotechnology in your own words.” .......... 30
Figure 6 Post-Visit Response to "What were these exhibits about?" ............................ 30
Figure 7 Chart - Success of the What is Nanotech exhibit in answering visitor questions ... 47

List of Tables
Table 1 How Exhibits Matched to the Project Content Goals for Covering Nanotechnology Science and Scientists ................................................................. 14
Table 2 Age Analyzed by Gender through Cross Tabulation of Visitors who Answered Pre- and Post-visit Surveys ................................................................. 19
Table 3 Responses to the Question, “What are these exhibits about?” ......................... 24
Table 4 Rank Order of How Often Visitors Mentioned Particular Exhibits and Programs as Locations Where they Learned Something New in the Exhibition ...................... 38
Table 5 Summary of How Often Visitors Mentioned Different Types of Exhibits or Programs as Locations at Which They Learned Something New ......................... 39
Table 6 Analysis of How Often Visitors Mentioned Particular Exhibits in Relation to the Exhibition Content Goals ................................................................. 40
Abstract

This report presents findings from the summative evaluation for the NSF-funded Windows on Research (WOR) project that was implemented at Lawrence Hall of Science, University of California, Berkeley. The overriding project objective was to conceive, develop, create, and execute strategies by which cutting-edge science research can be presented in a museum setting to the public in general and to school-age audiences in particular. The exhibition was opened to visitors in June 2004; the featured research topic was nanotechnology and the exhibition was called NanoZone.

The paper’s first sections delineate the specific project goals (e.g., public education, team collaboration, distinctive exhibit design, media portability, universal accessibility). A detailed description of each of the exhibition’s component parts follows (e.g., exhibits, programs, videos, demonstrations).

The Evaluation Methodology section covers the “who, what, where, why, and how” of evaluating the Windows on Research effort. The evaluation methods are described and the evaluators are identified. A review of the front-end research and initial project planning covers the limitations and obstacles that the WOR project was anticipated to encounter, and describes why certain strategies were adopted while others were dropped.

A section on formative evaluation describes how individual concepts were selected for exhibition content. This section summarizes how exhibits, programs, and technology were proposed and designed; and how prototypes were built, tested and refined.

The Findings section presents and discusses the evaluators’ probing questions as to the extent to which the exhibition components attracted, engaged and educated visitors. Visitors’ comments and experiences are shared and analyzed, as are visitors’ answers to interview questions that were used to rate whether stated learning objectives were achieved.

The exhibition’s component parts—exhibits, programs and technology—are analyzed for their relative effectiveness in accomplishing preconceived goals. Signs, accessibility, and visibility are considered. A section on experimentation considers the project’s successes and failures and its surprises, achievements, and disappointments, which are presented in the context of “lessons learned.”

The collaboration section pays particular attention to the value, challenges, and shortcomings of using a three-team collaborative approach to conceiving, building, and presenting the exhibition components. Budgeting and personnel issues are addressed throughout. Staff suggestions of opportunities for improving the development structure and implementation of this sort of project are identified, for the benefit of future attempts to present cutting-edge science research to a primarily uninformed public audience.

Finally, appendices and figures are used to illustrate the evaluators’ findings and flesh out technical details of the evaluation.
Executive Summary

This NSF-funded Windows on Research project was implemented at Lawrence Hall of Science, University of California, Berkeley. The overriding project objective was to conceive, develop, create, and execute strategies by which cutting-edge science research can be presented in a museum setting to the public in general and to school-age audiences in particular. A second goal was to use a three-team collaborative exhibition-development approach, and to evaluate that process continuously for efficiency and effectiveness. Third, the teams were charged with formulating a design for exhibits, programs, and technology that could easily be adopted by other, similar projects to present content from another leading-edge research discipline in an informal setting (e.g., hands-on science museum).

For Windows on Research, the chosen topic was the challenging concept of nanotechnology. The exhibition, NanoZone, was opened to visitors during June 2004 and offered hands-on exhibits, computer interactives, video and live floor programs. The target audience was middle school-children and their families. The vast majority of visitors interviewed during the evaluation were ages 8–16. Much of the data for this evaluation was obtained by evaluators’ first-hand observations and on-the-floor mediated interviews during site visits, through interviews with museum visitors before they experienced the exhibition and again immediately after they had used the exhibition (pre- and post-visit interviews), by tracking visitors’ paths through the exhibition, and during formal discussions with development team members.

Presenting New Science: The Findings

Does the exhibition engage? Observations and tracking showed that, in general, visitors were attracted to the physical and technology-based exhibits, and as expected, some more than others. During interviews many visitors said that they enjoyed themselves, and that the exhibits were, for the most part, compelling and entertaining, and provided a variety of visitor experiences.

Evaluators observed and visitors reported that engagement was enhanced by the fact that the final NanoZone exhibition was well-planned, with consistent and repeated themes that reinforced the main learning goals of the project. Those goals were to convey to visitors an understanding of (1) sub-visible size, (2) researchers as people, (3) applications of nanotechnology research, and (4) tools that are used in that research. This consistency was the result of a collaborative planning process in which learning goals for the exhibition were defined as the exhibits, technology and programs were planned. Another factor in successfully engaging the target audience was that the final exhibition attempted to present content in ways that might connect with examples from the real lives of young people. Staff report that a science writer, hired after development work began, contributed immensely to the exhibit’s consistency, intentional redundancy, and overall appeal.

Among the exhibition’s shortcomings, as reported by visitors, are that some areas were noisy during high-use times, and signs and some displays relied too much on text, requiring visitors to read lengthy descriptions. The NanoZone team made a concerted effort to use graphics, video, and captioned images to convey content. According to WOR team members, future
projects that seek to educate users about complex, leading-edge technology are encouraged to allow significant budget resources and time to develop and test multi-modal interpretive strategies that do not rely too much on expecting users to stop and read text. The most popular exhibits were hands-on or used interactive computer or video components.

**Does the exhibition educate?** Actual learning, as defined broadly, varied from station to station, depending in part on the complexity of the content being conveyed. Surveys and observations offer evidence of visitors’ learning behavior, content acquisition, and changing attitudes, and revealed that the majority (at least 75 percent) of visitors deepened their understanding of at least one of the main content themes of the exhibition. Comparing visitor responses to pre-visit and post-visit surveys showed evidence of increased content and conceptual understanding across all ages and by gender.

Nonetheless, visitor comments show that significant conceptual holes (misconceptions and partial understanding) remain in visitors’ understanding of nanotechnology and other content areas after using the exhibition. The data suggests that the exhibition was more successful in providing exposure to new technology and understanding the role of scientists than conveying in-depth content and understanding.

The importance of this finding for the field is two fold. It challenges developers to clarify the educational intent of a museum exhibition introducing new technology while considering each component’s ability to provide experiential learning and/or convey content about new technology.

The WOR team designed their exhibition around clearly articulated educational goals. However, in post-evaluation discussions WOR team members reflected on their mission of developing strategies to communicate cutting-edge science research. They asked, “Was our intent to convey in-depth content and understanding, or were we trying to encourage appreciation and motivate further exploration?” One team member questioned the ability of a museum exhibition to convey deep content about new research.

This study shows that in NanoZone different informal learning vehicles – museum exhibits, programs and interactive media – had different levels of success conveying content and understanding about nanotechnology. This finding invites future principal investigators and developers to carefully consider and test, during the early prototype stage, the methods they choose to introduce and help visitors learn about cutting-edge research.

In the case of NanoZone, visitors most frequently identified the interactive exhibits, both computer-based and physical, as the places where they learned the most about the exhibition’s nanotechnology themes. Videos were the next most-cited category, mentioned about half as often as the interactive exhibits. There were comparatively few mentions of the other (non-interactive) physical exhibits, programs, and demonstrations. It is important to note that programs were offered only once per hour so visitors who were interviewed may or may not have attended a program.
Programs provided an opportunity for visitors to interact with staff and allowed in-depth introduction to a topic. A consequence of the choice of topics was that they appealed more to adult visitors than to elementary and middle-school aged visitors. The team was aware that topics would appeal more to adults but faced what Dr. Molinaro called “the difficulty of finding relevant examples for this age group. (children)” In post-program interviews several parents and teachers observed that program topics seemed too advanced for middle-school children. Children rated programs lower than adults did. In balance a teacher observed that her students who were very interested in science and technology appeared engaged and interested in the program topic. Visitors reported and evaluators observed that the quality of presenters ranged from very good to below average.

In general the mixed-media approach appeared to help expose many visitors to new technology. The NanoZone team had success combining multi-media, hands-on, and interactive exhibits; incorporating live programs that went in-depth into select content areas; facilitating discussions of cutting-edge research, with a particular focus on scientists; and using familiar themes and objects to make complex information accessible, is noted.

**Experimentation and Portability**
The project team made a strong effort to work collaboratively and to produce an exhibition that was based on clear content goals. The team produced several innovative approaches to presenting complex scientific content to a mainly young audience. Although the exhibition occupied a fairly small space, it featured a range of exhibits that used a variety of media such as text labels, three-dimensional hands-on interactive displays, interactive computers, and live programs to deliver information about nanotechnology. Innovation and experimentation was seen in the physical, computer-based, and video-based exhibits, as well as in the programs area.

There was some success in producing examples of exhibits and technology that can be used to communicate content about another cutting-edge research topic. “Portable media” describes media and methods that are easily adapted for, or “ported” to, exhibitions presenting content and experiences in a science or technology other than nanotechnology. The test of portability is the ability of a NanoZone exhibit or technology designed to introduce nanotechnology to be adapted to introduce biophotonics, robotics or another new technology. The NanoZone exhibition clearly provides useful data on which exhibit types are effective and therefore worth adapting to other purposes.

Regarding accessibility for those individuals with disabilities, the NanoZone team showed strong initial interest in creating an ultra-accessible exhibition. While the team clearly met their goal of making final exhibition accessible for people with many kinds of disabilities, the effort to implement all the recommendations of the accessibility advisor was not carried to full fruition. A future possibility is a central person with the assigned role of ensuring accessibility for as many types of disabilities as possible across the exhibition. A direct report to the principal investigator or project manager could be considered.
**Collaboration**

Using a team-development approach to creating NanoZone brought to light the complex challenges that arise when different professional cultures intersect. The three teams felt the WOR project was a worthwhile experiment in collaboration and team-building between three distinct departments within the Lawrence Hall of Science. The departments each have their own culture, work style, demographic profile, and expertise.

The final section of this summative report evaluates the success of the collaborative effort from the point of view of the team members and leaders. While the process was not without its faults and frustrations, in general the players appreciated the chance to work together in this new way, learned much about each other, and gained insight into their own skills and motivations. According to interviewees the collaborative model will be used again at LHS for future projects.

**Additional Work**

During a no-cost extension the team voluntarily spent one year developing additional exhibit components and the nanozone.org website not evaluated in this report. Another well-qualified evaluator guided evaluation of additional components.
Introduction to Windows on Research Project

Background
This is the final evaluation report on the Windows on Research project that was developed and implemented at the Lawrence Hall of Science, part of the University of California, Berkeley. Lawrence Hall of Science (LHS) is a resource center for preschool through high school science and mathematics education, and a public science center with hands-on experiences for learners of all ages. LHS serves teachers and schools, school-age children, and families as its primary audiences. Of the more than 250,000 individuals, students, and teachers who visit LHS each year, 60,000 are school-age children, mostly in preschool through grade 6. Students visit LHS for field trips, summer camps, after-school classes, or to participate in one of the more than 2,100 separate school programs offered on-site at LHS annually.

Windows on Research was a two-year experimental project that produced an exhibition at LHS, which focused on engaging and informing the public about current scientific research. Following the initial two year commitment, the team chose to extend the project for 1.5 years using a no-cost extension. During the extension the team spent one year developing additional exhibit components and the nanozone.org website not evaluated in this report. Another well-qualified evaluator guided evaluation of additional components.

Funded by the National Science Foundation (NSF; award number 0206377), the project developed and evaluated different media, including a technology exhibit using artificial intelligence, to convey leading-edge nanotechnology research to the science center’s audiences. Led by Dr. Marco Molinaro, the LHS project team worked closely with research scientists representing a number of nanotechnology fields to develop the exhibits. There was extensive formative evaluation and refinement of all products to produce a final exhibition called the NanoZone, which opened in June 2004 and was evaluated formally in November 2004 during a three-day site visit. The NanoZone exhibition featured a range of live demonstrations and presentations as well as physical- and technology-based exhibits.

Three primary questions guided the summative evaluation and form the basis of this report. Those questions are:

1. Does the exhibition attract, engage, and educate the public about nanotechnology research?
2. To what extent does the exhibition promote public understanding of research in advanced science and technology?
3. In what ways has the team been experimental in its approach to using new media to present emerging and cutting-edge research through informal science?

This report documents the visitor experience at the NanoZone exhibition, the lessons learned about presenting cutting-edge scientific research to a public audience in an informal-science-education institution, and the collaborative efforts of the Windows on Research project team.
Project Goals

Three Main Goals
The Windows on Research project’s three main goals were to:
• Increase public understanding of cutting-edge research (specifically in nanotechnology);
• Develop a collaborative community among two groups within the Public Programs
  Division at LHS: exhibits and programs, and a technology unit that sits between all LHS
  divisions; and
• Develop “portable media” techniques that effectively introduce nanotechnology concepts
  and that could effectively communicate other cutting-edge technologies as well, such as
  biophotonics, genomics, and cybernetic architecture, so that future exhibits could be
  developed rapidly by LHS or other informal-science-education institutions.

Increase public understanding of cutting-edge research
This was a broad goal that encompassed (1) increasing public understanding of the nature of
nanotechnology, (2) portraying scientists in the field, and (3) highlighting scientists’
accomplishments as well as creating positive attitudes toward science and scientists.

Learning Outcomes
To meet this overall goal the project developed learning objectives to guide the exhibits’
scientific content and design so that the ingredients for learning opportunities existed
throughout the exhibition. The term “learning” included several things:
• Exposing visitors to age-appropriate scientific content and vocabulary;
• Eliciting behaviors such as reading, using prompts and clues, solving problems, formulating
  questions, and reflecting on the science content of the exhibits; and
• Engaging visitors in socially constructed active learning such that visitors may work with
  peers, parents, teachers, and others when engaged in activities such as constructing
  meaningful questions or playing the educational games.

Concept Inventory
From the project’s inception, the Windows on Research team created learning outcomes for
each NanoZone prototype exhibit, program, and technology. During early formative
evaluation, Edu, Inc. asked the team to create a concept inventory—a document to formally
articulate key vocabulary and concepts and link learning objectives to the National Science
Education Standards (National Research Council, 1998). The goal was to ensure a limited
number of age-appropriate concepts and allow conceptual redundancy across the exhibition.

In developing research questions for the summative evaluation, the concepts and learning
goals set by the learning-objectives document formed a basis for evaluating the educational
outcomes of the NanoZone exhibition.

Scientists as People
A sub-goal of the project was to expose visitors to the lives of research scientists, as well as
to showcase these scientists’ current nanotechnology research, the science related to that
research, and the products of that research. The purpose was for visitors to understand that
many types of people—both male and female, from different ethnic backgrounds—become
scientists. Moreover, by highlighting scientists’ life stories, visitors could see that scientists are ordinary people who have a common curiosity about the world and a desire to help society. Also, the exhibition was designed to convey how scientists conduct their work and the settings in which research may be done.

**Develop a collaborative community**

The *Windows on Research* project consisted of three teams within LHS—exhibits, programs, and technology—working collaboratively in a manner that had not been tried at LHS previously. The project also included external collaborators (such as scientists) and other individuals from within LHS—including a marketing specialist, a curriculum writer, the public-programs director, and an internal evaluator. Together, all the LHS staff members who contributed significant time to developing the NanoZone exhibition are referred to in this report as the NanoZone team. An internal organizational goal was, therefore, to explore how to conduct a collaborative team effort that drew upon different expertise to create a well-planned exhibition that met the project goals. The teams’ comments on collaboration are discussed in detail later in this report.

**Develop effective, transferable “portable media”**

Once the NanoZone exhibits were tested, created, and evaluated, it was hoped that the exhibits could be modified easily to present educational content from other cutting-edge science arenas. The goal was to provide a model to develop similar exhibitions for other subject matter. The technology displays, in particular, were seen as offering great potential to create such “portable media.”

**Exhibition Description**

**NanoZone Walk Through**

The exhibits were visually tied together by a design that featured each exhibit as a page from a fictitious magazine called *NanoZone*. As visitors enter *NanoZone* they first encounter a large, colorful panel representing the magazine’s front cover. There they can view a looping three- to four-minute video (featuring young people in the target visitor age range, 8 to 11) that introduces nanotechnology through fast-moving, colorful images and an energetic narrative. “NanoMall” is a series of graphics and projected images that advertise new products that were created using nanotechnology. “What the Heck is Nanotech” is a giant ceiling-to-floor teen magazine with printed information on nanotechnology.

Moving through the exhibits, one of the exhibits that visitors encounter includes “Measure Yourself in Nanometers.” Using an oversize sliding-height measuring device, visitors can measure themselves in various scales including nanometers, feet, and inches. “Look Familiar?” is a series of wall-mounted flip cards, each containing a series of images of everyday objects at increasing magnification. “Scientists Cards” are large trading cards with information on scientists (similar to what you would find on a ballplayer’s baseball card). The “Seeing Small” video is a looping video in which a talking scientist uses a series of images to introduce the scanning electron microscope. What is Nanotech is a computer-based question and answer kiosk that answers questions entered by visitors. Interactive Floor Programs are offered in the Facilitated Activities area near the back of the exhibition.
Layout of the Exhibition

Figure 1 Layout of the NanoZone Exhibition

Descriptions of the Exhibits and Computer Interactives
The NanoZone team created a range of interactive, video-based, and computer-based exhibits that was linked to the content in floor programs to form the final exhibition. Descriptions of each follow.
Interactive physical exhibits

“Measure Yourself in Nanometers”
The “Measure Yourself in Nanometers” exhibit encouraged visitors to measure themselves using a large, vertical-height slider (like the ones in a doctor’s office) that showed their height in both meters and centimeters and also in nanometers (billionths of a meter). Similarly, visitors could measure their feet in nanometers by standing on shoe templates, and could measure their hands in nanometers using scaled wall handprints. It was one of several exhibits whose purpose was to introduce the visitor to the scale of a nanometer.

“Zoom In!”
In the interactive exhibit called “Zoom In!,” visitors used a magnifying lens, an optical microscope lens, and a simulated Scanning Electron Microscope (SEM) to examine magnified blue-jean fabric, pollen, a bee’s body parts, and an ultra-small medical device. As the visitor turned the wheel, they increasingly zoomed in on the objects. The view through the SEM was simulated on a computer screen. The purpose of the exhibit was to introduce the SEM as one of the tools that researchers use to view objects at extremely small scale. This exhibit was related to a short SEM video and also a floor-program presentation, both of which are described later.

“Look Familiar?”
The interactive “Look Familiar?” exhibit presented visitors with pictures of everyday objects—items that were magnified hundreds or thousands of times under the microscope. Visitors were challenged to recognize four common items. They could then lift the flaps for clues and answers. The purpose of this exhibit was to introduce the concept of the size of a nanometer.

Other physical exhibits

Scientist “Collector” Cards (Laminated info cards)
The Scientist “Collector” Cards were large, laminated cards that visitors could pick up and read. They contained life-story information on the exhibition’s four featured nanotechnology scientists and covered such things as: What were they good at when they were young? What weren’t they so good at? What did they play with? What do they study now? The purpose was to show visitors that scientists are ordinary people, too, and as youngsters had interests and characteristics that today’s school-age visitors can also relate to.

“Pull up a Seat”
Circular stool seats that were used at the technology exhibits showed photos of tiny things magnified, such as an ant head, a quarter, lint, nano wire, silk, a mosquito eye, horsehair, and a red blood cell. The purpose was to show objects at extremely small scale.
Video-based exhibits

“What the Heck is Nanotech?”
The “What the Heck is Nanotech?” video was part of the opening exhibit that was designed to look like a magazine cover for the fictitious NanoZone magazine. The purpose of the short video was to introduce the term nanotechnology, show how small a nanometer is, describe who works in nanotechnology, and explain what makes scientific research exciting. In the video, young actors answer core questions about nanotechnology and illustrate concepts from this rapidly changing technology frontier.

“Seeing Small”
The “Seeing Small” video introduced visitors to the Scanning Electron Microscope (SEM). A video explained how the SEM lets scientists see some of the smallest things that exist. It showed how the SEM reveals tiny secrets, such as how a spider’s spinnerets make silk. The video also introduced a UC Berkeley scientist—a SEM expert.

“Shop the NanoMall”
The “Shop the NanoMall” video used a mock advertisement to introduce some of the potential products that might result from nanotechnology research. The video also explained whether any such products have actually already been produced. Accompanying information cards explained the science behind the real or imagined products—for example, a NanoSolar-Cell Vest in which tiny, lightweight solar cells (that could be made using nanotechnology) turn clothing into power sources to run small electric devices like an MP3 player or DVD player anywhere you are. Six products in all were featured.

Computer-based exhibits
There were two computer-based exhibits in the NanoZone exhibition, one called “Who’s in the NanoZone?” and the other, “What is NanoTechnology?” Although housed on individual computers, this module was actually a series of exhibits that presented different aspects of nanotech scientists and their research. The current versions of these computer-based exhibits are available at http://nanozone.org

“Fishing for Fun”
For each nanotechnology scientist a visitor could view a brief life story of that individual; play “Fishing for Fun,” a game in which visitors answered questions about what they had learned in the exhibition and (and could receive hints, if needed); and play another interactive game that presented more complex cognitive challenges in a game-like way related to elements of the featured scientists’ current nanotechnology research.

The “Fishing for Fun” game presented visitors with select-a-response questions (true/false, multiple choice) on topics related to the scientists and their work. The game was designed for a visitor to play against a fellow visitor in a race to build a bridge across a pond by adding planks, which were awarded when a correct answer was given. Some single visitors played the game on their own by playing both sides. Visitors could seek clues from the fish in the
pond and, if they answered incorrectly, they were given the correct answer and provided with more detailed information about the topic.

Advanced Game
The “advanced” game associated with each scientist was based on an aspect of his or her current nanotechnology research. It presented the visitor with a cognitive challenge and the visitor had to interact with it to do such things as test different treatments, vary the size of holes in a nanoscale biocapsule, or design viruses to form gold nanowires.

“Life Stories”
The section called “Life Stories” portrayed the nanotechnology scientists as ordinary people with academic strengths and weaknesses and normal childhood interests. The short stories presented, in a simplified way, the nature of the research in which these scientists are engaged. The purpose of this exhibit was to show visitors the real lives of scientists. Another on-screen feature was “Talk to the Scientist.” Visitors could click on a picture of a cell phone and hear each scientist talking about his or her research.

“What is Nanotechnology?”
“What is Nanotechnology?”—an exhibit built on a computerized question-and-answer database—encouraged visitors to ask questions about nanotechnology using a touch screen. Using artificial-intelligence software, it matched an answer to the visitor’s question from a question-and-answer database. The answers were delivered by a computer-generated human image. A controlled group of vocabulary words allowed visitors to form questions such as “How small is a nanometer?” and “In what ways will nanotech change the future?” A novel feature of this exhibit was that all questions and responses were recorded and project staff members were able to identify what questions were posed for which the system had no answer. They could then add a new answer to the database so that next time the system could answer that or a similar question.

“Fab Lab”
Finally, a technology exhibit that was part of the exhibition was “Fab Lab,” an interactive computer game about what motivates people to become scientists. This exhibit was a prototype and was not evaluated in the summative evaluation.

Description of Programs

Programs (Facilitated Activity Stations)

“Size Wheel”
Visitors used scissors to construct a size wheel to help them learn more about measuring things on the macro, micro, and nano scales.

“How Small Is That?”
What are the smallest of the small? Viruses? Bacteria? Blood cells? Visitors were challenged to test their knowledge of the macro, micro, and nano scales by identifying photos of things
so big that they can be seen by the human eye, or so small that they can be seen only under a microscope.

Programs (Live Floor Demonstrations)

NanoZone included three live demonstrations in which visitors learned about cutting-edge nanotechnology tools that real scientists had invented and were using. Demonstrators used larger-than-life models or props to depict developments in nanotechnology research. As presenters used props, a projection camera showed the prop on a large-screen television.

Presenters spoke from a script and used PowerPoint slides to illustrate the demonstrations. The program team developed a training program for presenters. Each presenter received one-on-one training and opportunities to practice. Those three demonstrations, Cancer Detecting NanoWire; Nanoporous Biocapsule; and Seeing Nano are described next.

“Cancer Detecting Nanowire” explained the biology of prostate cancer and introduced a nanobiomedical device that allows for ultra-early detection.

“Biocapsule” provided a lesson in the biochemical processes of diabetes and then used common household materials to illustrate Dr. Tejal Desai’s research in treating diabetes using a nanotechnology application.

“Seeing Nano” used props to illustrate the concept and workings of an atomic force microscope.

Coverage of Content Goals

Table 1 shows how the project team planned the content of the exhibits to match specified content goals for the exhibition as a whole. The four content goals related to (1) understanding what nano scale is (size), (2) using nanotechnology research (practical applications), (3) portraying researchers as ordinary people, and (4) showing the tools that researchers use to work at the nano scale. Each goal was deliberately covered in more than one exhibit to (a) ensure that visitors were exposed to some content related to those goals no matter which groups of exhibits they visited, and (b) reinforce visitors’ exposure to and understanding of that content. Some exhibits met certain content goals more strongly than did other exhibits, and some met more than one goal.
<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Content Goals (Low, Med, High)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive Physical Exhibits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure Yourself in Nanometers</td>
<td>Measure height, shoe size, and hand size in nanometers.</td>
<td>h</td>
</tr>
<tr>
<td>Zoom In</td>
<td>View 4 objects with eye and 3 magnification tools - hand lens, video microscope and SEM (simulated)</td>
<td>h</td>
</tr>
<tr>
<td>Look Familiar?</td>
<td>Lift doors showing magnified object with two doors underneath with successively lower magnification.</td>
<td>h</td>
</tr>
<tr>
<td>Other Physical Exhibits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientist &quot;Collector&quot; Cards</td>
<td>Large cards with personal information on scientists and their nanotechnology research.</td>
<td>m, h</td>
</tr>
<tr>
<td>Pull Up a Seat</td>
<td>Circular stool seats with pictures of tiny things magnified.</td>
<td></td>
</tr>
<tr>
<td>Video-based exhibits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What the Heck is Nanotech?</td>
<td>General introduction/attractor to the exhibit covering the main storyline points.</td>
<td>m, m</td>
</tr>
<tr>
<td>Seeing Small</td>
<td>Introduction to SEM technology.</td>
<td>m</td>
</tr>
<tr>
<td>Nano Mall</td>
<td>Advertisements for potential products that might result from nanotechnology research</td>
<td>m, l, h</td>
</tr>
<tr>
<td>Programs/demonstrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeing Nano</td>
<td>Visitors use models of 2 microscope technologies to experience how scientists &quot;see&quot; and work with things on the molecular level.</td>
<td>m, m, h</td>
</tr>
<tr>
<td>NanoWire Demonstration</td>
<td>Model and explanation of the cancer-detecting nanowire biomedical device.</td>
<td>l, h, m</td>
</tr>
<tr>
<td>Biocapsule Demonstration</td>
<td>Model and explanation of the Nanoporous Biocapsule device for diabetics.</td>
<td>m, h, m</td>
</tr>
<tr>
<td>Computer-based Exhibits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientist Life Stories (x4)</td>
<td>Life stories and information about four featured nanotechnology researchers.</td>
<td>l, h, h</td>
</tr>
<tr>
<td>Fact Fishing (x4)</td>
<td>2 Players explore information about a researcher and the nanotech device being developed in order answer MC or T/F questions.</td>
<td>h</td>
</tr>
<tr>
<td>Interactive Games (x3)</td>
<td>Interactive games highlighting key features and uses of nanotechnology applications</td>
<td>h</td>
</tr>
<tr>
<td>What is Nanotechnology?</td>
<td>Visitors form questions from a list of words about nanotech. Answers presented by talking characters.</td>
<td>m, m, m, m</td>
</tr>
</tbody>
</table>

Table 1 How Exhibits Matched to the Project Content Goals for Covering Nanotechnology Science and Scientists
Evaluation Methodology

Evaluation Team
The external program evaluation was conducted collaboratively by Douglas Spencer of Edu, Inc. and Mike Timms and Cathy Ringstaff of WestEd. Edu, Inc. had overall responsibility for the formative evaluation of the physical exhibits and programs and WestEd was responsible for the formative evaluation of the technology-based exhibits. The summative evaluation described in this report was designed and implemented by Edu, Inc. and WestEd together.

In addition to the external program evaluation, LHS conducted its own formative evaluation studies of exhibits as they were developed. This internal evaluation was led by Ann Barter and Coe Leta Finke.

Evaluation Stages
The evaluation occurred in three main stages as shown in Figure 4. Each stage is described in detail in the following sections, with particular emphasis on the summative evaluation, which is the main focus of this report.

Front-end Research

Initial Project Planning
During a project kick-off meeting in August 2002 the NanoZone team articulately presented initial concepts for exhibits, programs, and technology aimed at elementary-level and middle-school learners. Concerned that several of the concepts required science content that was not being taught in middle school, evaluators encouraged the team to learn all they could about the target audience. The NanoZone team proposed a combination of internal front-end research, to be led by educators and evaluators from Lawrence Hall of Science, and external front-end research, to be conducted by Edu, Inc.

National Survey
Front-end research included a national survey, interviews with visitors on the museum floor, and activity-based focus groups. The survey was administered to a random national sample of 500 people, both adults and children. It contained questions about an individual’s perception of the world that is too small to see, their knowledge of scientific terms (including “nano” and “nanotechnology”), and their ability to correctly assign size order to sub-visible objects.

Figure 2 The Evaluation Stages and Timeline

Front-end
National survey 500 people. Focus groups with teachers and 250 students grades 4-8.

Formative
Four rounds prototype testing with museum visitors. 200 children concept test new ideas.

Summative
Summative study of visitors’ experience and learning; collaborative process and new media.
The NanoZone team commissioned front-end research—classroom-based focus groups with over 250 students in grades four through eight. Activity-based focus groups documented the level of science understanding and cognitive understanding of children age 8 to 11. Edu, Inc. embedded questions in educational games based on the television game show “Jeopardy” and the board game “Trivial Pursuit.” Children recorded answers on game cards that were color-coded by age and topic. Drawing and diagramming activities documented children’s understanding of objects that are too small to see. Small-group conversations with seventh and eight graders probed these children’s scientific understanding. Focus groups were videotaped and the answers to survey questions were entered in a relational database.

White Paper: Learners’ Readiness

A white paper (Spencer, et al.) summarized visitor readiness to learn about new research. The paper, based on interviews with a combined total of over 500 adults, teens, and middle-school children from different regions of the United States, summarized respondents’ understanding of atoms, molecules, and comparative sub-visible scale, and their knowledge of the terms nano and nanotechnology. People also talked about the kinds of science that interests them, and where they get their information and news about cutting-edge research.

The white paper informed the development of the exhibits and exhibition in two significant ways. First, it provided a reality check, reminding the NanoZone team that 95 percent of people interviewed had not heard of nanotechnology and that, in general, the majority of adults and middle-school children alike showed limited knowledge and consistent misconceptions about atoms, cells, and other things that they cannot see. The second effect was to emphasize that middle-school children and teens get information from their media of choice, which may include television, music, the Internet, online discussion boards, and popular magazines. The resounding message was the need to find an age-appropriate hook to interest middle-school visitors and relevant, memorable vehicles to present unfamiliar content.

The white paper’s findings are supported by a review of informal learning with technology outside school that cites a 2002 study by Hayward et al. That study found that over 70 percent of youth age 9 to 14 includes video, computer games, music, and television in their leisure-time activities. The study documents the trend of an increasing presence of videogame consoles in homes, household Internet access above 80 percent, and the advent of digital television as media realities and educational opportunities.

Formative Evaluation

In January 2003 the NanoZone team began developing exhibits, programs, and technology. Each component had clear educational objectives based on information gathered and lessons learned during the two-pronged front-end research. Following the first formative site visit in March 2003, the evaluators and NanoZone team created a production schedule by which exhibition components were to be developed in a four-month iterative cycle, gradually moving from stage-one prototype (duct tape and cardboard) to stage-two prototype (plywood and paint)—with either internal- or external-evaluation feedback at each stage. Prototypes

During floor-trial evaluations visitors were observed using the prototype exhibits and interviewed as they finished using them, using observation and interview protocols developed by the external evaluation team. Data were gathered on the amount of time a visitor (or group of visitors) used the exhibit; the approximate age and gender of each visitor; the approximate age and gender of the dominant user (if visitors were in a group); how visitors used the exhibit and any relevant comments they made; level of visitor engagement; and any difficulties in use (e.g., navigation, use of equipment; visibility of signs).

In addition, some of the technology-based exhibits were reviewed by evaluators using a heuristic evaluation protocol that examined those exhibits’ usability and their potential for stimulating learning. Feedback from the formative evaluations was through written reports and meetings with the project team during the site visit. Exhibits were enhanced, redeveloped, or discarded based on this evaluation feedback.

In June and September 2003 Edu, Inc. led activity-based focus groups at a science museum and in school classrooms to test concepts for exhibits and programs. With the help of the LHS (NanoZone) technology team, Edu, Inc. developed a simple computer game to learn what upper-elementary children wanted to know about scientists. The game also tested several user interfaces to determine these children’s preferences.

**Summative Evaluation Study**

The summative evaluation of the final NanoZone exhibition was conducted in November 2004 during a three-day site visit by a five-person evaluation team. The exhibition had been running since June 2004.

As part of a no-cost extension the WOR team continued to build three additional components after this summative evaluation. The components include: “Fab Lab,” a media based exhibit; “Gecko,” an exhibit using geckos to introduce an aspect of nanotechnology research; and an enhanced Nanozone website.

The evaluation of exhibits developed under the no-cost extension is outside the scope of this summative study. The WOR project hired an external evaluator to assess the new exhibits. The evaluator will present his work in a separate report.

**Summative Instruments**

The summative evaluation used eight instruments that gathered a mixture of quantitative and qualitative data. The instruments were developed partly from instruments that had been used earlier during the formative evaluation (to evaluate individual exhibits during site visits) and supplemented with new instruments that were designed specifically to extract data on the exhibition as a whole.

Some visitors were interviewed before they entered the exhibit (i.e., pre-visit interviews) to capture individuals’ understanding of the smallest thing that they could think of, nano,
nanotechnology, and their perception of scientists. Interviews of visitors leaving the exhibition (i.e., post-visit interviews) asked those individuals what the exhibition was about, what they had learned, where they had learned it, and what they now thought about scientists (after experiencing the exhibition). Unobtrusive observations and mediated on-the-spot interviews documented visitors’ experiences at individual exhibits and programs. A post-visit interview asked visitors’ perception of scientists after using the exhibition. To evaluate floor programs evaluators used a protocol to observe programs and interview presenters. A sample of visitors was tracked to show the length of time specific exhibits were used. The instruments were pilot tested in a two-day trial in March 2004 and refined slightly for the summative evaluation in November 2004. The full set of instruments is in Appendix A.

To document the NanoZone teams’ collaborative experience, evaluators held separate interviews with members of each team and the principal investigator. In addition, for the “What is Nanotechnology?” exhibit, evaluators reviewed data generated from logs captured by the computer.

To promote objectivity, Dr. Steven Yalowitz, an independent, professional museum evaluator, was asked to view and provide feedback about the NanoZone exhibition. Finally, using a framework developed for a separate NSF-sponsored project, Dr. Yalowitz reviewed the exhibition from a visitor-centered perspective.

The evaluation team compared personal impressions during a peer debriefing session at the end of the evaluation. Data from the above instruments were entered in a relational database and analyzed using SPSS statistical software. Descriptive statistics such as frequencies, percentages and cross tabulations were produced from the quantitative data. Qualitative data from observations and interviews were coded by category, summarized and used to explain and support the findings from the quantitative data.

**Validity**

The evaluators took specific and intentional steps to create a valid, reliable data set. In a qualitative study such as this one, the term validity does not carry the same connotation as it does in quantitative evaluation. Reliability and generalizability, hallmarks of quantitative research, play a minor role in qualitative inquiry. In a qualitative study validity refers to the accuracy, authenticity, and credibility of researchers’ accounts.

Five steps helped ensure validity of the evaluation team’s observations, findings, and conclusions.

1. **Triangulation** – The study examines evidence from three different data sources (survey instruments, unobtrusive observation and mediated interviews, and tracking). The three combine to identify common and outlying themes.

2. **External auditor** – Dr. Steven Yalowitz, a respected museum evaluator, provided expert external review. Dr. Yalowitz participated in the original formative-evaluation site visit in March 2003 to become familiar with the exhibition. He returned 18 months later to review with the evaluation team the end result.
3. Peer debriefing – Following the evaluation the five-member research team met in a formal session to share personal impressions. This process exposed themes that were apparent to the majority of researchers.

4. Prolonged time – Three of the researchers were close to the exhibition during 24 months of front-end and formative evaluation. This prolonged exposure provided an in-depth understanding of the project, its evolution, and goals. The prolonged experience was balanced by adding two evaluators to the summative-evaluation team. New to the project, they offered fresh eyes to counter possible bias by the veteran project researchers.

5. Visitors’ own words – When appropriate, the summative report provides quotes from interviews and conversations with visitors. Consistent visitor comments identify recurring strengths and challenges.

Sample

Evaluators conducted a total of 65 pre-visit and post-visit interviews. Forty percent of respondents were female (n = 26) so 60 percent were male (n = 39). The majority (87 percent; n = 57) were school-aged, with 49 percent aged 8 to 11 (n = 32) and 38 percent aged 12 to 16 (n = 25). Eleven percent were adults and one person’s age was not recorded. These attendance patterns are typical of visitors to LHS during weekdays.

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>F</th>
<th>M</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unknown</td>
<td>1</td>
<td>0</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>8-11</td>
<td></td>
<td>11</td>
<td>21</td>
<td>32 (49%)</td>
</tr>
<tr>
<td>12-16</td>
<td></td>
<td>11</td>
<td>14</td>
<td>25 (38%)</td>
</tr>
<tr>
<td>29-39</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>40-60</td>
<td></td>
<td>2</td>
<td>3</td>
<td>5 (8%)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>26 (40%)</td>
<td>39 (60%)</td>
<td>65 (100%)</td>
</tr>
</tbody>
</table>

Table 2 Age Analyzed by Gender through Cross Tabulation of Visitors who Answered Pre- and Post – visit Surveys

Of 50 mediated on-the-spot interviews, 60 percent of respondents were in the target-audience range, age 8 to 11 (Note: The project’s official target was young people age 8-14) with boys and girls represented equally (n = 15 of each). Five children fell in the 12-to-16 age range, and most of those were female. Of a total of 83 visitors interviewed about their view of scientists, 53 percent (n = 44) were children age 8 to 11 (18 girls and 26 boys); 34 percent (n = 28) were age 12 to 16 (13 girls and 15 boys). The remainder of those individuals interviewed (n = 11) were adults, about evenly split by gender.

Challenges

Before discussing the findings of the summative evaluation, it is appropriate to contemplate first the considerable challenges that this project set for itself. These can be categorized under three headings: content, cognitive, and a combination of challenges. Each is discussed below.
Content Challenges

“Our task is to create an exhibition about a technology that you cannot see that really isn’t being made yet.” NanoZone Exhibit Designer (Quoted in September 2002)

Introducing nanotechnology through informal education is a formidable challenge. The difficulty from an educational perspective is that increasing public understanding of research often requires increasing public understanding of nanoscience. Consider the following definition of nanotechnology: “Deliberate manipulation of matter at size scales of less than 100 nanometers.” For many, understanding that abstract concept requires first learning a new term—“nanotechnology.” (That is, first understanding the root word “nano,” appreciating that there is a measure called “nanometers,” understanding the scope of “billion,” and, finally, knowing what a meter is.) Indeed, for learners to fully understand nanotechnology they must also understand the terms “matter,” “atoms,” and “molecule.” Moreover, learners must stretch their imagination to grasp that a sub-visible size scale exists in the first place, that sub-visible objects exist in different sizes, and that scientists can manipulate matter that they cannot see.

Cognitive Challenges

“Nanobots are a type of robot that can eat metal.” Boy, age 11

“Nanotechnology, yeah I know that. I heard about it on the Internet. It has to do with computers and information technology. Adult, age 28

Three national surveys, discussed below, conducted as part of NSF-funded nanotechnology education projects, indicate that most people do not understand nanotechnology or the size scale of nanoscience. Without a basic understanding of nanotechnology and its requisite science-based foundation, the public likely will continue to be equally impressed by credible scientific information as they are by purely fictional accounts of nanotechnology.

In November 2002 the NanoZone team commissioned a national survey that asked 500 people about their understanding of nanotechnology. Ninety percent of people surveyed had not heard of nanotechnology. Only 5 in 100 could accurately explain nanotechnology. In that survey adults were only slightly more successful than youth in size-ordering three sub-visible objects: cell, atom, and DNA.

In March 2004 Spencer and Angelotti asked 100 children and 50 adults at Disney’s Epcot® if they had heard of nanotechnology. Twelve percent said that they had heard the term. Only six people (4 percent) could accurately describe it.

In March 2004 Spencer and Angelotti asked 100 children and 50 adults at Disney’s Epcot® if they had heard of nanotechnology. Twelve percent said that they had heard the term. Only six people (4 percent) could accurately describe it.

A national survey of 1,500 people conducted in September 2004 by Waldron, Spencer, and Batt showed that 90 percent of people had not heard of nanotechnology. Again, only five percent (75 people; mostly ages 17 to 28) could give a reasonably accurate definition. Many who had heard the terms “nanobots” and “computer chips” admitted that their knowledge came from fiction or television. The few who knew the term “nanotechnology” said that they were avid readers, science enthusiasts, NPR listeners, or investors. In a finding similar to the
2002 WOR survey, children and adults alike had trouble putting sub-visible objects—germ, molecule, and atom—in the appropriate size sequence.

Field and Powell\(^7\) characterize this lack of understanding as “a critical shortcoming of our public information system.” They write, “Few people even know what research is being conducted, much less understand why it is being done and what the potential implications may be. The field of informal, public education is uniquely poised to reach the public at all levels, so that those who…make or will make decisions for themselves and their families, have access to accurate, up-to-date, unbiased, and substantive information.”

To understand nanotechnology, students must make a mental journey–crossing the macro-micro-nano bridge. This observation matches findings from interviews with education experts at Cornell University, focus groups with teachers, and an Edu, Inc. study of 600 elementary-age students. (The latter was part of the development of *It’s a Nano World*, a NSF-sponsored museum exhibition developed by Cornell University.)

In the present case, the NanoZone team’s goal was to help visitors cross the macro-micro-nano bridge using informal, unassisted learning modalities.

**Combined Challenges**

The challenge accepted by the WOR team was formidable. Team members created hands-on and minds-on museum learning experiences to introduce visitors to unfamiliar information that was complex and multifaceted. At the same time the team used a variety of media to develop content-distribution vehicles that could be adapted to present other technologies and difficult concepts sometime in the future. In addition, the team assembled and managed three diverse subgroups: exhibits, programs, and technology, each with its own culture and work style. Throughout the project the WOR team evaluated and verified that the exhibition was attracting, engaging, and educating visitors.
Findings

Evaluation Questions

The findings of the summative evaluation are reported as answers to several evaluation questions. The first is: 1) Does the exhibition attract, engage, and educate the public about nanotechnology research?

Does the Exhibition Attract?

Observation and tracking show visitors were attracted to the exhibits and programs.

Positive Affect

A majority of visitors showed positive affect as they interacted with exhibits. As visitors approached the exhibits, evaluators used unobtrusive observation to gauge whether the exhibits were inviting and easily navigated. Evaluators noted visitors’ affect and listened to their conversations as they figured out how to use an exhibit or game.

Seventy-five percent of the visitors observed showed a positive affect. Intrigue or interest was the most frequent affect observed across all visitors (44 percent). Evaluators observed pleasure in 25 percent of users and a neutral affect in 23 percent of users. Less than 3 percent of visitors displayed a negative affect. Neutral affects were often followed by intrigue or interest. An evaluator observing a young boy noted:

“Neutral [affect] at first, pleasure when succeeded. ‘Oooh!’—when he succeeded. He was excited.”

Average to Above-average Dwell Time

A majority of visitors remained at exhibits for a while and returned later. Tracking showed that over 75 percent of visitors observed spent, on average, at least 30 seconds at an exhibit, which is a strong indicator of attraction, with almost no “bounce-off” behavior. (“Bounce-off” is characterized by a visitor approaching an exhibit then looking, touching, or playing with its controls for less than five seconds, and then leaving without using the exhibit.) Only three observed uses lasted less than 5 seconds (two of which were by the same person). Further analysis of tracking showed an average dwell time (the average time spent by a visitor at exhibits in the exhibition) of over one and a half minutes per exhibit.

That figure is higher than the average for museums as a whole and higher than the average dwell time for science museums based on data collected by Serrell. A meta-analysis of Serrell’s compilation of tracking studies at 110 museum exhibitions showed visitors’ average use of exhibits within an exhibition as 1.28 minutes (77 seconds). The average dwell time for NanoZone exhibits exceeds Serrell’s average dwell time per exhibit at science museums (1.36 minutes). During the three-day site visit, evaluators consistently observed children and adults leaving NanoZone and returning later to spend more time using the exhibition.
Attractive Look and Feel
Overall, the exhibition had an attractive and unified look and feel. It made use of color and graphics to tie together the exhibits. Following post-visit and mediated on-the-spot interviews with children, several parents commented that the exhibition was attractive and professional. A mother said, “I like the choice of color and the way they used everyday things to talk about science.”

Last but not least, a review of the exhibition showed no obvious safety hazards.

Does the Exhibition Engage?

Long dwell times and repeated use indicate visitors were engaged

Expert opinion was that the exhibition was attractive and engaging, and provides a variety of experiences for visitors. The hands-on and computer-based exhibits were very popular; the introductory panels seemed to be a little underutilized. While NanoZone covers a relatively small amount of floor space, there is a rich variety of information and media in the exhibition. The follow sections provide evidence of engagement.

Use Time Exceeded Dwell Time

Actual use time was longer than dwell time. Dwell time is an average measure of how long a tracked user spends at exhibits. Use time is how visitors, tracked and untracked, actually stay at a particular exhibit. To judge visitor engagement, evaluators observed and tracked visitors’ use of the exhibits. More than half of the visitors showed exploration behavior such as asking questions, solving problems, and attempting to produce multiple outcomes—as well as repeated use. Nearly 60 percent of tracked uses were longer than one minute, unusual in the fast-moving world of science museums. Based on tracking studies conducted by Edu, Inc. at Epcot® and anecdotal evidence from evaluators at science museums, visitors often spend more time at a few popular exhibits and less time (30 seconds or less) at many exhibits, which lowers the average dwell time across all exhibits.

The longest tracked use at an exhibit was five minutes, however, several evaluators independently observed times of fifteen minutes or longer. During busy times at the computer-based exhibits, a group of several children would “claim” a terminal and take turns playing the game, often for fifteen minutes or longer.

Ease of Use, Repeated Use

Visitor behaviors showed that the exhibits engaged them. In addition to dwell time and use time, another important aspect of engagement is what visitors did while in the exhibition area. Ganomon (1999) posits that the first few seconds of a visitor’s interaction with an exhibit are crucial. He says, “An exhibit must respond to the visitor’s input within the first few seconds. This initial ‘hand-shake’ is vital to a successful interaction between visitor and exhibit.” During unobtrusive observation evaluators noted that in most cases visitors quickly learned to operate the exhibits, meaning that exhibits were intuitive and easy for visitors to use.
**Evaluators observed collaborative and problem-solving behavior.** Evaluators observing upper-elementary children noted:

- “Collaborative problem solving with partner.”
- “Worked with a friend to solve the problems.”
- “Working with friends.”

The following evaluator observations offer further evidence of interaction and repeated use, indicators of engagement among museum visitors, especially children:

- “They help each other rather than use it competitively.”
- “Large group around visitor. They make suggestions.”
- “Reads several cards at one time, compares cards against each other.”
- “Went back to games after interview—kept playing!”

**Recognition of Exhibition Themes**

**Many visitors were able to identify the main themes of the exhibition.** Other evidence that visitors were engaged by the exhibition is shown in their ability to identify what the themes of the exhibition were. During the post-visit interview, evaluators asked visitors an intentionally open-ended question: “What are the exhibits about?” Visitors were allowed multiple answers. The most frequent answers were nanotechnology and nano, followed by scientists and research, all of which were themes around which the exhibits in NanoZone were developed. This is positive evidence that the exhibition was engaging and that visitors were cognitively engaged in the major messages that the exhibition was designed to convey.

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanotechnology (applications)</td>
<td>60.00%</td>
</tr>
<tr>
<td>Nano (size and scale)</td>
<td>32.31%</td>
</tr>
<tr>
<td>Scientists and research</td>
<td>15.38%</td>
</tr>
<tr>
<td>Tools scientists use</td>
<td>4.62%</td>
</tr>
<tr>
<td>Atoms (basic science)</td>
<td>3.08%</td>
</tr>
<tr>
<td>Other</td>
<td>26.15%</td>
</tr>
</tbody>
</table>

Table 3 Responses to the Question, “What are these exhibits about?”

Almost half of the respondents (49 percent) were in the target audience, children age 8 to 11; 38 percent were ages 12 to 16. Nearly 50 percent of visitors who said the exhibits were about nanotechnology were children age 8 to 11. Another 40 percent were ages 12 to 16. Among the 8-to-11 year olds, significantly more boys than girls said the exhibition was about nanotechnology.

**Conceptual Redundancy**

**Built-in conceptual redundancy aided visitors’ engagement with the exhibition.** Visitor engagement was enhanced by the fact that the final NanoZone exhibition was well-planned, with consistent and repeated themes that reinforced the main goals of the project. Those goals were to convey to visitors an understanding of (1) sub-visible size, (2) researchers as people, (3) applications of nanotechnology research, and (4) tools that are used in that research. This consistency was the result of a collaborative planning process in which goals for the exhibition were defined and exhibits were planned. Exhibits were planned to address one or more of the four major content goals. Table 1 shows how this was mapped by the project team. Similar tables were produced to ensure visual consistency (redundancy) in the pictures and images that were used in the exhibits and the surrounding signs. Also, a table
was produced that ensured repeated use of relevant vocabulary words across all the exhibits. This latter process was also aided by hiring Deborah Rose, a science writer with expertise in writing for children. During their end-of-project interviews, several NanoZone team members said that the science-content writer was extremely important in helping the exhibition speak with one voice.

“Deb [Rose] had a very specific, defined role and wasn’t part of any one group and was able to look at everything. As a bonus she was straightforward and had a design sense.”

“Deb Rose was key in tying content together.”

—NanoZone team members

During formative site visits, the NanoZone team’s subgroups—exhibits, technology, and programs—developed signs, scripts, and copy written in different styles, at different reading levels, and using differing vocabulary. Deb Rose acted as an invaluable facilitator to help all three teams conform to a uniform style of vocabulary, grade level, and content. She also helped ensure that concepts and vocabulary were presented multiple times across the exhibition. For example, as Dr. Yalowitz noted, “The term ‘nanotechnology’ is used in almost every exhibit, so that visitors should be aware of the main theme tying all of the exhibits together.” Ms. Rose’s expertise as an educator and a children’s writer offered a unique skill set that markedly improved the final exhibition.

**Relevant Examples Hard to Find**

**Age-relevant content aided real-life connection for young visitors.** Another factor in successfully engaging the target audience was that the final exhibition attempted to present content in ways that might connect with examples from the real lives of young people. During formative evaluation evaluators and teachers consistently encouraged the NanoZone team to find ways to make nanotechnology relevant to the target audience. In July 2003 a teacher commented, “If you can’t make this real to my fifth graders, they won’t get it. If you can, they will. How does this affect them? Why does it matter in their lives?”

Conversations with children during the formative evaluation of earlier versions of the computer-based exhibit that presented the life stories of the four featured scientists showed that portraying scientists as children engaged young visitors. The NanoZone team selected a group of scientists to feature in which there was a balance of gender (two males and two females) as well as ethnic representation (two Caucasians, two non-Caucasians). That diversity is important to encourage girls as well as boys to see themselves as future potential scientists, and to ensure that all students may identify with their potential to become scientists.

The NanoZone team was also vigilant in searching for examples of nanotechnology that would appeal to a fifth-grade girl or boy. Unfortunately, few examples currently exist; most current applications are relevant to adult interests (e.g., cancer detection). Similar projects in the future should identify and test relevant real-life examples, if at all possible, to promote understanding of these new technologies to a school-age audience.
Exhibition Was Noisy

Sound levels occasionally interfered with some visitors’ enjoyment and use of the exhibits. As discussed later in the report, the interactive computer exhibits were very successful and well used. Part of their success was the use of audio to introduce concepts and information to a young audience while minimizing the need for visitors to read complex text. The three video-based exhibits also used sound successfully. An unanticipated by-product of this approach was that the resulting exhibition could become very noisy at peak times, which was exacerbated by the fact that the exhibition was located in the main entrance area of the museum, an area whose acoustics tended to echo. This shortcoming was noted by both evaluators and visitors. (Note: The project team reported that certain exhibits were moved to reduce noise overlap).

“Had trouble hearing, trouble knowing when simple click versus needed to use roller ball and click.” – Evaluator observation of child using a game.

“It’s really noisy in here so all the kids talk louder to hear each other which makes it even noisier.” – Mother of young visitor

When planning similar mixes of exhibits and programs in the future, attention needs to be paid to developing ways to control the noise footprint. Possible solutions may include spreading the exhibits over a large area, creating sound baffles between exhibits, or locating the exhibition in a room equipped with noise-dampening features. Serrell\textsuperscript{10} points out that exhibitions that separate activities can maintain a lively atmosphere but still serve those who need to concentrate to learn (for example, learners who find it difficult to read when a video is playing). In contrast, Coe Leta Finke, a member of the NanoZone team, points out that close proximity between exhibits encourages conversation between users.

Text-heavy Signs

Heavy use of text in some exhibits presented a barrier to some visitors. Another response to the challenge of conveying complex ideas and research was to develop exhibits that imparted information through text. For some visitors, this was acceptable.

“There are a lot of words which is okay for me as a parent. This is about nanotechnology and scientists who make it happen.” – adult visitor

For others, the amount of text used seemed too much.

“The exhibits take too much reading.” – Parent

“[Visitor] didn't read text on Zoom In.” – Notes from unobtrusive observation

“Obviously bored with reading Scientist Cards.” – Notes from unobtrusive observation

The NanoZone team made a concerted effort to use graphics, video, and captioned images to convey content, for example, with “NanoMall.” Future projects that seek to educate users
about complex, leading-edge technology are encouraged to allow significant budget resources and time to develop and test multi-modal interpretive strategies that do not rely too much on expecting users to stop and read text.

It is recommended that future projects consider a Director of Interpretive Design as a budget item and team member. This person’s role would be to ensure an interpretive strategy that uses multiple educational modalities (visual, audio, kinesthetic, written) to engage visitors.

**More Hands-on Activities**

**Hands-on activities were engaging.** Among the noncomputer-based exhibits, visitors who were asked said that they most frequently learned from, in order, “Measure Yourself,” “Zoom In,” “NanoMall” and the entry video (tied), the SEM video, “What the Heck is Nanotech?” and “Look Familiar.” “Scientist Cards” were mentioned, but less frequently than the others.

The NanoZone team knew that, for this project’s target audience, there should be several hands-on activities. However, the sophisticated content made it hard to conceive of appropriate, relatively simple demonstrations. Some visitors noted the lack.

“We need more stuff to use, not just to watch.” Boy, age 8 to 11

Evaluator observations and tracking data show that “Measure Yourself” was the most used hands-on activity. In addition, an evaluator observed that “Measure Yourself” was colorful, durable, and accessible for those in wheelchairs or with limited dexterity. (Note: Gecko Wall, an exhibit developed during the no-cost extension, was designed to address the need for a completely hands-on exhibit with little text.)

**Video Projection Engaged Visitors**

**Video projection in three areas proved engaging.** The entry video and video used in “NanoMall” were deliberate attempts to introduce nanotechnology in a way that appealed to the target audience. The entry video was developed based on front-end research that identified how upper-elementary students could best understand nano and nanotechnology. Evaluators observed significant casual use by visitors of the video that was projected onto a large screen at “NanoMall.” Tracking data showed that visitors spent an average of two minutes and 15 seconds watching the entry video.

Tracking showed a much higher dwell time for the entry video and the nanotechnology ads than for the other exhibits in general. (Note: The “What is Nanotech?” entry video is embedded in the center of the main exhibit wall. Nanotechnology ads are projected.) Besides catching their attention right away, the use of a projected image for the entry video allowed users to watch it from a convenient distance. Projection was combined with a large open space that allowed many users to view the video at the same time. Evaluators observed groups of teens socializing and watching the video. Families often watched as a group when entering or gathering to leave. The video’s short length and clear break between scenes offered viewers the option to watch, leave, and return. Over three days evaluators saw several children watching the video multiple times. Evaluators observed that the oversized billboard
format of images and messages at “NanoMall” also allowed visitors to view the exhibit from a distance or move closer and interact.

**The SEM Video was viewed less (in terms of frequency and duration), but visitors who watched it seemed engaged.** The SEM video was “about seeing stuff smaller and smaller with a special microscope,” according to a visitor age 8 to 11. Other visitor comments were positive and showed that visitors understood the concept. However, tracking and post-visit surveys showed that the SEM exhibit was used considerably less than were other exhibits, especially the entry video. During tracking periods no visitor watched the entire SEM video.

Dr. Yalowitz commented, “Compared to the hands-on and computer elements, the video elements seemed to be underutilized.” The reason for SEM’s low use is not clear. It may be because of its location, the fact that it is fairly lengthy, that it uses an adult narrator versus a child narrator, or that it is an information video in documentary format versus the colorful, fun format of the entry video.

**Programs, Technology and Cross-marketing Content**

*Programs provided the opportunity to cross-market content.* The program scripts provided the opportunity to reinforce content that visitors might already have seen or might encounter in other exhibits. Programs also provided presenters the opportunity to direct visitors to other exhibits that included content to help reinforce what visitors were exposed to during the floor demonstration. Following a presentation an evaluator did hear one of the presenters refer a visitor to one of the life stories on the computer in a conversation. However, in general evaluators did not observe presenters referring visitors to other exhibits.

Cross-marketing content could have easily been done in the technology exhibits. For example, Ratty could have invited the visitors to go see other parts of the exhibit on related topics, or information about other exhibits or programs could have been added on a slide at the end of the life stories.

**Does the Exhibition Educate?**

*Surveys and observation offer evidence of learning behaviors, content acquisition, and changing attitudes.*

This section considers two related questions:

1) Does the exhibition educate the public about nanotechnology research?
2) To what extent does the exhibition promote public understanding of research in advanced science and technology?

The summative evaluation offers four sources of data to examine the kinds of information visitors say they learned and where in the exhibition they learned it.

**Educating about Nanotechnology Research**

Pre-visit and post-visit surveys examined “to what extent do visitors gain an understanding of key concepts and vocabulary by using exhibits, programs, and technology?” Unobtrusive
observation and mediated interviews considered the extent to which the exhibition provided “open-ended, learner-centered, discovery-based experiences.”

**Most Visitors Acquired Some Content**

The majority of visitors deepened their understanding of at least one of the main content themes of the exhibition. Comparing visitor responses on the pre-visit and post-visit surveys showed some evidence of increased content and conceptual understanding across all age grades and by gender.

The pre-visit survey asked visitors four questions to explore their pre-visit understanding of small things, as well as the terms nano and nanotechnology.

When asked, “What is the smallest thing you can think of?”, slightly more than one-third (37.5 percent) of target-age visitors (ages 8 to 11) named a nano-scale object as the smallest thing they knew. The majority of males (61.5 percent) named a nano-scale object while 27 percent of females named a nano-scale object as the smallest thing that they could think of.

When asked, “What does the word nano mean to you?”, just over 38 percent of visitors said nano meant small, while 15 percent said “really, really small or tiny,” and 1.5 percent said $10^{-9}$. “Other” was the most popular response (43 percent). Other responses generally included macro objects like sand, dust, dirt, and salt.

Nearly 70 percent of visitors said that they had heard of nanotechnology, but only 10 percent could “explain nanotechnology to someone else who knows nothing about it.” Thirty percent of all visitors surveyed (pre-visit) said that they had not heard of nanotechnology. Just under half of the visitors were age 8 to 11, just over half age 12 to 16. About one third of visitors said nanotechnology was “the study of small things” or “small technology.” Over 50 percent gave “other” responses.

![Figure 3 Pre-Visit Responses to "What does nano mean?"](image1)

![Figure 4 Pre-Visit Response to “Have you heard of nanotechnology?”](image2)
Post-visit Understanding of Nano and Nanotechnology

In the post-visit survey, 60 percent of visitors said that the exhibits were about nano or nanotechnology. Most of these responses alluded to nanotechnology as a new technology dealing with the “really, really small.” Many children supported their definition with examples from the exhibition. Half of these visitors had not heard of nanotechnology prior to using the exhibits (according to their responses in the pre-visit survey).

When asked, “How would you describe nanotechnology in your own words?”, over 70 percent of the post-visit responses showed some basic but credible content acquisition. Forty-two percent of people said nanotechnology was about size, and 32 percent said it was about science and research. (Recall that, in the pre-visit survey, only 10 percent could explain nanotechnology and just 33 percent described nanotechnology simply as the “study of small.”) The remaining post-visit answers showed partial understanding or misconceptions.

Visitors age 8 to 11 said that nanotechnology “is really small and measured in nanometers”; “it magnifies 1-million times things that are regular everyday things”; and “is the study of extremely small things.” Other responses from 8-to-11 year olds ranged from: “Something is real but too small, can't see it”; “Futuristic technology to invent new things”; and “Nano are small—can't see with naked eye.” Others said, “It's very small, it can be technology and used for cures and a whole bunch of other stuff”; and “Very small ways of future research.” One child commented, “A very important science for technology. Nanobots are a type of robot that can eat metal.”

Those aged 12 to 16 said about nanotechnology: “It's pretty interesting and it's about small stuff”; “It's working with really small things and understanding them”; “Very interesting, very tiny, could be important in tech advances”; and “Scientists are trying to use nanotech to help our lives like cancer testing.” Visitors age 12 to 16 described nanotechnology as “Small stuff, [you] use computers to see it” and “Strong microscopes are needed to see the nanos.”
Visitors saw NanoZone as educational and enjoyable. A teacher said, “My kids love this. Look at them. They are having a blast!” Another said, “This [exhibition] covers the subject of nanotechnology in a way I just can not do in my class. This is all new information for me and I have a degree in biology.”

A girl age 8 to 11 said, “I learned from the whole exhibit.” A boy the same age commented “A very great thing. Fun!”

Dr. Yalowitz also observed, “Nanotechnology is a very challenging and abstract concept to interpret, since nano is not observable. The ‘scale’ theme is present in most exhibits and I think that the developers did a good job of working this into the exhibits.”

The “Measure Yourself in Nanometers” exhibit was effective in introducing the concept of the size of a nanometer. During several interviews visitors said that the exhibit “Measure Yourself” helped them to understand nano. A girl commented how “Measure Yourself” helps you imagine “just how teeny tiny a nanometer is and how it might be useful in measuring small things.”

What Visitors Learned

Evaluator Questions
Evaluator asked two questions to probe the kinds of information that visitors learned from using the exhibits and seeing the technology. The question, “What did you learn about [topic]?” was followed by, “How would you describe [topic] in your own words?”

Evidence of Improved Content Understanding

A majority of visitors surveyed improved their understanding on at least one of the four content goals of the exhibition. Seventy-five percent (49) of the 65 visitors who completed the pre- and post-visit interviews made comments indicating that they had expanded their understanding to some degree in at least one of the four content goals of the exhibition (size, research/applications, scientists, and tools). Details of how this breaks down over the four categories are discussed in the following sections.

Improved Understanding of Size and Nanoscale

A majority of visitors surveyed improved their understanding of size at the nanoscale. Just over half (55 percent; 36) of visitors who competed a pre- and post-visit interview showed some evidence of increased understanding of size at the nano scale. This was one of the content goals addressed in the design of the exhibition. In post-visit interviews, 60 percent (39) of respondents said the exhibition was about nanotechnology. People who said that they learned about “nano” said that nano was about size and measure (scale), one of the main content goals of the exhibition. Almost half of these responses were from children ages 8 to 11.
As 8-to-11 year olds described their simple understanding of nanotechnology, many referred to size and magnification. Their understanding of size at the nano scale is typified by comments such as:

“Nanos must be really small. It's really complicated—it was hard to help the bunny. Zoom In made me think of how small some things are.”

“I am over 1-billion nanometers tall.”

“Nanos are small—can't see with naked eye.”

“If it's small enough it is nano.”

Those ages 12 to 16 also showed a range of understanding about nano scale. Some showed a general understanding in comments such as:

“It’s very, very small; impossible to see.”

Other 12-to-16 year olds offered more concise responses that showed a more precise understanding of nano scale. Comments that show this include:

“How small it is—very tiny particles—1 billionth of a meter.”

“It's really small and measured in nanometers.”

 “[Nanotechnology is] based on very, very small things that you can not see with the human eye.”

Adults grasped the concepts, too. Comments that show this included:

“The people who wrote it [information in the exhibition] wanted you to get an overview of the concept of nanotechnology and the smallness of the scale.”

Several 12-to-16 year olds showed a partial understanding of nano scale.

“It's really small. It's a 1/10 of something.”

“It's the study of smallness and is 1 billion, 700-million something.”

“They are in your body. You can't see them with your naked eye.”

There were also misconceptions among 8-to-11 year olds, such as:

“If you measure your height in nanometers you might see yourself as taller.”

Almost Half Learned Something about Nanotechnology
Almost one-half of visitors surveyed learned new things about nanotechnology research and applications. Another content goal for the exhibition was to show the sorts of nanotechnology research being conducted currently and to demonstrate the sorts of applications this research might lead to in the future. Of the 65 visitors who completed pre- and post-visit interviews, 43 percent (28) made comments that showed they had gained some understanding of nanotechnology research and its applications.

Understanding among 8-to-11 year olds was shown in comments that contained references to experiences with exhibits that featured research and applications. Typical comments included:

“Technology with really small things.”
“[Nanotechnology is] really small things you can mess around with.”
“Zoom In shows really small parts of things. [I] learned that one nanometer is 1 billionth of a meter. Ratty [an exhibit component]—needs to get right-sized holes for capsules.”

Some of the 8-to-11 year olds gained only partial understanding, however. Comments that show such misconceptions include:

“A little micro chip thing.”
“It helps you heal yourself. Helps kill bacteria.”
“[Nanotechnology is] something that helps you heal yourself.”
“To turn every day objects into better stuff that won't break as easy using nanotech.”

Some 12-to-16 year olds gained new understanding of nanotechnology and its applications. This is seen in comments like:

“Rearrange atoms and stuff.”
“[Nanotechnology will] help make little tools for medicine.”
“Very interesting, very tiny, could be important in tech advances.”
“Nano is small. [It is] a futuristic technology to invent new things.”
“Working with small things like atoms and molecules to make other products.”

Several 12-to-16 year olds showed a partial understanding in comments such as:

“Used in pants, might be used in watches.”
“Your glasses won't get dirty, cars won't break down.”
“Little gold wires, very small things that make things that are able to do things.”
“Nanotechnology wires—that some viruses stick to gold and some don't. If you mix the virus with another virus you get another virus.”

During mediated (on the spot) interviews, adult visitors were complimentary about the exhibition overall. Adult responses ranged from wonder and interest to precise understanding.
“Didn't seem to jive with anything. Whole thing made me want to get more information in a different way, something written. I am blown away by the gold wire. Who thinks of these things!? This was neat—sucked me [in].”

“[I learned from] the bios of scientists (solar cells). I am intrigued by the Nanowire information. I’m a doctor [and want to know more about] being able to diagnose things differently.”

“Interesting and understandable…[I learned] that [nanotechnology] can be used in every day life.”

“Using ultra small tools.”

“Technology that has to do with using really small things in science, medicine, electronics, almost anything.”

“Research and development of very tiny bits of matter that have varying uses. Variety of products—modifying clothing, obtain and use energy, medical uses.”

“Technology that incorporates moving and changing things at the molecular level.”

Promoting Public Understanding of Research

To what extent does the exhibition promote public understanding of research in advanced science and technology?

Visitors Exposed To Scientists

A primary educational goal of the NanoZone team was to introduce visitors to scientists as people and science as a career. Information on a select group of collaborating scientists, their childhood, and current work was present across the exhibition, particularly in technology and programs. A strength of the project was that the team worked closely with the four featured scientists, who supplied the life stories and details of their nanotechnology research around which much of the computer-based exhibits were developed. These scientists brought expertise in the areas of materials science, chemistry, education, bioengineering, mechanical engineering, molecular and cell biology.

Dr. Yalowitz’s review of the exhibition commended the development team’s effort to include real people in the visitor’s experience by talking about scientists. His review recognized that the computer-based interactive exhibits as well as the cards about the scientists allowed visitors to see who is working with nanotechnology and what they are doing. The visitor programs (floor demonstrations) also reinforced this point.

Changes to visitors’ understanding of who conducts nanotechnology and to visitors' general view of scientists were measured in two ways during the evaluation. The post-visit surveys \((n = 65)\) revealed that visitors had learned something new about nanotechnology scientists. Also, evaluators conducted 85 short pre-visit interviews to capture visitors’ perceptions of scientists before these visitors entered NanoZone. An additional 25 post-visit interviews were
conducted to explore what visitors learned about scientists (and from which exhibit), and whether the exhibition changed their view of scientists (and if so, how).

Modest Understanding of Nanotechnology Researchers

**A small number of visitors showed increased understanding of who conducts nanotechnology research.** About 11 percent of those surveyed (post-visit) made comments that showed that they had learned more about scientists. Those who learned about scientists said things such as:

“Science equals experiments.”

“Scientists use certain bacteria to get some things down to nano size.”


A teacher commented, “I noticed that the scientists are featured in the computers and also in the demonstration.”

Before visiting the exhibition, 100 percent of visitors surveyed said that anyone can be a scientist, but their views of what scientists were like tended to be based on popular-culture stereotypes. For example, 60 percent of boys and 40 percent of girls said that scientists wear a white lab coat; and an even number of boys and girls said that scientists were men. Three times as many boys as girls said that scientists wear glasses and were old.

During the pre-visit interviews Dr. Spencer spent time asking probing questions (based on responses to 20 visitors’ answers to earlier pre-visit interviews). He learned that many children age 8 to 11 initially answered with stereotypical responses, but on further questioning decided anyone could be a scientist, although these children knew that scientists “had to be smart and go to school for a long time.” A teenage girl said, “[Scientists] work very hard and smart.” Before using the exhibition, visitors generally had few specific answers to where scientists worked or what they did.

**The exhibition changed some visitors’ views of scientists.** Post-visit interviews with visitors showed that they enjoyed learning about scientists. Several upper-elementary students commented that they enjoyed learning about what the scientists had been like as children and “learning about what inspired them.”

Half of the visitors who were asked said that the NanoZone exhibition “changed their view of scientists.” When asked how NanoZone changed his view of scientists, a boy said, “I didn't know what most scientists even did.” A girl age 8 to 11 said, “I learned about nanotechnology. They work really hard. Now I know it. They have to do a lot of stuff with animals. I didn't know.” An adult commented, “Looking at a young kid interested in science made me realize how young the interest starts.” Other comments about scientists included:
“Scientists make computer chips, discover plant life, [protect] endangered animals, study dust particles. It would take you a year to explain it all. I don't know everything.” (Boy, age 8 to 11)

“[I now have an] understanding [of] what scientists are inspired by. People who study science mainly aid research and nanotechnology.” (Girl, age 8 to 11)

Some visitors still expressed stereotypical views after experiencing the exhibition, such as by suggesting that scientists were “old men wearing glasses or goggles.” The use of “lab coats” and “black boots” were popular responses, too. In post-visit interviews, boys ages 8 to 11 tended to give slightly more stereotypical descriptions of scientists than did females of the same age. Those aged 12 to 16 gave fewer stereotyped responses. The few adults (7) in the pre- and post-visit interviews offered stereotyped responses with a higher frequency than did teenagers. (Interestingly, the finding related to adults seems counterintuitive and does not support the idea that the exhibition changed adult visitors’ views of scientists. A larger sample would be required to draw a defensible conclusion.)

Evidence that visitors received the exhibition’s intended messages (as proposed by the development team) was conveyed in comments by some visitors. Several visitors of all ages characterized scientists as ordinary people: “He can look normal, or he can wear a white lab coat”; “A normal person”; “No different from normal person”; “Regular person”; “They are also teachers called professors”; and “They're all different. They wear glasses, some are dads.”

An understanding of what scientists do seemed to deepen. Most people in the post-visit survey said that scientists conduct research and discover or invent things. Upper-elementary students said that scientists do such things as “Study science stuff”; “Experiment and test stuff”; “Study things to help people understand”; and “Invent stuff to help people.”

Youths aged 12 to 16 had an even more sophisticated view of scientists. They said, for example, that scientists study “…different science, environment, chemicals, nature, and records” and “…science, nanotechnology, biology, cells, ecology.” These kids also said things such as “[Scientists] form hypotheses and theories and figure out if they are true” and “[Scientists] study things like nanotechnology.”

There was also evidence of a deepening understanding of where scientists work. When asked where scientists worked, “in a laboratory” was the most common response. Other answers included: “outdoors”; “ocean, on-site”; “they work in hospitals”; “classroom”; and “depends on what type and the work they do.” Only three people said that scientists work at a university. A teenager added, “They have to be funded by somebody.” All but three of the 25 visitors who participated in this post-visit interview recognized that scientists work together and collaborated.
At the end of the post-visit interview the evaluators asked, “Did you know this (information about scientists) before you got here?” Thirty percent of visitors said that they did not, implying that they learned about scientists during their NanoZone visit.

Little Understanding of Tools Scientists Use

**Only a small number of visitors surveyed identified that they had learned about the tools that scientists use to conduct nanotechnology research.** One of the content goals of the exhibition was to enhance visitors’ understanding of the tools that are used in nanotechnology research. Of the 65 visitors who responded to both the pre- and post-visit interviews, about 14 percent (9) clearly identified having gained some understanding of this.

Comments that indicated such increased understanding were, for example:

“[You can] only see them with tools, magnifying glass, and must zoom in to see things (with scopes).”

“[I learned about] magnification.”

“Bee stingers at Zoom In. [You] can focus in on different parts of the bee. I looked at the stinger—it was very sharp and could stick into you easily.”

**Relative Effectiveness of Different Exhibits**

**Exhibits and Programs Contributed Unequally**

Exhibits and programs contributed unequally to the overall effectiveness of the exhibition. An analysis of the post-visit interviews (n = 65) reveals an uneven pattern of exhibit effectiveness against the stated goals of the exhibition. Visitors were asked what topics they thought the exhibits were about. When a visitor responded, the evaluator asked, “Where in the exhibition did you learn about [topic]?” Visitors were prompted with “Anything else?” until they no longer gave any more topics. Computer-based exhibits and interactive components were mentioned most frequently followed by video. Non-interactive exhibits and programs were rarely mentioned.

**Where Visitors Said They Learned**

Table 4 shows, in rank order, how often visitors mentioned each exhibit or program in their responses about where they learned about the topics they identified. Table 5 shows this information summarized by type of exhibit or program. Visitors most frequently identified the interactive exhibits, both computer-based and physical, as the places where they learned about topics that were the themes of the exhibition. Videos were the next most-cited category, mentioned about half as often as the interactive exhibits. There were comparatively few mentions of the other (non-interactive) physical exhibits, programs, and demonstrations. The low count for programs might be explained by the fact that the programs ran only every hour and so some, perhaps many, visitors may not have even seen a program event or demonstration. The low count for the non-interactive physical exhibits may be due to the fact that these were often background components, such as the text on the displays, and were easily overlooked (or might be considered to be part of a larger exhibit). There is evidence
that at least two people did not notice that information was presented on the stools. There was other evidence that the distinctive “Scientist Collector Cards” were rarely used.

The point of the above observations is that in the colorful, noisy, and sometimes chaotic museum environment, visitors suffer from information overload and simply miss passive content.

<table>
<thead>
<tr>
<th>Ranking by most-often mentioned</th>
<th>Name of exhibit</th>
<th>Total times mentioned by visitors in post interview ($n = 65$; multiple responses were encouraged)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Measure Yourself (physical interactive)</td>
<td>28</td>
</tr>
<tr>
<td>2</td>
<td>Zoom In! (physical interactive)</td>
<td>22</td>
</tr>
<tr>
<td>3</td>
<td>What is Nanotechnology? (computer interactive)</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>Scientist Life Stories (computer interactive)</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>Challenge games (computer interactive)</td>
<td>14</td>
</tr>
<tr>
<td>6 (tie)</td>
<td>NanoMall (video)</td>
<td>10</td>
</tr>
<tr>
<td>6 (tie)</td>
<td>What the Heck is Nanotech? (video)</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>What the Heck is Nanotech? (physical)</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>Fact Fishing (computer interactive)</td>
<td>5</td>
</tr>
<tr>
<td>10 (tie)</td>
<td>Seeing Small (video)</td>
<td>4</td>
</tr>
<tr>
<td>10 (tie)</td>
<td>Look familiar? (physical interactive)</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>Nano Wire (program presentation)</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Biocapsule (program presentation)</td>
<td>2</td>
</tr>
<tr>
<td>14 (tie)</td>
<td>Scientist “Collector” Cards (physical interactive)</td>
<td>0</td>
</tr>
<tr>
<td>14 (tie)</td>
<td>Seeing Nano (program presentation)</td>
<td>0</td>
</tr>
<tr>
<td>14 (tie)</td>
<td>How Small (program)</td>
<td>0</td>
</tr>
<tr>
<td>14 (tie)</td>
<td>Size Wheel (program)</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4: Rank Order of How Often Visitors Mentioned Particular Exhibits and Programs as Locations Where they Learned Something New in the Exhibition
<table>
<thead>
<tr>
<th>Type of exhibit/program</th>
<th>Number of mentions by visitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer-based exhibits</td>
<td>57</td>
</tr>
<tr>
<td>Interactive physical exhibits</td>
<td>54</td>
</tr>
<tr>
<td>Video-based exhibits</td>
<td>24</td>
</tr>
<tr>
<td>Other physical exhibits</td>
<td>6</td>
</tr>
<tr>
<td>Programs/demonstrations</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 5 Summary of How Often Visitors Mentioned Different Types of Exhibits or Programs as Locations at Which They Learned Something New

Table 6 (next page) shows an analysis of how often visitors mentioned particular exhibits in relation to the content goals that were designed into the exhibitions. The color-coding of the cells shows those content areas that the project team had deemed of high, medium, or low emphasis for given exhibits. The analysis shows a fairly good match between the developers’ intentions and the actual outcomes as recounted by visitors. As shown in the previous tables, the interactive computer and physical hands-on exhibits did the best job of meeting their content goals, with videos doing a reasonable job, too. In conclusion, the interactive exhibits in NanoZone produced the most desired effects on visitors and were better aligned with the content goals than were the rest of the exhibition’s components. This indicates that those types of exhibits may be more likely to be successful for similar exhibitions seeking to present other leading-edge scientific concepts.

Visitors who said the exhibits were about nanotechnology said that they learned about nanotechnology at (in this order): “Zoom In,” “Measure Yourself,” “What is Nanotech,” and “Then and Now.” At least 5 percent of the visitors also cited “NanoMall,” the entry video, and “Ratty Game.”

Over 30 percent of visitors who said that the exhibits were about “nano size” learned about nano at “Measure Yourself.” “Zoom In” and the entry video were also frequent responses. Visitors said they learned about scientists at “Then and Now” and to a lesser extent at “Techno Heads,” “What the Heck is Nanotech?,” “Cow Game,” and “Fact Fishing.” Visitors learned about “other” things at “What is Nanotechnology?,” “Measure Yourself,” “Scientists Life Stories,” “Zoom In,” and (for one visitor) the “Biocapsule” program. Table 6 shows where people said they learned about a topic.
<table>
<thead>
<tr>
<th>Exhibit or Program Name</th>
<th>Size</th>
<th>Applications</th>
<th>Researchers as People</th>
<th>Tools: See and Do</th>
<th>Other</th>
<th>Total Times Mentioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive Physical Exhibits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure Yourself in Nanometers</td>
<td>12</td>
<td>13</td>
<td></td>
<td>3</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Zoom In</td>
<td>4</td>
<td>15</td>
<td></td>
<td>1</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Look Familiar?</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Other Physical Exhibits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What the Heck is Nanotech? (text/images)</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Scientist &quot;Collector&quot; Cards</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pull up a seat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Video-based exhibits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What the Heck is Nanotech?</td>
<td>4</td>
<td>6</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Seeing Small</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>NanoMall</td>
<td>2</td>
<td>8</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Programs/demonstrations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeing Nano</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>NanoWire Demonstration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Biocapsule Demonstration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Computer-based exhibits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientist Life Stories (x4)</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Fact Fishing (x4)</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Interactive Games (x3)</td>
<td>5</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>What is Nanotech</td>
<td>2</td>
<td>13</td>
<td>1</td>
<td>4</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>39</td>
<td>86</td>
<td>7</td>
<td>1</td>
<td>13</td>
<td>146</td>
</tr>
</tbody>
</table>

**Key to colors**

- **Grand total**

**Content-goal emphasis in this exhibit**

- **High**
- **Medium**
- **Low**

---

Table 6 Analysis of How Often Visitors Mentioned Particular Exhibits in Relation to the Exhibition Content Goals
Few Visitors Said That They Learned from Programs

Programs Rarely Mentioned in Exit Interviews

Few visitors cited the programs as an area in which they learned about topics. One explanation for this finding may be that programs ran only once every hour, so some visitors who participated in the pre- and post-visit interviews may not have even had an opportunity to view a program. Of the five programs, three were demonstrations: “Nanowire,” “Biocapsule,” and “Seeing Nano.” “How Small” and “Size Wheel” were guided hands-on activities.

Because “How Small” and “Size Wheel” were run intermittently in an adjacent room, the connection between the exhibition and these activities appeared tenuous. (Note: Although evidence was not collected, evaluators separately and independently observed a weak connection between “How Small,” “Size Wheel,” and the overall exhibition.) Three of the 65 visitors interviewed mentioned the “NanoWire” demonstration as a place where they learned about nanotechnology applications and two said that they learned something at the “Biocapsule” demonstration. Visitors did not mention “Seeing Nano,” “How Small,” or “Size Wheel.”

Children Rated Programs Slightly Lower than Did Adults

Visitors who attended programs were asked to complete a survey to rate the presentations, and evaluators independently reviewed presenters and topics. Ratings (using a three-point Likert-type scale) produced an average score slightly below two (three being the highest possible score and one the lowest possible score). The survey form asked people rate the programs on a wide variety of dimensions. Responses to individual questions were averaged across all presenters to produce the overall rating. Ratings varied widely by presenter. Children generally rated programs lower than did the adults. Evaluators’ independent reviews, like the visitors’, also rated programs slightly the mid-point rating on the same three-point Likert scale.

Advanced Topics More Interesting to Adults

Choice of program subjects suited adult visitors best. The programs team made a strong attempt to present the difficult topics of diabetes, cancer, and atomic-force microscope. Adult visitors said that they enjoyed, learned from, and “were fascinated” by those subjects’ presentations. The topics proved more challenging to upper-elementary students, however.

Throughout the exhibition overall the project team tried to select content that would be appropriate for their predominantly school-age audience. Although there were many positive outcomes from focusing on the cutting-edge research of particular scientists, it also led to programs presenting complex science, often related to medical topics.

An evaluator observed that the choice of adult topics was present in the interactive computer games as well. Ratty dealt with diabetes, and the cow game was very complex and dealt with sick cows and cantilevers—which few kids understood. Evaluators overheard several adults
comment about how difficult the content was in both the Ratty game and the cow game. Because of difficult topics, adults seemed to draw most from the program demonstrations. Visitor comments included:

“I don’t know why they chose cancer and diabetes as topics for kids. As a parent in my forties I’m fascinated—but my kids weren’t really interested.”

“The subjects were way too complex for my class. They required too much background information. The kids had to sit through a ten-minute introduction to the biochemistry behind diabetes before they got to the nano device. I watched carefully and the only one engaged was that boy in the front row. He is my best student and has an IQ of about 200. The rest of the kids were fidgety and having hard time following along. It would be great for eighth graders.”– A teacher in a post-program interview

Rough and Unfinished Props
Several adult visitors, evaluators and members of the NanoZone team staff commented that the props seemed rough and unfinished. A mother commented, “I thought the ‘Biocapsule’ demonstration was pretty cheap. There was a scrubby-type thing like you use for dishwashing filled with rice or something and you could see the antigens or whatever leaking out. I was not impressed.”

NanoZone team members commented:

“I thought that they would go back and make more-sturdy props for a more-consistent look and feel so that they would look like they’re from the same exhibit.”

“Programs never made more-hardened versions of the demonstration pieces. That’s an area where we could grow if we had it to do over again.”

Unfinished props are mentioned here as a significant observation, but not because visitors necessarily learned less from a demonstration with homemade-looking props. Unfinished props are mentioned because, during two formative evaluation site visits in October 2003 and March 2004, evaluators presented visitors’ complaints about rough props and stressed that using prototype props in a finished exhibition did not meet the national standards normally associated with an NSF-sponsored initiative. The props did not appear to change in the one year from October 2003 until the summative visit in November 2004.

In the interest of fairness, following the site visit an evaluator asked rhetorically “Were there were legitimate reasons such as lack of budget, time, or expertise that prevented the programs team from honoring visitor’s complaints about rough props? Was the intent of using simple props to make it clear that even kids can do science?”
Programs Let Visitors Interact with Staff
Dr. Yalowitz observed the programs to provide the teams with a third-party professional review. He commented that the “visitor programs allowed users to learn much in-depth information about a relevant nanotechnology topic. They also gave the visitor a chance to interact with a staff member. This kind of experience is more fluid than exhibits since, to a certain extent, the presenter can change the focus of a presentation based on the interests and composition of the audience.”

Quality of Presenters Varied
The quality of program presentations varied. A challenge faced by NanoZone and other projects that use live demonstrations is that each presenter’s knowledge and presentation skills are different from those of other presenters. The LHS staff member in charge of developing the programs and training the presenters was also the exhibition’s primary presenter. An experienced professional, his presentation skills were powerful and polished. An adult leaving one of his presentations commented, “I just saw the most amazing presentation. It made the whole thing incredibly clear.”

Other presenters were work-study students from UC–Berkeley. A challenge mentioned by the program staff was the short tenure of work-study students, which required a continual cycle of recruiting and training. The presenters all received personalized training and had ample opportunity to practice before presenting to a live audience.

Training Received Good Reviews from Presenters
Presenters were interviewed about their training program. A presenter commented, “Yeah—the training was good. [The lead presenter] worked with me one-on-one until I felt confident. I thought he did a good job.”

Use of Projection Camera and PowerPoint Slides Mixed
The relative inexperience of some student presenters showed through on occasions. For instance, evaluators observed that some presenters didn’t use the projection camera at all while others were inconsistent and seemed unpracticed in their use of the camera. Some presenters were not facile in their use of the PowerPoint slides.

Some PowerPoint Slides Complex
Some presentations involved PowerPoint slides to show complex diagrams. During formative evaluation visits in October 2003 and March 2004 the evaluators strongly suggested that simplifying the diagrams would help presenters and visitors alike. The slides did not appear to change in the one year from October 2003 until the summative visit in November 2004.
Experimentation

How Has the Team Been Experimental?
In what ways has the team been experimental in its approach to using new media to present emerging and cutting-edge research through informal science?

The project team made a strong effort to work collaboratively and to produce an exhibition that was based on clear content goals. The team produced several innovative approaches to presenting complex scientific content to a mainly young audience. Although the NanoZone exhibition occupied a fairly small space, it featured a range of exhibits that used a variety of media such as text labels, three-dimensional hands-on interactive displays, interactive computers, and live programs to deliver information about nanotechnology. Innovation and experimentation was seen in the physical, computer-based, and video-based exhibits, as well as in the programs area. As one might expect, some new ideas worked better than others. One common factor was that those exhibits which underwent several rounds of user testing were generally more successful than the others.

Experimentation with New Media in Physical Exhibits

Experimentation with new media was seen in the physical exhibits. “Zoom In!” stands out as one interactive physical exhibit that typified the innovative use of different media and iterative evaluation, and which was quite successful as an exhibit. “Zoom In!” was innovative in how it combined a hands-on physical exhibit with a computer-based display. The interface was extremely challenging to develop. Visitors were very confused and critical of the interface during the first two rounds of formative testing. Thereafter the exhibits and technology team worked together to successfully develop an interface considerably more intuitive than what was initially proposed.

An 8-to-11 year old boy using “Zoom In” repeatedly said, “Oh, cool. Wow! Ohh! [You can] see things, like bugs. Look at it. Cool. Wow!” In a mediated interview this boy said, “Zoom In [was about] the texture of things. About science. [They] wanted kids to learn how to see things close up.”

The “Scientist Collector Cards” were an experiment to present facts from the featured scientists’ life stories in a non-computer-based format. Developed in response to kids’ interest in trading cards (established during formative evaluation), the large format and text-heavy presentation were not attractive to most children. One evaluator saw a nine-year-old sit for ten minutes and carefully read each card. A second evaluator observed an adult read several cards at one time and compare cards against each other. Still, the more-frequent observation is represented by a visiting girl about whom an observer wrote: “Looks bored as mother reads, but then gets more interested, but only temporarily.”

An innovative approach to providing unity to the exhibition and tying together the exhibits using diverse media was to use a magazine theme throughout the exhibition. The large entry exhibit was like the cover of a magazine and the other exhibits’ graphics, layout, and colors also related to the magazine theme. That approach achieved the result of presenting NanoZone as a unified exhibition and was visually attractive. The largest panels were
successful in that they drew attention to the exhibition. However, the text toward the top of the large panels was far above most people’s sight line, which may have reduced the chances that visitors actually read it. A member of the NanoZone team felt that the concept of a life-size walk-in magazine did not prove as engaging as had been hoped. Visitors did not readily identify that it was themed like a magazine. Once prompted, a nine-year-old boy commented, “That’s a magazine? Oh, yeah, I see it now.” Whether the magazine theme was actually successful points to the central challenge of finding content that appeals to a fifth-grader. It also questions the need for a large anchor exhibit (entry point) to introduce advanced technology. Anchor exhibits are a staple of exhibit development for hands-on topics, and square feet is a traditional measure of the breadth of an exhibition. However, the generally decentralized design of NanoZone and its comparatively small space requirement in many ways proved very effective for introducing content and concept-heavy new technology. Two questions remain to be answered: Are large anchor exhibits needed for exhibitions that present new technology when several small, integrated exhibits already provide ample content and hands-on/minds-on activities? Does the emerging reality of multimedia on the museum floor reduce the total square feet expected of a comprehensive exhibition?

**Experimentation in Computer-based Exhibits**

**There was much experimentation in the computer-based exhibits.** The most innovative exhibit in the NanoZone exhibition was “What is Nanotechnology?” This computer-based exhibit made use of an experimental technology that has not, to our knowledge, ever been used in a museum setting. It used proprietary software called “TechnoHeads” that uses artificial-intelligence search algorithms to find appropriate answers to visitors’ questions. At first the project staff struggled to find the best use of the software and was frustrated by the failure of some early versions of the manufacturer’s software. The team then tried two versions of an exhibit and eventually developed an interface that was easy for visitors to use regardless of their typing or spelling skills. That effort produced a high success rate in successfully answering visitor questions. As shown in Figure 5, the ability of the system to answer questions was improved considerably relative to the experimental, early versions.

Those improvements were due to the team’s consistently evaluating the exhibit, reviewing the visitor questions actually posed, and adding new answers to the database. During the three-day summative evaluation the system answered 90 percent of almost 1,100 valid questions asked by visitors.

Another exhibit that explored the advantages of computer-based media was the interactive exhibit collectively called “Who’s in the NanoZone?” This computer-based interactive exhibit incorporated three main activities: scientist life stories, the fact-fishing games, and the challenge games. If considered as one exhibit, it was the exhibit most mentioned by visitors as the place where they learned the most about the content presented by the exhibition (37 mentions in 65 interviews). “Who’s in the NanoZone?” was experimental in several ways. It used a slide-like presentation of cartoon-like images with narration to present the life stories and work of four scientists. During formative evaluation those proved to be appealing to young and older visitors alike.
For “Fact Fishing” and “Challenge,” the exhibits used the attractive power of an electronic game-like format to hold visitor attention and present some serious concepts in a stimulating way. These games went through many iterations before the summative evaluation. During formative evaluation, evaluators noted that many visitors used the games in this exhibit before listening to the life stories of the scientists, as the following observation illustrates:

“Didn't read story—went straight to game.”—Unobtrusive observation of visitor using Cow Game

In the early versions of “Fact Fishing” and the “Challenge” games, this behavior posed a potential problem, since most of the content material needed to successfully answer the questions or address the challenge were in the life stories. While dwell times suggest that the games held visitor interest, it is doubtful that they learned any content during the early stages of the project from using this part of the exhibit. Over time, however, developers added features to the games that gave visitors exposure to content that was similar to that in the life stories. For example, in “Fact Fishing,” when a visitor answered a question incorrectly, a window popped up with relevant content information that visitors could read.

The holding power of this exhibition was very strong; dwell times of ten to fifteen minutes were not unusual. However, there is still ample room to fine-tune this type of exhibit so that students do not simply play the games before acquiring the knowledge they need to fully understand the challenge and content of the game. For instance, the game could be built around a progression of learning-playing-learning. This would allow the user to learn the content and have a fun experience almost simultaneously.
Experimentation in Use of Video

There was experimental use of video as a medium to convey nanotechnology topics. The exhibition featured three different videos (Entry Video, SEM Video and Nanotechnology Ads [More like a cartoon or animation than traditional video]), each with a different style and mode of presentation. The documentary format of the SEM video (a middle-age scientist talking about and demonstrating the workings of an SEM) was relatively quick and inexpensive to deploy. According to visitors, however, it was less compelling than the other videos, and tracking showed that it was used less than was the entry video.

The entry video, an original production, was praised and consistently used by visitors. Producing it was expensive, however, as it involved staff time, outside vendors, and production costs. Nevertheless, that money was well spent as everyone involved contributed to making a significant improvement between the video’s initial draft and its final version.

Arguments for using video to explain technology or introduce scientific tools can go either way. For instance, original productions tend to be expensive and time consuming and may not be cost-effective in the long run. On the other hand, in the Edu, Inc. summative study of *It’s a NanoWorld*, an exhibition hosted at Disney’s Innoventions at Epcot®, it was reported...
that a children’s video on nanotechnology received strong praise from the small number of visitors who used it.

**Experimentation with Portable Media**

Some Success Developing Portable Media

There was some success in producing exhibits that use “portable media.” A stated goal of the Windows on Research project was to “evaluate different media to translate the leading edge of nanotechnology research for the science-center audience.”

“Portable media” is a term coined by evaluators to describe media and methods that are easily adapted or “ported” to similar yet distinct projects from those for which they were initially developed. (For instance, perhaps an exhibit designed to present nanotechnology concepts could be easily modified to present, for example, new information on string theory.) During classroom-based front-end research, several rounds of public focus groups, and formative evaluation, the project team tested several methods to communicate leading-edge research content. This section summarizes the team’s effort to develop portable media—that is, techniques using new media and exhibits to present nanotechnology or other cutting-edge research.

For the purpose of this report, to be defined as portable a medium must meet three criteria: (1) effectively deliver content (in the present case, nanotechnology); (2) possess the ability to easily substitute one new technology for another (in the present case, nanotechnology for something else); and (3) be affordable and easily used by the average informal science-exhibition development team.

The NanoZone exhibits that showed promise as portable media are discussed below.

Interactive Computer Games as Portable Media

**Interactive computer-based games served as a portable media.** NanoZone developed three distinctive interactive games based on the research areas of three of the four featured scientists, proving that this is a highly adaptable platform. Education design requires specialized expertise in designing educational media, which the ScienceView team at LHS possessed. In addition, the team members had experience as scientists, too. Not all informal science institutions would have this expertise available in-house, but could engage contractors to work on such exhibits.

Video Projection as Portable Media

Video projection provided a low-cost alternative to create a “big screen” display of content. Content for the NanoMall video was produced using computer-generated cartoon-like characters, which avoided the costs generally incurred with professionally shot video and postproduction treatments.

Billboards and Wall Space as Portable Media

Using posters and other large displays is a time-proven technique used by teen marketers in malls and movie theaters. The cost of developing such materials is within the reach of most development teams that have access to a talented graphic artist and education specialist.
Including areas in the exhibition to post content in an advertising format is a low-cost way to display or announce information that can later be updated. For example, the NanoZone team created the NanoMall, an area with colorful advertisement for nanotechnology-related projects aimed at youth. The NanoMall billboard and wall space provide museum managers with the option of updating content to reflect new advances in research just as an advertiser updates ads to reflect new products or ad campaigns.

Media-assisted Live Demonstrations as Portable Media

After considering the experience of the NanoZone programs team, live demonstrations with professional or student presenters proved to be a relatively inexpensive media to engage visitors and encourage one-on-one interaction between visitors and staff. Efficacy depends on the relevance of the subject, the quality of props and supporting media, and the abilities and training of the presenters.

Interpretive Strategy Enhances Portable Media

The unified look and feel of NanoZone provided a professional appearance. The “What the Heck is Nanotech?” teen-magazine theme cut across exhibits, games, web, and print. Visitors, staff members, and evaluators all commented on the obvious impact of the exhibition components speaking with a unified voice. A well-planned and intentional interpretive strategy appeared to promote the success of portable media.

Professional Science Writer for Kids Unifies Portable Media

Hiring a science-content writer resulted in having a unified style for all the exhibits’ content. Exhibit staff members commented, “If we started again from square one, we would have a design director to handle things down to the same font. [The content writer] wasn’t put into place early enough, and needed to be a budget item.” In staff interviews all project teams independently and profusely praised the efficacy of the science writer.

Experimentation Results in a Successful Template

Overall, the general approach to conveying leading-edge scientific research to an informal science-education audience was successful. The NanoZone exhibition presents information in ways that should increase the likelihood of promoting public understanding of new research:

1. Using multi-media, hands-on, and interactive exhibits;
2. Incorporating live programs that go in-depth into select content areas;
3. Facilitating discussions of cutting-edge research, with a particular focus on scientists; and
4. Using familiar themes and objects to make complex information accessible.

Those four approaches may be considered as one template for explaining new research to the public. Using familiar themes or personally relevant information is especially important in providing an easy-to-understand context for that new research. It provides visitors with a starting point from which they may learn more about a topic. Finding and presenting common themes would be one way to do this, but being able to personalize the presentation of information would also be effective. Certain elements, such as the live programs and exhibits like the computer-based “What is Nanotechnology?” and the physical, hands-on
“Measure Yourself in Nanometers” allowed for interactivity and relevancy for the visitor. Additionally, including life-story information on actual researchers was a good step as it personalized science in a way that doesn’t happen when you simply talk about concepts and processes.

In his external review Dr. Yalowitz suggested, “Certain elements, such as the multi-media hands-on experiences and live programs, should help promote understanding of new research. These types of experiences allow for more in-depth addressing of topics, which is necessary to explain a more abstract topic like nanotechnology. Since visitors may not have much prior experience with nanotechnology (or another new technology), the use of familiar themes and objects (e.g., flies, denim, and cancer) should help contextualize nanotechnology (or another new technology) and make it more accessible.”

These approaches should increase the likelihood that visitors will be interested in and, hopefully, learn about the new research being discussed. Testing with visitors should ultimately determine whether the project has been successful in promoting public understanding.

Programs were Experimental but Faced Difficult Challenges

There was experimentation in the programs offered. The programs team faced a complex and daunting task—not only to create programs, but also experiment with models for developing content-rich programs to introduce complex leading-edge technology. Programs had to be scientifically accurate, fun, exciting, and relevant to upper-elementary students.

The Director of Floor Programs had a clear and innovative vision for creating an immersive program environment to help visitors “have a visceral experience” of the realm of nanotechnology. It was agreed during formative evaluation that programs and live demonstrations had the potential to be the voice of the exhibition, presenting concepts and contents while cross marketing—drawing visitors’ attention to related content and experiences in other areas of the exhibition. The program team considered, discussed, and experimented with several concepts ranging from a planetarium-type experience of ultra small to an activity that allowed visitors to experience a progression of diminishing scale worthy of a Disney or Universal Studios production.

The person initially responsible for creating programs, a graduate student in education at UC–Berkeley, left the project nine months after it had begun. Program development then fell to a new staff member who had no prior exposure to the project and started three months later. As such, the new person entered the project without having the advantage of the full two years of thinking and development enjoyed by the exhibits and technology directors. This observation is meant only to point out the challenge of recruiting and retaining talented, like-minded professionals.

In the final analysis the task of creating a single blockbuster event proved incredibly challenging and beyond the budget and available time set aside for this project. The resulting three demonstration programs did, however, make creative use of a big-screen display to
support the demonstrations together with a projection camera so that visitors could see small demonstrations on the big-screen display.

The big-screen TV, situated in the NanoZone exhibition area, was turned off for 50 minutes of each hour. Those unused 50 minutes could have been an ideal vehicle to passively present additional content or information. This finding does not conflict with the recommendation for more hands-on exhibits. Rather, it suggests that the big-screen television could have at least displayed a schedule of the program presentations so that visitors knew what was coming up next and when. At best, it was an ideal vehicle to present “content bytes”—small pieces of information about nanotechnology. That expensive big-screen television, a luxury for many museums, provided an opportunity to experiment with portability—to explore a medium that could present nanotechnology content and be easily adapted to present another cutting-edge technology. Regrettably, that opportunity passed without being realized.

Overall, the program media proved flexible and adaptable. The choice of live demonstrations meant that new programs could be added as new nanotechnology research is conducted.

**Consider Mediation to Help Visitors Learn**

Mediation is ultimately important to help museum visitors understand new technology. Learning about new technology requires prerequisite content knowledge that many visitors do not have. For example, understanding a simple definition of nanotechnology requires learning or recalling the terms nano, nanotechnology, atom, and molecule. Then learners must stretch their minds to imagine the sub-visible realm, size, and scale of nano science. They must discover or remember that there exists a job called “research scientist”—people whose job it is to develop new technology. In the formative evaluation stages, it was noted that young visitors seemed to benefit when a parent, teacher, or other adult acted as a mediator, pointing out the salient parts of exhibits, helping youngsters understand the challenges of the interactive exhibits, and summarizing new information.

**Ultra Accessibility for the Disabled—a Partially Realized Opportunity**

The Americans with Disabilities Act (ADA) says that museum exhibits must be accessible to visitors with hearing, motor, and visual impairments. Crane et al. remind us that changes in exhibits to meet ADA requirements “are highly likely to benefit other adult visitors…and children.”

The exhibits team made a strong and appropriate effort to make the exhibits accessible for those in wheelchairs and those with limited dexterity. Videos had closed captioning and several computer games had audio components. The exhibits met basic accessibility requirements. For example, “Measure Yourself” was ingeniously engineered for those in wheelchairs. The exhibition was inaccessible for blind visitors, however.

The team invited a disability specialist from the Berkeley Center for Independent Living to inspect the exhibit. This person made several recommendations communicated through the evaluator and in a separate interview documented by a programs assistant. The accessibility consultant’s most basic suggestion was to incorporate signs with the international disability symbol to invite those with disabilities to request staff assistance.
Program developers were encouraged to revise scripts to be descriptive for blind visitors and to create demonstrations accessible to those who cannot hear. Admittedly, this is a difficult challenge that requires outside expertise. It did not happen.

The issue of ultra accessibility is raised because accessibility is a complex issue requiring specific expertise and coordination, especially in a collaborative effort of three separate teams. The NanoZone team showed strong initial interest in creating an ultra-accessible exhibition, but the effort was not carried to full fruition in the final exhibition. A future possibility is a central person with the assigned role of ensuring accessibility for as many types of disabilities as possible across the exhibition. A direct report to the principal investigator or project manager could be considered.

**Collaboration**

**Internal Collaboration – Conversations with the Windows on Research Teams**

**Collaboration – Opportunity and Challenge**

A central aspect of the Windows on Research project was collaboration between three departments at the Lawrence Hall of Science. As with any partnership, the collaborative produced success and difficulties emerged.

The teams were experimental in their efforts to discover new ways to communicate leading-edge technology. The collaboration provided visitors with exposure to content and team members learned from the sometimes pleasant, sometimes difficult marriage.

The collaboration forced teams to work together and learn from each other, examine the best way to structure an interdepartmental collaboration and acquire project management skills. The teams discovered differences in their philosophies, culture, and appetite for innovation and tolerance of risk.

The National Science Foundation’s investment in the Windows on Research project resulted in completion of the task at hand, the NanoZone exhibition, and provided longitudinal growth of individual team members and future partnerships within the Lawrence Hall of Science.

**Three Cultures**

In describing the development of the Global Digital Museum software project, Gay, Reiger and Martin\(^4\) (1999) explore the negotiation that takes place when diverse groups come together to collaborate on a common project. They posit that each group has unique characteristics and its own understanding of what makes a digital environment educationally useful, and those beliefs have to be accommodated in the final product.
Like the Global Digital Museum, NanoZone was a research prototype and brought to light the complex challenges that developers face when different professional cultures intersect. Windows on Research represents the first multi-year collaboration among three distinct departments within the Lawrence Hall of Science: exhibits, programs, and technology (ScienceView). The departments each have their own culture, work style, demographic profile, and expertise.

This section documents the process of internal collaboration from the perspective of the collaborators. Exhibit, program, and technology team members discussed the success and challenge of having three Lawrence Hall of Science teams working together to produce NanoZone. Evaluators conducted a separate interview with each team. Team interviews lasted 60 to 90 minutes, with different combinations of evaluators conducting each interview. Evaluators also held an individual interview with Dr. Marco Molinaro, the Principal Investigator for the Windows on Research project.

The following summary presents common issues raised by the teams as a whole or by individual team members. This section uses representative quotes to summarize the interview responses and to present the teams’ experiences and insights. Except when needed for emphasis or clarity, the speaker or their department is not mentioned. This section presents evidence of collaboration through the voices of the interviewees.

**Understanding of the project goals**
Dr. Molinaro, the Principal Investigator, offered this overview: “There are different types of goals. There is a content set, a collaborative set, and there’s an overarching set, which is best conveyed as, ‘which is best described as being experimental in our approach, taking risks.’”

**Interpreting Research vs. Content**
All departments generally agreed on the goals for the Windows on Research project. Some perceived the goal as interpreting cutting-edge research; for others, the goal was to educate specifically about nanotechnology.

“The global goal is to present a window into emerging science.”

“Figure out how to best communicate the latest research to the public.”

For most staff members the goal of the project was not about presenting the latest research but rather to present specific content to museum visitors. For example:

“To attract/engage the public in nanotechnology.”

“To produce exhibits around nanotechnology.”

“To bring awareness and understanding of nanotechnology to the public.”

Other comments about content included showing “the idea of sub-visible size and scale,” “the concept of the nanometer,” and “the relevant nanotechnology applications.”
Scientists as People
Each group interviewed said that a goal of the project was to bring a human face to science research. “[Our goal was] presenting to the general public the concept of scientists as people and communicating what scientists do and who the scientists are.” Or simply, “to provide a bridge between scientists and the public.”

Create a Model for the Field
A goal of the project was to create portable education technique that could communicate leading-edge research in topics other than nanotechnology. An interviewee commented:

“Another goal—this entire experience that LHS has had should be used as a model for other groups in developing exhibits on emerging science. It shows the methods by which people can get new science up on the floor quickly.”

Experimentation and Collaboration
Each group said that a goal of the project was to be experimental in testing new ways to show the public nanotechnology.

“This was an experiment. The experimentation was really the product, as opposed to the actual physical/media exhibits.”

“This was an experiment of LHS employees’ ability to work together in a new way; an experiment of working with scientists to convey their research. The collaboration among the different museums was an experiment. The NanoZone exhibition was a by-product.”

“This experiment asked, “How can a science center work with scientists to convey their research?” “How can it collaborate with other science centers around the country?,” and “What’s the best way to share information about cutting-edge research to a wider public”

Were the project goals obtained?

Interpreting Research
Exhibits staff members said that it is a challenge to interpret cutting-edge research through hands-on experiences. The paradox is that hands-on activities are needed to engage visitors, but nanotechnology is hard to illustrate using hands-on activities. While some staff felt multimedia worked well to introduce scientists and technology, others complained that multimedia games lack a kinetic experience.

“It’s hard to keep the manipulatives in new science, but they’re critically important to keeping people engaged.” (The term manipulatives refers to hands-on exhibits Editor)

“We learned that some things work well—multimedia games work well, scientists as people is consistently interesting.”
“You can not neglect kinetic experiences in the mix of experiences. That can get lost in the media exhibits.”

“It is very hard to come up with a 3-D piece to talk about technology. But you’ll lose people if you don’t have those physical experiences.”

Content
In general, the teams felt that the exhibition successfully communicated content, as this quote illustrates:

“The content goals seem to be relatively well attained.”

A couple of interviewees said that visitors need quick and clear background information to understand nanotechnology (and other new science):

“The concept of stepping people up will need work.” (“Stepping people up” refers to helping people quickly understand background information needed to understand nanotechnology.)

“One of the challenges of creating exhibits to teach new research is the need to give people pre-requisite concept. This is not exclusive to nanotechnology. It also applies to other new research.”

Some of those interviewed strongly recommended the use of staff members to help visitors quickly understand new technology. This observation supports the role of mediation in helping visitors understand difficult content.

“Staff interaction gives people opportunities to learn quickly. [Visitors have] their preferred way of learning. Some prefer working alone, others like working with people.”

Scientists as People
Many staff members did not meet the scientists that they were portraying, and commented on the difficulty of creating presentations about their work. One person commented, “It was hard to establish a relationship, to have access to them, and to get information out of them.” Dr. Molinaro pointed out that since the majority of the primary pieces that dealt with scientists were produced by the technology team, the technology designers had the most contact with the scientists. He noted that, “With the new Gecko exhibit, everyone involved is meeting with the scientists as this is a more hands-on, low tech exhibit.”

Those who did not meet the scientists thought it would have been helpful if they had the opportunity:
“It would have been nice to meet the scientists and get to know them before we translated their information.”

Some staff members offered recommendations to others who might try to use a similar approach in designing an exhibition about cutting-edge research:

“I would tell the field to be prepared that scientists don’t have a lot of time. Think of ways to make it meaningful to them and of ways to expedite the process for them.”

“I would try to establish a local scientist base.”

Arun Majumadar, a featured scientist, said that he was “Happy to help.” He complimented a staff member on “not using much of my time.” He added, “I’m pleased to serve as a role model.”

Dr. Majumadar offered these recommendations for the future: “Nanotechnology is interdisciplinary. Instead of featuring individuals, you should focus on the team of scientists. You should also feature graduate students. They do all the work and they are closer in age to the target audience.” (Note: Coe Leta Finke reports that The Fab Lab, an exhibit/technology developed during the no-cost extension, does exactly this).

A second scientist said that the quality of interaction with LHS was “very good. I was happy to be approached and pleased to contribute because I believe in the mission of making nanotechnology accessible to the public.”

Create a Model for the Field

All of the teams suggested that any model for the field must address collaboration and a consistent look and feel among teams. Three very similar quotes below are presented for emphasis.

“Consistency on the floor is an issue. It needs to look like one group worked on the entire exhibit, not that three different groups came in and put their work on the floor.”

“Consistency of presentation across all disciplines in the exhibit is important. We needed an overall design eye on all the exhibits. There was no one person who controlled all design oversight for each piece.”

“The visitor experience will be more consistent if there’s a uniform look and feel; visitors will understand that the exhibits, programs, and technology are all part of the same exhibition.”

Despite their efforts to create a model for the field, all staff members cited cultural differences and different work styles as major challenges among the three teams. The teams also had to adjust to the differences between their respective media (e.g., difference between developing exhibits and developing technology). These differences initially resulted in an inconsistent look and feel among prototype exhibits, technology interfaces, and program
props. The project leaders, to their credit, eventually hired a science writer to create a uniform message, reading level, and tone. Despite these improvements, however, one team member concluded,

“We’ve given the field a push and a nice background, but we haven’t yet reached the goal [of creating a model for the field].”

Experimentation

The team member’s perceptions of experimentation varied.

“The goal of being experimental was a partially attained goal.”

“We made inroads in experimenting with how to present cutting-edge research but I don’t feel the visitor has a deep understanding when they leave.”

“I love things we tested that didn’t work that we shared with colleagues.”

One aspect of experimentation was developing techniques to present content using real-life examples appropriate to a fifth grader. Several people expressed concern over the limited success of finding relevant examples of nanotechnology that a fifth grader would find interesting.

“This team’s experience was that presenting the consumer application of the new technology didn’t really appear until the end of the project.”

“Relevancy is the huge issue to presenting current research.”

(Note: As more nanotechnology-based products reach market, relevant applications may be easier to present).

How effective do you think the collaboration was in meeting the goals of the project? What issues emerged relative to the collaborative effort?

Dr. Molinaro provided this overview:

“There were levels of collaboration. There was internal collaboration among staff members, external collaboration with the scientists, and further collaboration with external partners like science-museum professionals and the media.”

“Internal collaboration went beyond exhibits, programs, and technology teams. It included collaboration with administrative teams and with the evaluators—both internal and external evaluators. Also, it included the school groups and teachers and general visitors who helped us test the prototypes.”
**Ideal Team**
The creation of educational electronic environments, especially in museums, requires the participation of technical, content/curatorial, design, and education professionals. The ideal educational software team has six main team members: education specialist, technology specialist, content specialist, copyright and intellectual-property specialists, and evaluation specialist. The NanoZone team’s experience suggests that museum exhibitions, especially those mixing exhibits, technology, and programs, require a science writer and a design coordinator as well.

**Copywriter**
The teams unanimously stressed the positive and unifying role of the science copywriter. “Deb Rose was the final copywriter. She takes the technical copy and writes it in a way that’s age appropriate.”

There was consensus across all groups:

“You need a copywriter to create a uniform presentation, especially when you’re working with multiple input sources (e.g., a collaborative). It’s a skill to be able to write for the floor.”

“Deb Rose unified the voice and made sure that the language was appropriate for the audience. She made the messages for the public more understandable. At first I didn’t realize the value of that—a unified voice.”

“The copywriter also wrangles content and kept track of where it was and how complete it was. [The copywriter] had a very specific defined role and wasn’t part of any one group and was able to look at everything.”

“Deb, the editor, was key in promoting dialogue and consistent content.”

“Deb brought cross-dialogue across the departments. She was very effective.”

**Design Expertise**
A staff member suggested that future projects consider a Design Director to unify design decisions across the three teams in the collaborative.

“I wish we had had a design person in a parallel role [like what Deb Rose accomplished for the writing and content]. A design director to handle things from overall look and feel down to using the same font wasn’t put into place early enough. It needed to be a budgetable item.”

**Evaluation**
A project of this scale and complexity benefits from constant contact with teachers, museum visitors and curriculum experts. On a regular basis, internal evaluators provided the
exhibition developers with a reality check of visitor wants and needs and provided contact with outside education experts.

The external evaluators feel that the project benefited substantially from the presence of Ann Barter, an internal evaluator and doctoral candidate at UC–Berkeley, and LHS staff also commented about the value of her contribution. The internal-evaluation work of Coe Leta Finke, a doctoral candidate in Education at UC–Berkeley, was also a positive influence, according to staff members who complimented her contributions.

According to many team members, the evaluation process, both internal and external, contributed to the collaboration:

“All the teams got exposure to making prototypes and being evaluated.”

“I learned a lot working with the internal evaluation team.”

“The external evaluators provided an essential outside checks and balance. If the funding didn’t require outside evaluators, we probably wouldn’t have had them.”

“For many people at LHS, this was their first time working with an outside evaluator.”

**Content Expertise**

Content expertise in nanotechnology centered on Dr. Darrell Porcello, a scientist and media designer and Dr. Molinaro, the principal investigator. Team members commented about the value of having content experts available for collaboration, as these quotes illustrate:

“Darrell and Marco were primarily where the content knowledge resided. I feel like there was good collaboration getting the content expressed and worked on in between Darrell and Marco and the rest of the group.”

“In some of the floor demonstration there was also quite a bit of information that took advantage of the content skills of people on the technology team.”

**Management**

The evaluators feel that the project benefited from adapting a private-sector project management system from Lucas Arts, a Marin County video-game development company. The system involved setting milestones and tasks for each of the three project teams. Several points emerged from staff discussion of the project management structure ranging from team structure and leadership models to professional development and the model transferring to other projects at LHS.

“The big professional development opportunity I got with this project was going to Lucas Arts and seeing how they manage their three-year game-development process—which is what we modified to lead this group. That was very strong professional development.”
“The Lucas Arts [management plan] has transferred to other projects in the Hall.”

“I liked the milestone structure. Each team identified their goals, but there was flex so each department could work as it needed to.”

“This project named group leaders that met in addition to whole-group meetings. All this was planned at the beginning of the project.”

**Dedicated Manager**

In retrospect, several team members, leaders, and the principal investigator spoke in favor of hiring a dedicated project manager to oversee logistics, operation, and production schedules.

Several ideas came out of discussion of the many roles of a manager. These include the need for a leader and keeper of the vision, a neutral mediator to ensure equity between teams, a skilled project manager, and someone to offer reflection on time spent in meetings.

“I’m not debating the wisdom in collaboration, but in practice the collaboration worked best when a strong mediator was in place.”

“All three departments were very invested in themselves. There really needs to be one person that quickly disperses any disagreements.”

“One thing I would do different—I would like an intermediary who represented all three teams to keep things organized, goals intact, agenda moving forward. It would be efficient to have that.”

“The difficulty, the complexity in this project is that we didn’t have a (full-time) unified project manager for the whole project.”

“In a collaborative effort, management needs a firm hand or the ideas of what people are doing shift.”

“Marco was from the technology group–and he was always very careful not to favor technology groups. I respect that.”

“I would suggest a project-manager position that determines production schedules for all three groups. Need someone not vested in a single group. There was no budget set aside for that person, but it might have helped.”

Dr. Molinaro said, “[For the future] I would suggest an independent project manager because I think it is more realistic and keeps the vision focused. I would also caution, depending on how a project is structured internally, that might be a difficult thing to achieve. Unless you took someone in from the outside, they all already had a home base.” He indicated that having a home base weakens a manager’s influence over other divisions.”
“We did spend a lot of time in meetings. Some were effective, like when they were getting at the heart of what the exhibit would focus on.”

“While it was tiresome in meetings we got to listen to everyone’s point of view about how they’d tackle that program. Those difficult meetings were rich with learning.”

**Role of the Principal Investigator**

Dr. Molinaro defined his role of Principal Investigator as, “carrying the overall vision of the project.” He observed, “My role somewhat shifted over the three years. Overall, especially initially, it was getting groups together, developing a common thread for us to work together, developing a language, making sure the vision of the project was kept going, really urging experimentation in the project. I was urging collaboration, facilitating experimentation.”

He continued, “I was also pushing the content. There was a tendency to go very simple on the content and so I feel like my role was keeping some science in the content. I played that role a lot in the first year and half.”

Dr. Molinaro also maintained the relationship with the funding agency. “External relationships were all me.”

Several people, including Dr. Molinaro, suggested that the ideal PI should “be more focused on the vision and the ways in which the vision can be achieved, rather than on all of the intricate political and people issues.”

**Collaboration Promoted Redundant Messages**

The evaluators urged the project to develop conceptual redundancy to ensure that key messages and concepts are repeated across the exhibition. This effort resulted in collaboration and a concentrated effort between teams to achieve unified messages.

“I think the collaborative was pretty effective, which is evident in the redundancy seen in all the components—the exhibits, the technology components (all the scientists in each of the components), and the programs.”

“[The redundant messages] reinforced the knowledge that people were getting; more in-depth.”

“The collaborative improved the consistency of the exhibition. It encouraged redundancy, which was helpful to the visitor, and promoted the cohesiveness of the overall experience of nanotechnology.”

“One of the paramount goals of a museum-education project is to promote a high-quality visitor experience. It took a lot of discussion and time getting the team up to speed on the visitor experience. You need knowledge of the public, and how the different modalities work for museum visitors. People came around to understanding visitor experience and now are invested in the visitor experience.”
**Different Cultures and Communication**

During each interview the subject of differing cultures and communication surfaced. Although employed by the same museum, NanoZone was the first time many of the team members worked together. Important issues emerged —cross-team dynamics, relationships between new co-workers, differing priorities and production schedules, and communication.

A salient point for future projects considering a collaborative venture is a collaborative community that results and this community may range between highly functional to highly dysfunctional. According to LHS staff, clear shared expectations and an honest and critical assessment of partners appears to increase the likelihood of successfully working together.

“We got to know each other much, much better, we got to understand each others’ processes much, much better.”

“Structure, respect, and communication were of utmost importance.”

Each team mentioned that working with different production schedules was an issue. An interviewee said:

“Time takes a different scale for each department.”

Interviewees made several additional time-related comments. To paraphrase: Different departments work on different timelines. The exhibits team had a long-view fixed-production schedule. The technology team had the luxury of rapid prototyping and testing. Those working on floor programs traditionally have a long development window. Because of the need to develop and test activities, scripts, and props, and to train presenters, the program team could not easily propose changes once decisions were made regarding subject and content.

Several people raised communication as an issue.

“Communication felt like a big problem.”

“Remind yourself that the way one group may do things may not line up with another group’s efforts.”

“I would warn people that there may be a lot of frustrations about how things should go. [In our experience] those expectations that were not met weren’t communicated.”

“Meeting notes that documented goals, who is doing what, timelines, etc, were helpful. The group has to agree on a method of communication.”
**Internal Website**

The team was led by technologists at Science View who built a robust internal website used to communicate project progress, document meetings, and focus on internal evaluation. The website documents the history of the project and offers a digital record of the experiments—both successful and not. The evaluation section provides clear educational objectives for each component and the steps taken to evaluate them.

Staff comments about the usefulness of the website varied from enthusiastic to faint praise. As expected, tech-savvy team members were the most supportive.

> “Have you seen the website? It has photos and descriptions of all prototypes.”

> “They had planned to share information over their internal website but that didn’t work. Not everybody was comfortable with getting information that way. They did try very hard to set up a process for communicating and sharing ideas.”

**What effects do you think resulted from the collaboration?**

Even in large museums staff and departments may be isolated from each other. The exhibit designers may or may not have regular contact with technology designers who may rarely interact with floor programs or education staff and so forth. According to staff, this collaboration provided each team access to other teams. Members say they gained more knowledge and experience collaborating that they would have not gained working in isolation.

> “This project started the culture of collaboration. All players needed to learn how to work together.”

> “We learned a lot about how each of the other teams works.”

> “An effect of the collaborative was bringing to light a whole series of issues about what it takes to make a collaborative work.”

> “Showing new technology research was new to us. We were working with new people and a new subject, and we were asked to present new research. That made for a big challenge.”

> “The difficulty of the topic increases the challenge of the collaboration if the collaborators have never worked together.”

**Were there any areas where the collaborative was not effective?**

All four interviews mentioned the development of programs as a challenge and a learning experience in terms of cross-team communication, culture, and expectations. The programs team had a vision for programs based on an immersing “visceral environment.” The ideas were creative and innovative, but proved beyond the budget and available time.
“Until [programs] got into development, they didn’t realize how difficult it would be. I would warn other people considering such collaboration that they’re going to have to spend a lot more money on content to get people up to date.”

“[Programs] didn’t budget it that way [to develop a visceral environment] in the beginning because they didn’t know what they’d be developing.”

“It’s not that they [programs] didn’t address some things, but that their initial demos didn’t work and so they had to make a choice to work on the things that worked.”

People commented about the program team’s role on the project:

“At the beginning, floor programs were not on equal footing with the other components, and what they had to do wasn’t a priority in the eyes of the other members of the collaboration. Because of the evaluation feedback, it prompted a change of perception and brought floor programs closer to equal footing.”

“It took time during the project for the other two teams to appreciate the expertise of the floor programs.”

Here are paraphrases of multiple comments about differing culture and communication. The integration— and in some cases lack of integration— between floor programs and the other teams provides a useful lesson in the difficulty and complexity of maintaining communication and bridging different ethos.

• It was not clear whether [programs] would be getting help from other teams.

• Our team wanted to help them, but it wasn’t clear that they wanted help.

• It was a difficult match—a young, fast moving, and innovative technology team with an older and more established programs area.

• One of the barriers that the collaboration came up against was the culture of innovation versus a culture of tradition.

• The ability of a collaborative to be successful relies on partnering young, creative, experimental, and open-minded staff members with experienced, mature, and sometimes more-conservative staff members while allowing equal voice in conveying their ideas to a leader group.

• It is important not to underestimate the power of the existing political structure of the organization to promote or inhibit experimentation, or to dampen or enhance the effect of the collaborative.
Science View came to understand the floor programs team, what its aims and thinking were. Creative media was able to help some of the presentation components. It was an enhancement, a push into new territory.

Did the collaboration have any effect on you professionally?

Without exception staff reported, often enthusiastically, positive professional development resulting from the collaboration. Themes include learning how other departments develop their respective product (exhibits, programs and technology); how to work within a collaborative; understanding evaluation; and exposure to other museums and museum professionals through Association of Science and Technology Centers (ASTC).

“Yes. I learned a lot more about how media was developed.”

“I have a better understanding of all the new issues that come up trying to do something with so many partners.”

“Yeah! It had big impact. I gained practical experience to make exhibits with kids.”

“I learned a lot about the evaluation process from what Ann did. That’s an area of interest for me.”

“Doing the project has definitely helped me develop professionally.”

“I learned a ton.”

“Just going to ASTC and communicating with other people in similar situations was a huge professional development impact. I got to talk to their leaders and see different models.”

“Trying to work and set up a collaborative with the Boston Museum of Science and the Science Museum of Minnesota— that was a very strong professional development opportunity because I got to see how these different groups handle it, and even if it could work, and to see how these different groups handle these types of things, what they do.”

Did collaboration extend to other projects?

Interviewees offered examples of how the NanoZone collaborative has or will extend to other projects within the Lawrence Hall of Science. Active collaboration between exhibits and technology was mentioned frequently. The exhibits team suggested that multimedia is a new reality on the museum floor and a new resource for exhibit developers. The programs team suggested that the collaborative opened communication, making future partnerships more likely.
“The exhibits and technology teams are going on with the hands-on universe project and this is going well. The technology group is much more incorporated into the Hall [LHS]. With the floor programs I can’t think of any examples.”

“Not collaborating is not an option. Multimedia is part of the exhibit experience now. There is a structure and pace of development required now because of the field. Multimedia is what’s expected and what works and is the current reality of the field.”

“The channels of communication have been opened. If a project falls in my lap and I have challenges, I’m more likely to seek help with technology or exhibits.”

**Portability—What lessons did you learn about creating methods that could communicate content for other cutting-edge research topics?**

During front-end and formative evaluation the team tried, tested, and discarded several approaches to creating a kid-friendly vehicle to communicate nanotechnology that could be easily adapted to another cutting-edge technology. The team settled on a teen-magazine format. To guide the project the team commissioned Edu, Inc. to conduct focus groups with target-age students to test magazine formats, teen models, and advertising strategies. Edu, Inc. also interviewed children’s librarians.

Interviewee comments suggest two significant challenges—developing exciting and relevant examples of a new technology and developing a dynamic interactive medium to present content. Staff expressed some satisfaction with creative strategies such as advertising and a simulated mall. The teams suggested that the marriage of technology and exhibits offers benefits in developing techniques to communicate new technology.

“We struggled with a metaphor or physical analogy to hook elementary or middle-school children into technology, in this case nanotechnology.”

“The concept of ‘advertising’ as a way to distribute content is interesting.”

“If I had to do it again, I’d focus more on the NanoMall.”

“While the magazine format gave the group a hook to hang their design on, the idea of the magazine as a structure that they were walking into didn’t work as well as we had hoped. The magazine format didn’t add or register to many people. I don’t feel that the structure is so compelling that other museums would want to adapt it. However, it did pop, and had color, and was kid-friendly.”

“The back page was more graspable and more real and introduced nanotechnology in the context of a kid’s life.”

“The magazine was a convenient construct to include articles and more information. It worked okay, but [may not be] the best way to exhibit current research.”
“[Interpreting nanotechnology means] building an exhibition about things you can’t see that haven’t happened yet.”

“The topic was challenging and not comfortably suited for kinetic experiences. I worry that others putting new science on the floor in any topic will encounter the same issue.”

“I learned that it’s a distinct professional expertise, designing multimedia for the museum floor.”

“The things like integrating the ad wall into the overall look. There was good creativity on the arts side that matched the creativity we were coming up with on the technology side.”

**Final Statements**
At the close of interviews some people made final statements on practical tips on team organization and project management. Two representational statements are below.

“Know who your teams are and define the leadership very clearly to make a decision group. Make sure that the leaders of the groups have a shared vision and understanding of the approach that will be taken to complete the project. If your hierarchy allows it, have one person as day-to-day project manager over all the teams and let the principal investigator focus on the vision.”

“I would favor fewer people [working on the project] at higher percentages of time rather than a smaller number at a smaller percentage of time. You can have slivers for small jobs like editing.”

**Overall Conclusions**
In general, interviewees said that they benefited from the numerous opportunities presented by the collaboration. The teams agreed on the project outcomes and felt they achieved their goal of exposing the public to new research. Interviewees focused considerable attention on professional development and the process of the collaborative. The experience forced each team to work with other departments, learn the realities faced by different departments and how they approach and schedule their work.

Individuals within each team said that they grew as professionals and acquired working relationships with other departments that they would apply to future projects. Many staff members said that they learned about prototyping and benefited from working with internal and external evaluators.

The teams suggested a dedicated project manager, a designer and copywriter independent of any team. They suggest the role of the PI concentrate on external relations and keeping the project vision alive and growing.
Project management using private sector practices was successful. Communications across professional culture and between staff of different age were recurring themes. A balance between innovation and tradition were suggested.

The challenges of developing portable media and finding techniques “to best communicate the latest research to the public” proved difficult. NanoZone struggled with finding relevant examples and exciting hands-on exhibits to communicate the complex content of nanotechnology. The team was highly experimental and innovative to the project’s end. They had success with projection, use of media and use of advertising techniques as portable media. Two examples of computer-based exhibits that took innovative approaches were the What is Nanotech exhibit and the “Who’s in the NanoZone” exhibit.

In sum, the collaboration, while sometimes challenging, enabled staff members to interact with each other in new ways that helped expand their experience and changed the way they interact with departments within their own museum.
Appendices

Appendix A Evaluation Instruments

Pre-visit and Post-visit Survey

PRE VISIT SURVEY - Script: We are trying to understand what people think about this exhibition. I want to ask for your help. I have five short questions now. This will take about 30 seconds. When you are done we will do a short interview that lasts about three minutes. Will you help?

<table>
<thead>
<tr>
<th>Visitor ID</th>
<th>Date (circle):</th>
<th>Nov 9</th>
<th>Nov 10</th>
<th>Nov 11</th>
<th>Gender (circle):</th>
<th>Female</th>
<th>Male</th>
<th>Time:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age: (circle):</td>
<td>&lt; 7</td>
<td>8-11</td>
<td>12-16</td>
<td>17-21</td>
<td>22-28</td>
<td>29-39</td>
<td>40-60</td>
</tr>
</tbody>
</table>

1) What does a scientist look like?

Check all that apply

- Anyone
- Young
- White lab coat
- Old
- Usually a man
- All ages
- Women are scientists
- Other:

2) What does a scientist do?

- Research
- Discover or invent things
- Solve problems
- Help people
- Other:

3) Some scientists work with really small things… What is the smallest thing you can think of?

- Quark
- Atom
- Electron
- Molecule
- Proton
- Other: (enter response)
- Neutron
- Other: (enter response)

4) What does the word nano mean to you?

- Nanosecond
- A unit of measure
- Small/Tiny
- 10^-9
- Really really small or tiny
- Other: (enter response)
- Neutron
- Other: (enter response)
5) Have you heard the term nanotechnology? (Circle) Y / N IF YES GO TO # 6
IF NO, GO TO END

6) How would you explain nanotechnology to someone else who knows nothing about it?

When you have looked around the exhibition, please come back to me so that I can ask you a few more questions.
POST VISIT “Now that you’ve had a chance to look at the exhibits can I ask you a few more questions?”

What do you think these exhibits are about?

<table>
<thead>
<tr>
<th>Response Order</th>
<th>Concept Area</th>
<th>Exhibit Code</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N  Nano, micro, macro (size and scale) [nanometer, micrometer, millimeter]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Where in the exhibition did you learn about nano/size?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What did you learn about nano/size?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How would you describe nano/size in your own words?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NT  Nanotechnology (applications)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Where in the exhibition did you learn about nanotechnology?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What did you learn about nanotechnology?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How would you describe nanotechnology in your own words?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A  Atoms, molecules or cells (Basic science)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Where in the exhibition did you learn about atoms, molecules or cells?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What did you learn about atoms, molecules or cells?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How would you describe (atoms, molecules or cells) in your own words?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S  Scientists and research</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Where in the exhibition did you learn about scientists?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What did you learn about scientists?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How would you describe scientists in your own words?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T  Tools scientists use (SEM, Microscope, AFM)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Where in the exhibition did you learn about tools scientists use?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What did you learn about tools scientists use?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How would you describe tools scientists use in your own words?</td>
<td></td>
</tr>
</tbody>
</table>
Other (describe)

Where in the exhibition did you learn about other?
What did you learn about other?

How would you describe other in your own words?
Scientist Interview

Script: We are talking to people to see what they can tell us about scientists. Could I ask you a few short questions? This will take about two minutes.

Date (circle): Nov 9 Nov 10 Nov 11 Gender (circle): Female Male Time:
Age: (circle): < 7 8-11 12-16 17-21 22-28 29-39 40-60 > 60

1. What does a scientist look like?

<table>
<thead>
<tr>
<th>Check all that apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anyone</td>
</tr>
<tr>
<td>White lab coat</td>
</tr>
<tr>
<td>Usually a man</td>
</tr>
<tr>
<td>Women are scientists</td>
</tr>
</tbody>
</table>

2. What can you tell me about their work?
Where do they work?
- In a lab
- At a university
- Work for companies
- Work for the government
- Other:

What kind of work do they do?
- Research
- Discover or invent things
- Solve problems
- Help people
- Other:

Do they work alone or together?
- Work alone
- Collaborate
- Other:

3. Did you learn about scientists in this exhibition?
Where did you learn about them?

<table>
<thead>
<tr>
<th>Exhibits</th>
<th>Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry/Video</td>
<td>Nanowire Demonstration</td>
</tr>
<tr>
<td>Zoom In</td>
<td>Biocapsule Demonstration</td>
</tr>
<tr>
<td>ESEM Video</td>
<td>Seeing Nano</td>
</tr>
<tr>
<td>Measure Yourself</td>
<td>How Small is That</td>
</tr>
<tr>
<td>What the Heck</td>
<td>Size Wheel</td>
</tr>
<tr>
<td>WITWIT Doors</td>
<td></td>
</tr>
<tr>
<td>Scientist Cards</td>
<td></td>
</tr>
</tbody>
</table>

Technology
- Techo Heads
- Then and Now
- Fact Fish
- Ratty Game
- Cow Game
- Angela Game

4. Did this exhibition change your view of scientists? Y / N In what way?
Unobtrusive Observation and Mediated Interview

The purpose of this interview is to observe and document the degree to which visitors are attracted to and engaged by exhibits and technology.

<table>
<thead>
<tr>
<th>Date (circle):</th>
<th>Nov 9</th>
<th>Nov 10</th>
<th>Nov 11</th>
<th>Gender (circle):</th>
<th>Female</th>
<th>Male</th>
<th>~ Time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age: (circle):</td>
<td>&lt;7</td>
<td>8-11</td>
<td>12-16</td>
<td>17-21</td>
<td>22-35</td>
<td>36-50</td>
<td>50+</td>
</tr>
</tbody>
</table>

Exhibit or Technology Name:

**OBSERVATION**

*Affect* (Which of the following emotions, if any, do visitors show as they use the exhibit or technology? Check multiple values. Note your observations and impressions.)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Pleasure</td>
<td>☐ Neutral affect</td>
<td></td>
</tr>
<tr>
<td>☐ Displeasure</td>
<td>☐ Surprise</td>
<td></td>
</tr>
<tr>
<td>☐ Frustration</td>
<td>☐ Intrigue and/or interest</td>
<td></td>
</tr>
</tbody>
</table>

*Exploration* (Do visitors show any evidence of inquiry-like behavior as they use the exhibit or technology?)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ Questioning</td>
<td>☐ Attempting to produce multiple outcomes</td>
<td></td>
</tr>
<tr>
<td>☐ Repeated use</td>
<td>☐ Multiple visits</td>
<td></td>
</tr>
<tr>
<td>☐ Problem solving behavior</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INTERVIEW**

*Script:* We are evaluating this exhibit to be sure it is easy for people to use. Could I ask you a few questions? This will take about two minutes. You can stop at any time.

*INVITATION/NAVIGATION* (Can the visitor use the exhibit or technology as intended?)

*Possible questions:* What does this exhibit do? –or– What are you supposed to at this exhibit? –or– Can you show me how to work the exhibit? –or– Is there anything you find confusing or unclear?

*CONCEPTUAL UNDERSTANDING* (What is the visitor’s understanding or perception of the exhibit or technology?)

*Possible questions:* What is this exhibit about? –or– What subject in school could this exhibit help teach? –or– What do you think that the people who built this exhibit wanted you to learn? – or– Tell me in your own words what this exhibit is about.
Programs Instruments

Children’s Post-program Survey

Program Name: 
I am ______ years old

Circle I am a GIRL     BOY

Please circle the best answer

1  I could hear what the speaker said.     Always   Sometimes   Never
2  The speaker used words that I knew.     Always   Sometimes   Never
3  The speaker invited people to ask questions. Always   Sometimes   Never
4  The speaker asked questions.     Always   Sometimes   Never
5  The speaker used the video screen.     Always   Sometimes   Never
6  The demonstration made it easy to understand TOPIC  Always   Sometimes   Never
7  The speaker told us about other places in NanoZone where we could learn about TOPIC Always   Sometimes   Never

8  In your own words what was the program about?

FOLLOW-UP INTERVIEW WITH RANDOM SELECTION OF RESPONDENTS

9  Did you learn anything new?
Tell me more.
**Adult Post-program Survey**

Program Name: 

Please circle - My age is 17-21  22-28  29-39  40-60  60+

Circle I am Female  Male  

<table>
<thead>
<tr>
<th></th>
<th>Please circle the best answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I could hear what the speaker said.</td>
</tr>
<tr>
<td>2</td>
<td>The speaker used words that I knew.</td>
</tr>
<tr>
<td>3</td>
<td>The speaker invited people to ask questions.</td>
</tr>
<tr>
<td>4</td>
<td>The speaker asked questions.</td>
</tr>
<tr>
<td>5</td>
<td>The speaker used the video screen.</td>
</tr>
<tr>
<td>6</td>
<td>The demonstration made it easy to understand TOPIC</td>
</tr>
<tr>
<td>7</td>
<td>The speaker told us about other places in NanoZone where we could learn about TOPIC</td>
</tr>
</tbody>
</table>

8 In your own words what was the program about?

9 Did you learn anything new?

Tell me more.
Evaluators’ Program Review

This form records the evaluator’s subjective review of a program

<table>
<thead>
<tr>
<th>Program Name:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluator:</td>
<td>Time:</td>
</tr>
<tr>
<td>Presenter's Name:</td>
<td></td>
</tr>
</tbody>
</table>

**Education**
- Material was presented at an appropriate grade level
- The presentation was jargon free
- New vocabulary was defined and explained
- Key content was presented multiple times

0

**Presentation**
- The speaker could be heard
- The speaker encouraged visitors to ask questions and interact
- The speaker made appropriate use of support technology
- The speaker used words that visitors knew
- The demonstration made it easy to understand TOPIC
- Script directs visitors to related content in the exhibition

0

**Accessibility**
- Narrative was accessible for disabled visitors who cannot see or cannot hear

0

**Cumulative Average**

0

**Cumulative Score**

0
**Presenters’ Review of Training**

Note: Evaluators interviewed presenters record responses on a 3 point Likert Scale

*This form rates the presenter's perception of their training as a presenter*

<table>
<thead>
<tr>
<th>Presenter's name</th>
<th>Evaluator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modules trained in</td>
<td>Date</td>
</tr>
<tr>
<td>Trainer</td>
<td></td>
</tr>
</tbody>
</table>

We were allowed to evaluate and make suggestions on improving the training sessions
We were encouraged to make good use of support technology
We were trained in techniques to ensure narrative is accessible for disabled visitors who cannot see or cannot hear
We were encouraged to direct visitors to related content in the exhibition
We were trained to explain and reinforce new content and vocabulary multiple times
We had the opportunity to practice presentations multiple times without fear of embarrassment
I could see and review my own presentation on video
I had the opportunity for peer review by other presenters
There was formal evaluation to determine when I was ready to present in front of visitors
There is written documentation of who has completed training and is qualified in what module
Training is repeatable by other trainers
Is the training designed so that some one other than the person who trained you could do the training?
Over all I rate training as  (3 = Best; 1 = Worst)
Staff Interviews on Internal Collaboration

Questions for Collaborative Interview with LHS Staff

We are interested in learning about your experience working as one team in a three-team collaboration within LHS to build the exhibition.

We are documenting the collaborative experience between the LHS teams to help the National Science Foundation learn what worked and did not work. This will help NSF think about the advantages and disadvantages of funding future collaboratives.

Nothing that you say will be attributed to you personally without your permission.

1. In your own words, what is your understanding of the goal of the NanoZone project? Was this goal attained?

2. What was your team's part in the project?

3. How effective do you think the collaboration was in achieving the goals for the project?
   **Probing questions**
   - Why do you say that?
   - What examples can you give to support your view?

Effect of the Collaboration
4. What effects do you think resulted from the collaboration?
   **Probing questions**
   - For example, in terms of the quality of the exhibits?
   - What examples can you give?
   - Can you give any examples of disadvantages or negative effects?

5. Did the collaboration have any impact on you professionally?
   **Probing questions**
   - If so, what impact did it have?
   - If not, why did it not impact you?

Future Plans
6. Will the collaboration be extended to other projects within LHS? Why or why not?

7. If such a collaborative project were to be done in the future at LHS or another museum, what advice would you give to those involved?
References


5 Spencer, D. and Angelotti, V. (June 2004). “It’s a NanoWorld—a summative study.” A report to the National Science Foundation. Arlington, VA.


