Windows on Research

Front-End Research

Evaluating Museum Visitors’ Readiness for and Interest in Learning New Science

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Executive Summary

Edu, Inc., presents a brief summary of information on youth and adults’ readiness to learn about and their interest in science research.

Citing four information sources, Edu presents six principles to guide the development of exhibits, programs, and technology. Research carried out by the Windows on Research (WOR) team; Edu, Inc.; and the *It’s a NanoWorld* project at Cornell University show the following.

Based on WOR, Edu and Cornell surveys, most people are unfamiliar with the term “nano” and few know anything about nanotechnology. About half have difficulty defining the terms “atom” and “cell.” People use taglines to explain DNA.

Children learn based on their personal experiences and, of course, most children have no experience with what they cannot see or have not seen.

Museum visitors need help crossing the mental bridge from the macro world to the micro world.

Most people are interested in learning about new scientific discoveries, and many of these people get their information about science discoveries from reading, popular media, and the Internet.

A primary lesson learned by the Cornell *It’s a NanoWorld* team is not to overestimate visitors’ understanding of science. Edu encourages the WOR team to realize that as scientists and science museum professionals, they have advanced knowledge of science and nanotechnology.

Many museum visitors may have weak science skills and little exposure to nanotechnology. The challenge is to develop programs and exhibits that educate and inform an audience by understanding the audiences’ limitations and potential, and by “meeting learners as they are.”
Contents

OVERVIEW 1

AUDIENCE 1

INFORMATION SOURCES 1

USING INFORMATION 2

GUIDING PRINCIPLES 2

Nano Literacy 2

Principle One: Many museum visitors have a limited ability to articulate the science needed to understand current nanotechnology research. 2

Some Scientists Assume People Know “Nano” 3

Many People Do Not Know 3

Molecular Self Assembly 3

The AFM Experience 4

Why the AFM Did Not Work: Learners Learn from Prior Experience 4

The SEM Experience 4

High-Risk Exhibits: AFM and SEM Lessons Learned 5

Nano-Literacy Challenge 5

Known Experiences 5

Principle Two: Children learn based on known experiences and physical senses 5

Macro-Micro-Nano Bridge 6

Principle Three: People surveyed need help building and crossing the Macro-Micro-Nano bridge 6

Understanding “Nano” 6

Principle Four: Many people do not understand the concept of nano 6

Interest in New Science 7

Principle Five: People surveyed are interested in new science especially as it relates to improving their lives 7

Where Do You Learn about Science? 7

Principal Six: People surveyed get information about new science from popular media, publications and the Internet. 7

What Do You Know about “Nano” and “Small”? 8

ABOUT THE AUDIENCE 8

Prior Science Learning 9
Overview
The Windows on Research (WOR) team is conducting front-end research to create effective, engaging exhibits, programs, and technology. WOR’s research has four broad objectives:

1. Determine museum visitors’ ability to articulate the science needed to understand current research, especially that of upper-elementary and middle-school students.
2. Determine the public’s interest in current scientific research.
3. Determine how people surveyed currently learn about new science discoveries.
4. Determine potential visitors’ interest in how research happens, and research as a career.

Audience
Lawrence Hall of Science (LHS) identified three audiences for its WOR exhibits, programs, and technology components:

1. Secondary students and teachers (grades 4—8) who visit the museum on school-sponsored field trips;
2. Children (grades 4 and higher) and their families who visit the museum; and
3. Learners at a distance who will use WOR web-based technology components

Information Sources
The team is using four sources of information to learn about the general public’s understanding of research and science. This information will inform the design of exhibits, programs, and technology components.

1. WOR “nano” and “size surveys”. In a combined effort, the WOR team and Edu, Inc., used surveys to investigate teens’ and adults' understanding of the science of small things. The survey populations included museum visitors and non-visitors.

   WOR administered 27 “nano” surveys and 28 “size” surveys at LHS and public areas of Berkeley, California. Edu administered 60 “nano” and 60 “size” surveys. Edu sampled a mix of urban, suburban, and rural respondents in five diverse locations in upstate New York. The Edu sample comprised two-thirds non-museum visitors and one-third museum visitors.

2. “Where do you get your information?” surveys. Edu and WOR are conducting surveys of teens and adults to determine their interest in new science and from what sources respondents learn about new science. Edu included questions on where people get science information on the “nano” survey.

3. Activity-based focus groups. Edu is developing and testing “Amazing Science”—activity-based focus groups for upper-elementary and middle-school children. Focus groups will be held at LHS in February 2003 and will investigate these three areas:
a. Youth understanding of the microscopic world (aka - the “science of small”);
b. Youth interest in research and new science; and
c. Where youth get information about new science.

4. Cornell University’s *It’s a NanoWorld* research and experience. In 2001 and 2002, Edu and researchers from Cornell University sponsored focus groups to investigate early elementary kids’ and adults’ understanding of nanobiotechnology. Edu led focus groups with over 300 early elementary students in Florida and New York. Edu and Cornell combined to: (1) lead teacher focus groups on the challenge of teaching about elementary science; and (2) interview expert advisors in early elementary education.

*It’s a NanoWorld* is a museum exhibition for early elementary children sponsored by an NSF-funded program at the Nanobiotechnology Center at Cornell University.

**Using Information**

Edu proposes a three-step process to use research data to enhance WOR exhibits, programs, and technology:

1. Distill guiding principles from research data;

2. As needed, re-articulate WOR goals and refine current prototype exhibits and programs in light of guiding principles and audience input during formative research; and

3. Create web-based storyboards to test new exhibit and program ideas with kids, teachers, and experts prior to investing in and developing further exhibits or programs.

**Guiding Principles**

**Nano Literacy**

**Principle One: Many museum visitors have a limited ability to articulate the science needed to understand current nanotechnology research.**

Like computer literacy, nano literacy implies having basic information needed to understand nanotechnology. To understand and be conversant about how a personal computer works requires an understanding of the most basic underlying concepts of computer science (e.g., hardware, software, and Internet).

Similarly, understanding nanotechnology and its applications requires fluency in basic scientific principles (e.g., atoms, cells, DNA). Understanding nanotechnology means understanding the concept of nano.

The majority of people surveyed were not nano literate. Most students and adults surveyed do not understand nano; that is, they have not heard of or have misconceptions about...

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nanotechnology. Moreover, they have a shaky grasp on “nano-cepts”, the prerequisite concepts needed to understand nanotechnology (i.e., atoms, molecules, DNA, cells).

The NanoWorld team’s experience with prototypes of early exhibits dramatically showed that many museum visitors do not understand cells, DNA, and the scale of the microscopic world. Visitors’ ability to understand nanotechnology depends on understanding the science on which that technology is built.

**Some Scientists Assume People Know “Nano”**

Many scientists are highly nano literate. They exhibit a justifiable excitement and enthusiasm about sharing with the public news about the latest breakthroughs and accomplishments in nanotechnology.

Such scientists have an advanced knowledge of technology and are fluent in the concepts needed to appreciate nanotechnology. Some of these experts, however, mistakenly assume that all museum visitors also some level of “nano” and science literacy.

**Many People Do Not Know**

WOR and Cornell surveys clearly show that many members of the public are not nano-literate, and that some have gross misconceptions about what “nano” means. For instance, most people have no mental image of what $10^{-9}$ means. The majority of people surveyed initially had difficulty articulating concepts of atoms, molecules, and cells.

For many adults, especially those without college-level science, the microscopic world is shrouded in the fog of nearly forgotten science. The world smaller than a cell is often uncharted mental territory.

Prior to grade five many children have limited exposure to science learning. Early elementary classes, depending on state and district, often focus more on skill-based reading and writing and less on content-based science and history. Many elementary-school teachers have weak science skills. Students in grades seven and eight are more likely than younger students to have working mental images of cells. They are often more able to articulate the concepts of a microscopic world. Hence, these children may have an easier time understanding nanotechnology than do some adults.

**Bottom line: the WOR team should not assume science literacy in students or adult visitors. To build a public understanding of research, WOR may consider as one measurable outcome helping learners to become nano-literate.**

**Molecular Self Assembly**

An example. Appreciating molecular self-assembly requires nano-literacy. Self-assembly means understanding at minimum four nano-cepts: Nano, nanotechnology, nanofabrication and molecule. If learners can not easily articulate what a molecule is, do not know what “nano” means, and have never heard of or misunderstand nanotechnology, they cannot understand nanofabrication. No fundamental understanding of nanofabrication means not having an appreciation of molecular self-assembly.
The AFM Experience

To help visitors understand the tools of nanotechnology the exhibit team for *It’s a NanoWorld* prototyped several versions of an interactive hands-on model Atomic Force Microscope (AFM).

The concept proved too advanced. Visitors did not understand the technology. Adults did not “get it,” and elementary-school students were lost and confused. Numerous attempts and revisions showed that an AFM required too much background knowledge for visitors to understand its principles. During evaluation, even when the exhibit concept was explained to visitors, many still did not comprehend it.

Why the AFM Did Not Work: Learners Learn from Prior Experience

Visitors had no experience or frame of reference with which to appreciate an AFM. Many visitors, adults and children alike, had never used a conventional microscope. Some children, even those in middle–elementary grades, confused a microscope with a telescope. The majority of visitors had no mental image of an atom. This meant they could not appreciate a technology that “provided a picture of an atom.”

An exhibit developer tried using a diving board to model the spring-cantilever mechanism. While it was a fun activity, a diving board is symbolic and middle-elementary students are literal. Their learning is based on prior experiences. None had experienced the cantilever mechanism of an AFM.

Others have suggested using the analogy of a phonograph needle to model the semiconductor tip of an AFM. But a generation of young visitors who only know music through CD and MP3 technology lack the phonograph frame of reference.

Understandably, it was difficult for exhibit developers to let go of their advanced (yet fun) ideas in favor of simpler concepts that visitors could understand and enjoy.

The SEM Experience

The *It’s a NanoWorld* research showed that second and third graders were very interested in Scanning Electron Microscope (SEM) micrographs of common objects, especially when they saw micrographs next to normal-scale photos. They also enjoyed guessing what the object in a SEM micrograph was and then seeing if they were correct.

When asked “How do scientists take these pictures?” children either could not answer or suggested a camera on a very powerful conventional microscope. They listened attentively as researchers showed them a picture and introduced an SEM. Children specifically said they “liked the pictures” but thought that actually seeing a SEM in a museum “would be really boring.” When asked why, they replied: “It doesn’t do anything”, “It just sits there”, and “It just doesn’t sound fun.”
High-Risk Exhibits: AFM and SEM Lessons Learned

Expecting visitors to understand advanced scientific equipment through unmediated exhibits is asking a lot. It is setting up many visitors to fail. Interpreting advanced equipment in a fun and interactive way is a difficult, time-consuming assignment for exhibit developers and a risky investment for the sponsor. Any team considering including artifacts like advanced equipment must carefully consider: (1) the return on development investment and (2) the likelihood of successfully engaging and educating visitors.

Modeling advanced-technology tools through exhibits is much like a neurologist showing a fifth or sixth grader a MEG machine and asking them to intuitively understand the workings of Magnetoencephalography, with no prior explanation of brain cells or experience in neurophysiology. (MEG is a technology that measures and displays magnetic signals generated by biological events.)

Nano-Literacy Challenge

WOR has wisely funded front-end research. The Cornell Nanobiotechnology Center has generously shared information it has gained through research and hard experience. Edu, while primarily an evaluator, is acting as an advocate for learners and a resource for the WOR team.

In the summative evaluation one measure of the WOR team’s success is its ability to listen to and learn from visitor-based research. WOR’s ability to promote public understanding of research rests on its willingness to appreciate the limits of learners’ background knowledge.

Known Experiences

Principle Two: Children learn based on known experiences and physical senses

“Children draw upon their experiences. If they haven’t experienced “smallness” in terms of particles and things they cannot sense, then we need to create concrete experiences that teach children about “what they cannot see” in order to prepare them for the “nano” world.”

- Verne Rockcastle, Professor Emeritus, Cornell University; expert in K–12 science education

Children learn by making comparisons to what they know through experience. Direct experiences for children tend to dispel misconceptions. Piaget, a recognized voice in cognitive development, asserts that children are concrete and literal. They find it difficult to understand that something is there if they cannot perceive it using their senses. It is hard for them to suspend their disbelief when learning science.

Developers should be aware of the “parroting” phenomenon (i.e., kids will repeat what the adult says but not have any understanding of the concept they have just articulated).
Macro-Micro-Nano Bridge

Principle Three: People surveyed need help building and crossing the Macro-Micro-Nano bridge

Many visitors find the mental shift from macro scale to micro scale difficult. Some are unable to make the shift from micro scale to nano scale. Edu encourages exhibits, programs and technology that help visitors make the mental journey from macro to micro (e.g., Zoom Station).

Many survey respondents struggled to communicate the concept of an atom, cell, and DNA in simple language.
- Cells were more familiar than atoms, but descriptions were often inaccurate
- DNA is somewhat familiar to some, foreign to others
- Many people don’t know that DNA resides inside cells

The Cornell NanoWorld research found that children in grades K–3 often confused cells with cell phones, thought that 1,000 was a big number, and that an ant is the smallest living thing. Most had no working concept of one billion and did not understand $10^{-9}$.

The Cornell and WOR research showed that taglines were effective and memorable for many elementary children. Several third graders said things like “DNA makes you you”; “It is a finger print of who you are.”

Understanding “Nano”

Principle Four: Many people do not understand the concept of nano and have misconceptions about cells, atoms, and DNA

Edu’s survey research indicates that “nano” is a new concept for most survey respondents. Cornell research corroborates a lack of public understanding about nano.

Survey responses fell into these three classes (percentages are drawn from different questions and do not add up to one hundred):

Don’t Know Nano
23% percent don’t know the term nano (blank stares)
90% cannot describe nanotechnology

Heard I—Don’t Really Know It
67% showed partial understanding or misconception
Nano means:
- “Measurement”
- “Time”
- “Computers”
Only six out of 60 people (10 percent) had heard of nanotechnology. This 10 percent said they learned about nanotechnology from work, school, parents, or self-study. All of these people wanted to learn more about nanotechnology.

Survey respondents had varying levels of difficulty articulating the concept of atoms, cells, and DNA. Atom was the most difficult to articulate, cell less difficult. A large percentage were able to define DNA, many used a metaphor to describe DNA.

Thirty of 60 people were able to correctly rank atom, DNA, and cell in ascending order (by size). This means half could not.

**Interest in New Science**

**Principle Five: People surveyed are interested in new science especially as it relates to improving their lives**

Three out of four people said they were “interested” (46%) or “very interested” (29%) in learning about new scientific discoveries; 18% were “somewhat interested” and 7% were “not interested.” Of those surveyed, 43% were “interested” in how scientists move individual atoms, 17% were “very interested.”

Half of the people asked expressed an interest in learning about advances in medicine and health care. One in five was interested in discoveries that improve the quality of life. Several people commented that they were looking for information that connected to their lives—for example, improved communication, cell phones, computers, and environmental protections.

Those under the age of 18 seemed very interested in learning more about gadgets.

**Where Do You Learn about Science?**

**Principal Six: People surveyed get information about new science from popular media, publications and the Internet.**

People surveyed said they learn about new science from popular media, reading, and the Internet. Middle and high-school students said they learn about some science in school, but that it “is boring.”

Many students said they learned about science and technology from links they come across while surfing the worldwide web. Researchers noted that while students are active recreational Internet users, many appeared to be passive learners. A passive learner is not actively seeking information, but becomes interested when she encounters interesting information.
Adults reported getting science information from the news, television news shows (such as 20-20), the Discovery Channel and other cable channels, PBS, and network crime mystery shows (such as CSI Miami, and Forensic Files).

Several young adults said that they get their science information from links that appear on their AOL “personal page.”

**What Do You Know about “Nano” and “Small”?**

Focus groups held at LHS in February 2003 will determine childrens’ understanding of nano, size, and interest in new science (for grades 4–8).

**About the Audience**

During small-group conversations at LHS on February 27, students will share their interests in their own words.

Teachers offered the following observations about students in grades three through eight.

**Grades Three and Four**

Students are beginning content-based education in science and social sciences versus the skill-based learning (reading, writing, arithmetic) of K–2. The strongest readers may be reading at an eighth-grade level. Many slow readers and non-English speakers are still developing reading skills. They may be reading at a first- or second-grade level.

“Third and fourth graders are still playful. You need to start with what they know.” In general, they are emotionally at peace with the world.

**Grade Five**

Students are spending more time on content-based science and experiments, depending on the school and teachers. Many are becoming strong readers while some may still be reading at the grade-two or -three level. Students are beginning to move from arithmetic to basic mathematics.

Emotionally, very strong feelings of superiority, top of heap, oldest, most mature, brazen in the school setting. Willing to take and love challenges. (“Tell them they can't and they will try harder.”) Ready to jump in if it looks like fun, more fear and trepidation toward the end of the fifth-grade year.

Beginning to test boundaries outside of school. Experiencing early preadolescence. Some fifth graders have their first boyfriends and girlfriends. Some begin smoking, drinking, and getting into fights. Others are working and getting paid. “Fifth graders are like little adults in terms of their outlook on the world. They are very bright and have knowledge of world beyond their years.”

**Grade Six**

Students are beginning to get a background in science. The amount and quality of science education varies by classroom and school.
Students have an active social life outside of school. Many enjoy extracurricular socialization, participation in sports, and entertainment such as video games and movies. Growing independence. Beginning of emotional turbulence.

**Grades Seven and Eight**

Beginning of subject-specific concentrations. Curriculum tracking based on perceived academic ability may begin at this point. Because the middle school curriculum varies by state, the WOR team should interview California middle school teachers or curriculum experts.

Students are 12, 13, and 14 years of age. They are emotionally independent and “hormonally challenged.” They are finding themselves, establishing independence from parents, and testing boundaries, but still semi-receptive to authority.

“Kids are hesitant to show an interest in anything a teacher has to present, but if you can make it interesting they will be interested. They are old enough to understand some more difficult challenges and process more-complex information.”

“Seventh and eight graders are a difficult but pivotal group. They are transitioning from childhood career fantasy to real career choices. Science has to come to them. It has to be cool.”

**Prior Science Learning**

During surveys, Edu asked 50 people “How much science have you had?”

Fifty people responded.

- K–8 – 11 people
- 8–12 – 20 people
- 13–16 – 17 people
- 16+ – 2 people