MULTIMEDIA RESEARCH
33 BROWNS LANE • BELLPORT, NY 11713 • (631) 286-8925

Summative Evaluation of Awareness of Nanotechnology by the Museum Public

for
Nanoscale Informal Science Education Network
by
Barbara N. Flagg, Ed.D.
Director, Multimedia Research
and
Valerie Knight-Williams, Ed.D.
Director, Knight-Williams Research Communications

Research Report No. 08-023
September 29, 2008

This material is based on work supported by the National Science Foundation under Cooperative Agreement No. 0532536. 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.

We would like to acknowledge the tremendous support of staff at the four museums, which participated in this summative evaluation.

At Museum of Science: Christine Reich, Elizabeth Kollman, Sarah Soule, Nick Matthew, Caroline Shlager;

At North Carolina Museum of Life + Science: Brad Herring, Kate DeAlmeida, Jeff Stern;

At Oregon Museum of Science and Industry: Scott Ewing, Anders Liljeholm, Amanda Thomas;

At Science Museum of Minnesota: Kirsten Ellenbogen, Murphy Pizza, Claire Hoolihan, Sarah Cohn, Jennifer Scott, Stephanie Long, Mahmoud Hakima, Rebecca Wall-Sclavi.

Additionally, we recognize the cooperation of the respective museum marketing, membership and data services departments, without which we would have no control group.

We would also like to thank Divan Williams of Knight-Williams Research Communications for helping to edit the final report for readability and consistency.

For questions regarding this report, contact Barbara Flagg at Flaggb@aol.com.

TABLE OF CONTENTS

EXECUTIVE SUMMARY
SUMMATIVE EVALUATION OF AWARENESS OF NANOTECHNOLOGY BY THE MUSEUM PUBLIC

Over the previous three years, the Nanoscale Informal Science Education Network has researched, designed, implemented, and evaluated public deliverables covering various aspects of nanoscience, nanotechnology, and nanoengineering. Working with four NISE Net museums, Multimedia Research used a web-based post-survey design to assess nanotechnology awareness in a sample of museum visitors exposed to nano-topic programs, exhibits, forums and activities (treatment group) compared with a sample of museum members who were not exposed to the deliverables (control group).

- Those exposed to nano-topic deliverables in the museums were significantly more likely to report having heard more about nanotechnology than those who were random museum members not exposed to the deliverables.

- The treatment group was significantly more likely to describe an association with nanotechnology; however, there were no differences between the treatment and control groups as to coded categories of associations. Associations with nanotechnology described by both treatment and control groups most frequently indicated an awareness of the nanoscience of nanotechnology and the potential benefits.

- Asked about their information sources for nanotechnology, a majority of both the treatment and control groups who had heard of nanotechnology indicated that print and the Internet were sources. Significantly more respondents in the treatment group than the control group remember exposure to nanotechnology in science centers, but this result would be expected since the treatment group was recruited at nano-events sponsored by the museums. Significantly more of the treatment group also recalled reading about nanotechnology on consumer product labels; exposure to the museum nano-deliverables may have raised their awareness sufficiently to motivate them to check out labels.

- Significantly more of the treatment group than the control group reported an awareness of benefits and risks of nanotechnology; however, the treatment group did not differ from the control group with respect to the kinds of benefits and risks they were able to describe.

- The treatment group was more likely to have heard of nanotechnology in applications with clothing or fabric, solar technology, air and water purifiers, paints or coatings, cosmetics or skin lotions, and insulation. About three-quarters of both groups felt that they were familiar with medical and computing applications.

Exposure to nano-topic deliverables appears to increase the museum public's confidence in their awareness more than influencing the specifics of their awareness. In closed-ended questions, the treatment group reports a greater awareness of the term nanotechnology, its benefits, risks, and

applications, but in open-ended questions, those exposed to public deliverables demonstrated no differences in their depth or breadth of awareness compared with those not so exposed.

Most of the treatment group could specifically identify having heard about or experienced one or more of the 39 nano-topic public deliverables. Respondents described the impact of the deliverables as informative, increasing their awareness of the term itself, or improving their understanding of nano scale or nano properties. Although this evaluation did not focus on the differential influence of deliverable types, significant associations between type of deliverable and some of the dependent variables reinforce the proposition that different kinds of deliverables emphasize different content and modalities and thus influence awareness of nanotechnology in different ways.

INTRODUCTION

NISE Network

Funded by the National Science Foundation, the Nanoscale Informal Science Education Network (NISE Net) is a national infrastructure of science museums and university-based nanoscience research centers. NISE Net includes three core partners (Museum of Science, Exploratorium, and Science Museum of Minnesota) and numerous sub-awardees[1] Over a period of five years (2005-2010), NISE Net partners are collaborating to foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology through a wide variety of public deliverables including forums, programs, activities, exhibits, and a public website.[2]

Over the initial three years of the NISE Net project, the partners have collaborated to research, design, implement, and evaluate public deliverables covering various aspects of nanoscience, nanotechnology, and nanoengineering. This summative evaluation assesses how exposure to nano-topic museum-sponsored deliverables affects the museum-going public's awareness of nanotechnology. The evaluation focuses on awareness, defined here as the breadth and depth of familiarity with nanotechnology, as it is the first stage of learning about a new concept.

METHOD

Study Design

The summative evaluation is a post-survey design with nonrandomized comparison groups, looking at the impact of the nano-topic deliverables on public awareness at four NISE Net museums: Museum of Science (MoS), North Carolina Museum of Life + Science (NCMLS), Oregon Museum of Science and Industry (OMSI), and Science Museum of Minnesota (SMM). The four museums represent the core NISE Net museums (MoS, SMM) and the subawardee group (NCMLS, OMSI). The four museums also represent a wide range of museum membership size.[3]

---

[1] Subawardees include, in alphabetical order: Association of Science-Technology Centers, Cornell University, Ft. Worth Museum of Science and History, Houston Children's Museum, Inverness Research Associates, Maryland Science Center, Materials Research Society, Multimedia Research, New York Hall of Science, North Carolina Museum of Life and Science, Oregon Museum of Science and Industry, Purdue University, Sciencenter, University of Wisconsin – Madison. Cornell and Purdue Universities were no longer subawardees in year three when this evaluation was completed.

[2] For more information about NISE Net and the public deliverables, see www.nisenet.org.

[3] Approximate membership list size: NCMLS, 6,800; OMSI, 28,000 members; SMM 35,000 members; MoS 44,000.

The summative evaluation compared an adult group that we know was exposed to museum-presented nano-topics to a control group that was not exposed. To obtain the "exposed" or "treatment" group, staff at the four museums gathered email addresses volunteered by visitors who were exposed to nano-topic deliverables during February to May, 2008. The "non-exposed" or "control" group was drawn randomly from membership lists of each museum. Both groups were recruited to answer an online survey in summer 2008.

The evaluation addressed NISE Net's general goal of increasing the museum public's awareness of nanotechnology by looking at differences between the treatment and control groups on the following dependent variables:

- Self-reported level of awareness of the term "nanotechnology"
- Unaided top-of-the-mind verbal associations with the term "nanotechnology"
- Breadth of nanotechnology information sources
- Awareness of benefits and risks of nanotechnology
- Awareness of applications of nanotechnology

In addition, the study assessed the treatment group's self-described changes in awareness as a result of exposure to museum deliverables.

Procedure

Over a four-month period (Feb. - May, 2008), the four participating museums collected email addresses from adults who were observed attending one of 39 programs, exhibits, forums, and activities addressing the topics of nanoscience, nanotechnology, and nanoengineering. To collect email addresses, museum evaluators and presenters invited adult visitors who were exposed to nano-topic deliverables to fill out a paper form, which requested their email address to receive an invitation in June to complete an online museum survey for a $5 gift certificate. The nanotechnology content of the survey was not mentioned.

The relatively smaller museums (NCMLS, OMSI) each committed to gathering at least 100 email addresses, while the larger museums (SMM, MoS) each committed to gathering 400 addresses. These email addresses formed the recruitment list for the treatment group. An equivalent number of random email addresses drawn from respective museum membership lists made up the control group. Duplicate addresses and museum addresses were not included in the two lists.

Over the four months, museums presented four general types of public deliverables: (1) programs/stage presentations/speakers; (2) exhibits; (3) forums; and (4) activities/demos. Each museum offered a different set of events, and a few events occurred off-site. Many events took place during NanoDays, March 29 – April 6, 2008.[4] Table 1 on the next page lists the 39 deliverables, including 20 developed with NISE Net,[5] 11 products unique to the individual

[4] Find more description of NanoDays at http://www.nisenet.org/nanodays. Reports from the individual museums as to what they did during NanoDays are also available.

[5] Find complete descriptions of NISE Net products at www.nisenet.org/catalog. The product titles used in Table 1 are those presented in the evaluation surveys in order to remind the respondent of the experience. Table 1 titles are not necessarily those used in the NISE Net catalog.

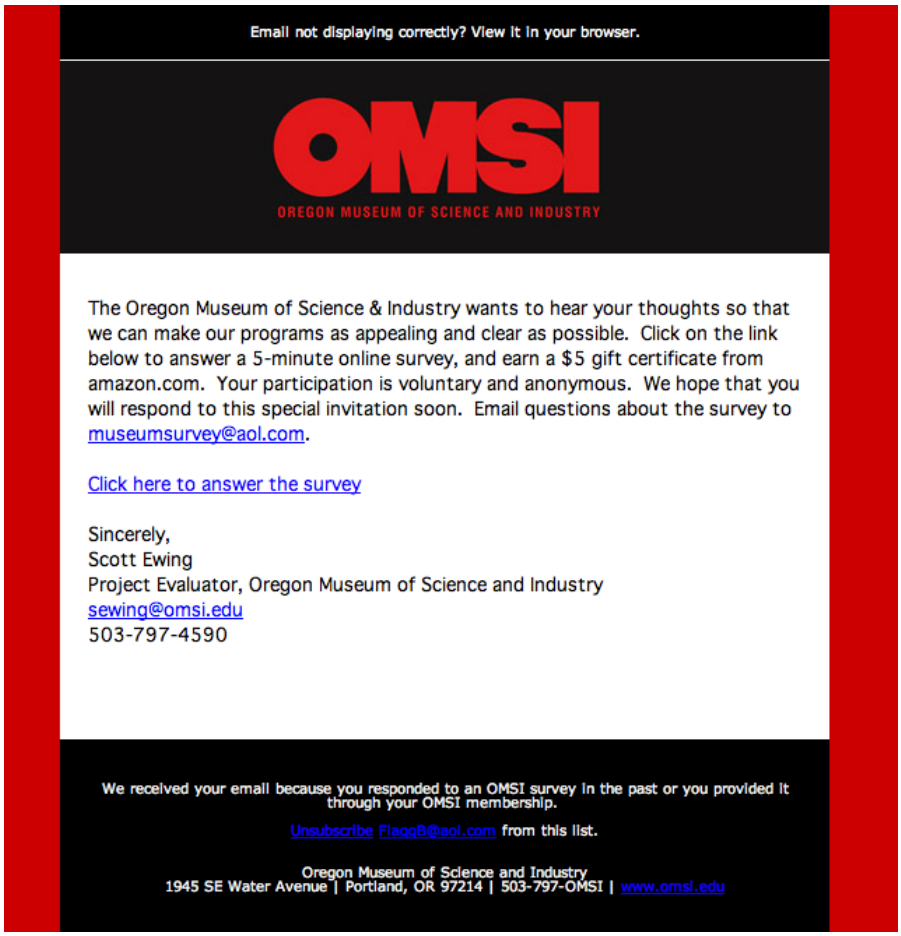
museums, and 8 activities developed by other organizations.[6] Other nano-topic products may have been available in the museums during the four month period, but email addresses to form the treatment group were obtained only from those who were exposed to Table 1's events.

Table 1. Nanotechnology Deliverables Presented to the Museum Public

Public Deliverables **[asterisk * before title indicates deliverable was developed with NISE Net]**	**MoS**	**NCMLS**	**OMSI**	**SMM**
Programs/Stage Presentations/Speakers:				
Computing the Future (history of computers)	✔			
Cyborg: Where man Meets Machine (cyborgs & bionics)	✔			
Nano Brothers Juggling Show	✔			
Moving Atoms…With Nanotech Pioneer Don Eigler	✔			
*The Earth on Edge (nanotechnology & alternative energy)	✔			
*The Wonderful World of Carbon Nanotubes	✔			
*Treating Tumors with Gold	✔			
*Wheel of the Future (game show)				✔
*NanoDreams (puppet show)				✔
BrainStorm (solar)			✔	
Science Pub			✔	
Exhibits:				
*Bump and Roll (cabbage leaf and water)				✔
*Changing Colors (iridescent butterfly)				✔
Forums:				
*Nanotechnology and Alternative Energy	✔	✔	✔	✔
Nanotechnology in Cambridge: What do you think?	✔			
Activities/Demos				
*Forces Activity (pouring water)	✔	✔		
*Liquid Crystal Sensor Activity (make your own)	✔	✔		
*Reactions Activity (antacid tablets)	✔	✔		
*Ferrofluids Activity (magnetic material)		✔		
*Measurement Activity (how small is nano)		✔		
*Solutions Activity (smelling mouthwash)		✔		
*Aerogel demo (lightest solid on earth)			✔	
*Inkjet Printer Demo (how computer printers work)			✔	
*Piezoelectricity Demo (squeezing crystals for electricity)			✔	
*Sizing Things Down Demo (card game)			✔	
Gecko Man Computer Game	✔			
Electrospinning Demo (draw nanofibers from liquid)	✔			
Nano-enhanced Bone Repair Demo (nanoparticles of bone)	✔			
Nanotechnology in Enhanced Ration Packaging Systems for the US Military Demo (nanoparticles in food packaging)	✔			
Stained Glass Activity (make stained glass, make buckyball)	✔			
Shaky, Sticky, Bumpy Computer Simulation		✔		
Small Wonders activities/demos:				
Anti-bacterial Silver				✔
Groundwater Clean Up (nano-iron cleans water)				✔
Invisible Sunblock				✔
"Liquid" Metals (bouncing metal balls)				✔
Nano Gold for Cancer Therapy				✔
Reversible Sunglasses (lens color changes)				✔
Seeing Scale (different scale butterfly pictures)				✔
Stain Resistant Fabric				✔

6 *Small Wonders: Find the Nano in Your Life* cart-based activities were developed through a partnership between two NSF-funded Materials Research Science and Engineering Centers at Penn State and Cornell Universities and The Franklin Institute in Philadelphia. Find complete descriptions at http://www.mrsec.psu.edu/museum/third/Small_Wonders_Summary.asp

In mid-June, 2008, each museum emailed a similarly worded survey invitation to those exposed to Table 1's deliverables (treatment group, N = 1039) and to a randomly drawn list of museum members (control group, N = 1039). The term "nanotechnology" was purposely not mentioned in the invitation to increase the chances of capturing those who were not familiar with the field. As an example, OMSI's email invitation is shown below.



Email not displaying correctly? View it in your browser.

OMSI

OREGON MUSEUM OF SCIENCE AND INDUSTRY

The Oregon Museum of Science & Industry wants to hear your thoughts so that we can make our programs as appealing and clear as possible. Click on the link below to answer a 5-minute online survey, and earn a $5 gift certificate from amazon.com. Your participation is voluntary and anonymous. We hope that you will respond to this special invitation soon. Email questions about the survey to museumsurvey@aol.com.

Click here to answer the survey

Sincerely,
Scott Ewing
Project Evaluator, Oregon Museum of Science and Industry
sewing@omsi.edu
503-797-4590

We received your email because you responded to an OMSI survey in the past or you provided it through your OMSI membership.

Unsubscribe FlaggB@aol.com from this list.

Oregon Museum of Science and Industry
1945 SE Water Avenue | Portland, OR 97214 | 503-797-OMSI | www.omsi.edu

About two weeks after the initial invitation, a second invitation was sent to those who had not yet answered the survey. All respondents who completed the survey were emailed a $5 Amazon.com gift card. Data were collected until one week passed with no new survey responses.

The survey was drafted by the two authors, drawing on the overall goals of NISE Net and current published literature about the general public's awareness of nanotechnology. Survey drafts were revised based on feedback from NISE Net core and sub-awardee museum representatives, NISE Net in-house evaluators and non-NISE evaluator colleagues. The draft was also piloted and revised with feedback from a small group who had participated in a 2007 MoS forum.

In the final self-administered web-based survey, closed- and open-ended questions measured:

- Classification variables: gender, age, education, ethnicity, disability, last visit to museum
- Dependent variables:
  - Self-reported level of awareness of the term "nanotechnology"
  - Unaided top-of-the-mind verbal associations with the term "nanotechnology"
  - Breadth of nanotechnology information sources
  - Awareness of benefits and risks of nanotechnology
  - Awareness of applications of nanotechnology
  - Awareness of or participation in museum nano-topic events (from Table 1)
  - Self-described change in awareness as a result of exposure to museum deliverables.

Sample

The survey invitation was emailed to 1039 nano visitors (treatment group) and 1039 museum members (control group), totaling 2078 invitations. After emailing invitations, 114 bounced, 3 recipients unsubscribed, and 1 address belonged a museum staff member, yielding a total of 1960 delivered invitations to 945 of the treatment group and 1015 of the control group.

Of those on the invitation lists, 554 adults completed the initial demographic and background survey questions, but 17 stopped answering the survey upon being asked an open-ended question about associations with nanotechnology; 6 left the survey when asked an open-ended question about benefits; 7 quit at an open-ended question about risks; and 3 broke away when asked about attendance at museum-specific nano-events. The 33 adults who partially completed the survey reported a lower level of education than those who fully completed the survey,[7] but these two groups did not differ on other classification variables (recency of last visit to museum, gender, age, ethnicity, disability). Partially completed surveys were not retained in the data set for the summative evaluation.

The response rate reported for this evaluation is Response Rate 5 (RR5) as defined by the American Association for Public Opinion Research (AAPOR).[8] RR5 is calculated as the number of fully completed surveys divided by the number of delivered surveys. For the treatment group, the survey invitation produced 309 adult invited respondents who completed the survey, yielding a RR5 response rate of 33% (309/945). For the control group, the survey invitation elicited 212 adult invited respondents who completed the survey, yielding a RR5 response rate of 21% (212/1015). The response rate of the treatment group is significantly higher than the response rate of the control group.[9] This difference is likely due to the fact that the treatment group had previously agreed to receive a survey.

[7] χ^2 (3, N = 554) = 12.56, p = 0.0057.

[8] American Association for Public Opinion Research. (2000). Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys. Ann Arbor, MI: AAPOR.

[9] χ^2 (1, N = 1960) = 34.38, $p \leq$ 0.0001.

To optimize response rates, the survey invitations were emailed twice directly from each museum, and an incentive of a $5 gift certificate offered. Nonetheless, both the treatment and control group response rates are lower than the average rate of 39.6% reported in a meta-analysis of 68 web-based surveys.[10] The participating museums report that response rates of their own email campaigns run about 20-30%. However, there may be systematic and unknown differences between those who responded to the survey invitation and those who did not, raising the possibility of non-response bias influencing the representative quality of the groups.

In the control group, 25 respondents reported having experienced one or more of the nano-topic deliverables. As the control group was designed to include only those not exposed to nano content at the museums, these 25 respondents were eliminated from the data set. The demographic and background characteristics of the 496 respondents included in the data set are given in Table 2. The treatment group includes 309 adults who were exposed to a museum-sponsored nano-topic deliverable, and the control group includes 187 adults who did not report experiencing a museum-sponsored nano-topic deliverable.

Table 2. Demographic and Background Characteristics of Treatment and Control Groups[11]

Classification Variables		**% of Treatment Group (N = 309)**	**% of Control Group (N = 187)**
Gender	Male	37%	29%
	Female	63%	71%
Age		Range: 18-73 yrs Mean = 39.9 yrs Median = 39 yrs	Range: 18-82 yrs Mean = 42.3 yrs Median = 41 yrs
Race/Ethnicity	White, not of Hispanic origin	90%	90%
	Asian-American/Asian	7%	6%
	Hispanic/Latino	2%	1%
	African-American/Black	1%	2%
	American Indian/Alaskan Native	0%	1%
Highest level of education	High school graduate or less	4%	4%
	Some college or technical	13%	11%
	College graduate	30%	32%
	Courses or degrees beyond college	52%	52%
Temporary or Permanent Disability	Yes	5%	3%
	No	95%	97%
Last Visit to Museum	Within the last six months	97%	81%
	Within the last year	1%	13%
	More than one year ago	1%	5%
	Never visited	1%	0%

[10] Cook, C., Heath, F., & Thompson, R. L. (2000). A meta-analysis of response rates in Web- or Internet-based surveys. *Educational and Psychological measurement*, 60, 821-836.

[11] Table percentages are rounded so columns may not equal 100%.

In Table 2, the treatment and control groups differ with respect to age and last visit to museum:

- At a mean age of 39.9 years, the treatment group is significantly younger than the control group at a mean age of 42.3 years.[12] Although there is a statistically significant age difference, two years may not be a meaningful difference.
- The treatment group is more likely to have visited the museum within the last six months compared with the control group,[13] but this is an artifact of the rescruitment of the majority of treatment respondents from on-site. One museum recruited at off-site nano-events, resulting in the 3% of the treatment group who had not visited the museum within the last six months.

The treatment and control groups do not differ with respect to gender distribution, although both samples have more females than males. Racial/ethnic minorities comprise 10% of both samples, and more than half of both samples report education beyond a college degree. A small portion of both samples have a temporary or permanent disability.

Data Analysis

Qualitative responses were analyzed deductively drawing on NISE Net goals[14] and inductively by looking at the responses themselves for keywords and key phrases. The two evaluation authors, blind to group assignment, independently coded random ordered open-ended responses. Kappa coeffficients for the categories ranged from 0.82 to 0.99. The kappa coefficient measures how much better than chance the agreement is between the two coders. With perfect agreement at 1.0, the kappa coefficients for the coding categories are very high. The few disagreements were settled with discussion between the two authors. Coding did not judge accuracy or misconceptions of responses because the focus of this study was on awareness and not knowledge. All responses quoted in the text to illustrate categories are verbatim and may appear to include errors but are presented as the respondents typed them. All tables present rounded percentages so totals may differ from 100%. Treatment and control group comparisons were made with non-parametric chi-square tests appropriate for categorical data. Statistical significance is reported in footnotes if p values are less than .05.

[12] Two sample t test df = 420, t = 2.365, p = 0.0185

[13] A 2x4 chi-square test indicated that the relationship between group and last visit to museum was significant, χ^2 (3, N = 496) = 44.70, $p \leq 0.0001$.

[14] See nisenet.org for goals of various deliverables.

RESULTS: AWARENESS OF TERM "NANOTECHNOLOGY"

Those who were observed being exposed to nano-topic deliverables in the museums (treatment group) were significantly more likely to report having heard more about nanotechnology than those who were random museum members (control group). Both groups reported having heard significantly more about nanotechnology than the average American.

A basic indicator of "awareness" of nanotechnology is how much a person feels they have heard about the topic. Survey respondents answered a multiple-choice question about how much they have heard about nanotechnology. Table 3 presents the question results for the treatment and control groups. Self-reported level of awareness of the term "nanotechnology" is significantly related to group;[15] whereby the treatment group of those observed as exposed to nano-topics in the museums was significantly more likely to report having "heard a lot" about nanotechnology compared with the control group of museum members (22% vs. 12%, respectively).

Table 3. Awareness of nanotechnology

How much have you heard about nanotechnology?	% of Treatment Group (N = 309)	% of Control Group (N = 187)
Heard a lot	22%	12%
Heard some	42%	40%
Heard a little	26%	32%
Heard nothing at all	8%	13%
Not sure	2%	2%

[15] A 2x5 chi-square test indicated that the relationship between group and awareness was significant, χ^2 (4, N=496) = 11.63, p = 0.0204.

Both the treatment and control groups felt more aware of nanotechnology than random samples from three national survey studies: 65% of the treatment group and 52% of the control group reported having heard "a lot" or "some" about "nanotechnology" compared with national sample results of 27%[16], 20%[17], and 19%[18]. Respondents in the treatment and control groups were interested enough to visit or join a science museum and thus could be expected to rate themselves as more aware about a science topic than the average citizen.

The 8% of the treatment group who had "heard nothing" is not significantly different from the 13% of the control group who had heard nothing. However, the 8% of treatment respondents had been observed at a museum attending one of a variety of nano-topic deliverables, including programs/presentations (40%), activities (32%) and exhibits (28%). Among the possible reasons why the 8% had "heard nothing" may be that the term "nanotechnology" was not used in a museum deliverable, or the exposure was too short for the term to be assimilated, or the term simply was forgotten from a months-earlier visit. Respondents in both groups who reported having heard nothing about nanotechnology were directed to the end of the survey rather than completing questions about nanotechnology when they were not aware of the topic; thus, for the remainder of this report the treatment group N is reduced to 284 and the control group N is reduced to 162. Only those who had heard of nanotechnology were asked to answer further questions about the topic.

[16] Peter D. Hart Research Associates, Inc. (2007 Sept.). Awareness of and attitudes toward nanotechnology and federal regulatory agencies. Available at Project on Emerging Technologies at www.wilsoncenter.org. In August, 2007, Hart Research Associates conducted a representative national telephone survey of 1014 adults.

[17] National Science Board (2008 Jan.). Science and Technology: Public Attitudes and Understanding. Chapter 7 in Science and Engineering Indicators 2008. Available at National Science Foundation at www.nsf.gov/statistics/seind08/. In 2006, the University of Chicago National Opinion Research Center interviewed face-to-face a representative national sample of 1854 adults.

[18] Kahan, D. M., Slovic, P., Braman, D., Gastil, J., & Cohen, G. (2007 March). Nanotechnology risk perceptions: The influence of affect and values. Available at Cultural Cognition Project at Yale Law School at http://research.yale.edu/culturalcognition/. In December, 2006, Knowledge Networks conducted a nationally representative online survey of 1500 adults.

RESULTS: ASSOCIATIONS WITH THE TERM "NANOTECHNOLOGY"

Those who reported top-of-the-mind associations with the term "nanotechnology" comprised significantly more of the treatment group than the control group; however, there were no differences between the groups as to their categories of associations.

Awareness of nanotechnology can be revealed through a person's associations with the term. The survey asked respondents for their unaided top-of-the mind verbal associations in an open-ended request: *Write any thoughts, ideas, emotions, questions, or definitions you associate with the term "nanotechnology."*

Ten categories fully describe the data set:

I. Awareness of nanoscience of nanotechnology
II. Awareness of benefits or potential benefits of nanotechnology
III. Awareness of risks or potential risks of nanotechnology
IV. Awareness of nanotechnology as a developing field
V. Awareness of nanotechnology as difficult to comprehend and important to learn about
VI. Recollection of museum-presented nano-topic deliverable
VII. Awareness of science fiction portrayals
VIII. Emotional response to nanotechnology
IX. Have a background in nanotechnology
X. No associations

Each category was coded dichotomously according to whether or not an open-ended response included the category. A full response could be coded into more than one category, but the same text word or phrase could not be included in more than one category. For example, the following response is coded into categories I, II, III, and IV: *Small stuff* (I) *that has many very useful applications: medical, climate (pollution), energy production* (II). *A lot of research and development still needed before we can use it* (IV*), and a lot of care needs to be taken to avoid bad effects, unplanned consequences* (III).

Each of the ten categories is described below with illustrative verbatim responses:

I. Awareness of nanoscience of nanotechnology: This category captures the respondent's awareness of nanotechnology as a science, including references to size or scale; references to manipulation or engineering of small things; descriptions of size/scale-dependent properties; or mentions of nanoscale structures. Keywords include the following plus their synonyms: *small, itty bitty, little, microscopic, particles, submicroscopic, molecule, atomic level, nano scale, nano level, nanoparticles, nanometer scale, 10^{-9}, one billionth of a meter, manipulate, engineer, design, build, make, create, property, ability, nanotube, nanowire.* Respondent examples include:

Nano meaning small, so technology very small.
Study of itty bitty things.
Technology on an atomic or molecular scale.
Ground breaking in its ability to change its properties as the particles get smaller.
I usually think of devices or materials on a molecular scale, and the applied science to gain control of things (matter) on that scale.
Nanotechnology involves using carbon atoms to manufacture microscopic (nanometer size) tubes and balls and combining them in useful ways.

II. Awareness of benefits or potential benefits of nanotechnology: This category includes responses that a) state benefits exist or potentially exist; b) imply how an application is beneficial; or c) give an application of nanotechnology that on face value is beneficial. Keywords include *benefit, help, effective, efficient, practical purposes, solution, faster, better* and synonyms. Respondent examples include:

Small machinery to help with manufacturing genetic medicines to help soldiers with strong vests as well as robots.
Ability to create consumer products that are smaller, faster, more exact, environmentally responsible and cost effective.
Developing nano-sized switches for computer applications and even health care applications. Nano-sized circuits for electrical applications. Some companies use "nano technology" to reduce weight of their products to make them lighter and stronger.
Small technology that will help in our lives to make them better.
Very very small. Potential uses in bio medicine, manufacturing, tech fields, home assistive technology, etc.
Expect positive impact on society.

III. Awareness of risks or potential risks of nanotechnology: This category includes responses that a) state risks exist or potentially exist; b) imply how an application is risky; or c) make reference to regulation or caution. Keywords include *risk, bad, negative, harmful, unknown, problems, side effects, safety, caution* and synonyms. Respondent examples, which often presented benefits alongside risks, include:

Good and Bad.
Ability to enhance existing products. Negative and unknown impacts from nano particles.
Quite a bit of useful potential in health industry, along with a bit of risk.
It has great potential for benefits, but also has potential and actual risks. We should proceed with it, but with caution.
Revolutionary technology, concern for health and safety of workers, environment, safe and proper disposal, proper labeling.
There is a lot of promise to nanotechnology. But, like all things disruptive scientifically, it must be developed conscientiously. Who knows if that will happen. I consider it like atomic energy - it either gives us clean (more or less) power to run our homes or uncontrollable energy to kill.

IV. Awareness of nanotechnology as a developing field: Responses in this category suggest that the field of nanotechnology is still in its early days. Keywords include *developing, cutting-edge, future, emerging, new* and synonyms. Respondent examples include:

An emerging growth area across many industrial and consumer product fields.
Emerging technology, not yet clear how useful it will be.
The future growth area for industry and medicine.
It's the way of the future.
Lots more study needs to be conducted.
Next big thing.

V. Awareness of nanotechnology as difficult to comprehend and important to learn about: In this category, respondents talk about nanotechnology being difficult to grasp or understand and/or mention that it is important to become better informed or learn about nanotechnology. Keywords include *learn, inform, know, comprehend, understand, difficult, hard* and synonyms. Respondent examples include:

I don't feel remotely qualified to answer this question! Would love to see an exhibit to help me feel a little more informed.
Don't know enough about it to have much to say, something I should know more about.
NT is a great discovery, I am not very familiar with it, but I am very interested in learning more.
I don't know a whole lot about the applications for nanotechnology or current research in the field, but I am interested in it.
I think very smart people are involved in nanotechnology. I think nano is about as hard to get my head around as is infinity.
Nanotechnology sounds like some sort of "way-out-there: scientific process far beyond my means of comprehension. It evokes great passion as well as fear in the press. And, I don't know enough about it.

VI. Recollection of museum-presented nano-topic deliverable: Responses in this category recalled exposure to nanotechnology at one of the museums. Respondent examples include:

The most prominent thought that comes to mind is the presentation I saw at the Museum of Science regarding the use of nano-sized gold particles to treat cancer.
Learned about at OMSI pub night.
REALLY small! I am not sure what it is used for, but at NCMLS we saw a demonstration of stuff that looked like water but was actually some kind of nanoparticle.
Saw a puppet show at the Science Museum [of Minnesota]. *My 9 year friend loved it! Otherwise I've never heard anything about it.*
We watched a great skit about nanotechnology which gave concrete examples of what it was being used for.
I learned the significance of the work being done – the show we attended was entertaining and informative.

VII. Awareness of science fiction portrayals: In this category, respondents made reference to science fiction or wrote about portrayals of nanotechnology in science fiction. Respondent examples include:

Sci-fi has done a great job of showing the possible pitfalls of nanotech. Stargate's replicators or that King? movie where the guy grows extra eyes in the back of his head etc. Sweet.

Michael Crichton wrote a book called "The Swarm" about nanotechnology. Many science fiction writers have written about the worry that the world will end as "grey goo," owing to nanotechnology

I think of sci-fi movies/tv shows when I think of nanotechnology. The word makes me think of little machines crawling around in the body.

Despite everything else I've read, my strongest association with "nanotechnology" is from a Star Trek Next Generation TV episode when the Nanites take over the computer and become a sentient being..

OMG SUPER SOLDIERS!? that is pretty much what comic books have imprinted on me about nanotech.

Most of what I have heard has been science FICTION, so when I hear real examples of nanotechnology I am astonished. I have to double check to make sure what I am reading is for real.

VIII. Emotional response to nanotechnology: This category includes emotional responses to nanotechnology. Typically, responses in this category are single words in a series of single words. Keywords include *amazing, astounding, cool, exciting, hopeful, creepy, scary* and synonyms. Respondent examples include:

Experimental Promise New cures Exciting

exciting, endless possibilities, cutting-edge technology

esoteric using 10x(-9) sized particles for innovative applications scientific engineering amazing interesting

promising michael crichton corruptible creepy

really cool stuff

hopeful

IX. Have a background in nanotechnology: Responses that indicate that the respondent has a background in nanotechnology are included in this category. Respondent examples include:

I am a scientist working in the area of nanotechnology, and I simply love my work..

As a materials scientist with a PhD from MIT, I am quite knowledgeable about nanotechnology.

My background is in mechanical engineering from CMU and MIT -- so I know quite a bit about nano.

X. No associations. Those who tried to skip the question were asked to indicate that they had no associations with nanotechnology before moving to the next question.

Table 4 presents each category and the percentages of treatment and control group responses that were coded into those categories. The top-of-the-mind associations with "nanotechnology" were distributed in not significantly different percentages across eight of the ten coding categories for both treatment and control groups. The treatment group (12%) was more likely to mention a museum-presented nano-topic deliverable (category V) than the control group (1%), but this could be expected because the treatment group was chosen for their exposure to the deliverables.[19] Those who had no associations with nanotechnology (category X) comprised significantly more of the control group (22%) than the treatment group (11%).[20]

Table 4. Category Percentages in Nanotechnology Awareness Responses

Category for "write any thoughts, ideas, emotions, questions, or definitions that you associate with the term 'nanotechnology' "	**% of Treatment Group (N = 284)**	**% of Control Group (N = 162)**
I. Awareness of nanoscience of nanotechnology	53%	44%
II. Awareness of benefits/potential benefits of nanotechnology	46%	44%
III. Awareness of risks/potential risks of nanotechnology	13%	11%
IV. Awareness of nanotechnology as a developing field	16%	17%
V. Awareness of nanotechnology as difficult to comprehend and important to learn about	8%	9%
V. Recollection of museum-presented nano-topic deliverable	12%	1%[21]
VII. Awareness of science fiction portrayals	7%	8%
VIII.Emotional response to nanotechnology	6%	7%
IX. Have background in nanotechnology	1%	2%
X. No associations; Don't know	11%	22%

[19] χ^2 (1, N=446) = 19.05, $p \leq 0.0001$

[20] χ^2 (1, N=446) = 10.33, $p = 0.0013$

[21] This member recalled being sent information about a forum but did not attend.

RESULTS: NANOTECHNOLOGY INFORMATION SOURCES

A majority of both treatment and control groups reported that print and the Internet were their information sources for nanotechnology. Significantly more respondents in the treatment group as compared with the control group remember exposure to nanotechnology in science centers and on consumer product labels.

Respondents were asked about their information sources for nanotechnology to evaluate whether or not exposure to the nano-topic museum deliverables would influence the treatment group's awareness of nanotechnology news in other sources. Given eight different information sources, respondents indicated, via a yes/no response, whether or not they "clearly remember reading, seeing or hearing about nanotechnology" from each source. Table 5 below indicates that major sources for more than half of both the treatment and control groups included print and the Internet.

Table 5. Nanotechnology Information Sources

In which of the following do you clearly remember reading, seeing or hearing about nanotechnology?	% of Treatment Group (N = 284)	% of Control Group (N = 162)
Museums, Science Centers	78%	37%
Print: Newspapers, magazines, journals, books	69%	72%
Internet	62%	63%
Television	53%	49%
Word of Mouth: Family, friends, coworkers	51%	44%
Movies	40%	31%
Radio	27%	27%
Consumer product labels	12%	5%

The treatment group was significantly more likely than the control group to name "museums, science centers"[22] as a nanotechnology information source (78% vs. 37%). This difference would be expected because the treatment group was recruited at nano-events at the museums; however, with this recruitment procedure, one might also anticipate that more of the treatment group would consider "museums, science centers" as a nanotechnology information source. The treatment group was also significantly more likely than the control group to choose "consumer product labels"[23] as a nanotechnology information source (12% vs. 5%)

[22] χ^2 (1, N=446) = 73.60, $p \leq 0.0001$

[23] Fisher Exact test = 0.0174

RESULTS: AWARENESS OF BENEFITS OF NANOTECHNOLOGY

Significantly more of the treatment group reported an awareness of benefits or potential benefits of nanotechnology compared with the control group; however, the treatment group did not differ from the control group with respect to what kinds of benefits they were able to describe.

To assess the range of respondents' awareness of nanotechnology, the survey asked if they were aware or not aware of any benefits or potential benefits of nanotechnology. Reported awareness of benefits was significantly higher in the treatment group (78%) than in the control group (61%).[24]

To assess the depth of awareness, those who were aware of benefits were asked to explain, as best they could, any benefits or potential benefits of nanotechnology. Eight categories fully describe the data set:

I. Awareness of health or medical benefits
II. Awareness of benefits related to new materials, structures, machines, engineering or manufacturing processes
III. Awareness of applications in consumer goods
IV. Awareness of information technology benefits
V. Awareness of energy benefits
VI. Awareness of environmental benefits
VII. Awareness of benefits that do not fall into other coded categories
VIII. Awareness of benefits but did not give example of benefit

Each category was coded dichotomously according to whether or not an open-ended response included the category. A full response could be coded into more than one category, but the same text word or phrase could not be included in more than one category. For example, the following response is coded into categories I, II, and III: *I have heard of items such as windows that can be manufactured with nanotechnology to help keep them clean.* (III) *I have heard of material that can help be improved by nanotechnology to make them stronger.*(II) *I have heard of the improvement in medicines or cures for diseases if problems in the body can be helped by nanotechnology.*(I)

[24] χ^2 (1, N=446) = 15.20, Fisher Exact test $\leq$ 0.0001

Each of the eight categories is described below with illustrative verbatim responses:

I. Awareness of health or medical benefits: This category captures the respondent's awareness of how nanotechnology is being used in the field of medicine to improve health. Keywords include the following plus their synonyms: *health, medicine, drug, cancer, disease, cure, surgery, treatment.* Respondent examples include*:*

From the presentation I saw, the nano-sized gold particles are injected into the bloodstream where they can leak out at the site of the cancer tumor. When the skin is placed under infrared lights the particles heat up to kill the cancerous cells around it.

Some things I've read suggest it makes possible better health.

Targeted drug delivery systems

In the health and medicine arena it could have the potential to help surgeons or help with antibody/disease damage.

Medical benefits-disease diagnosis and treatment

This is a potential in the future, for nanotech to be used to help our bodies on the cellular level.

II. Awareness of benefits related to new materials, structures, machines, engineering or manufacturing processes: This category includes responses that describe new materials, structures, or machines, or describe engineering or manufacturing processes with references to properties of stronger, lighter, better, cheaper, or faster, Keywords include *material, structure, machine, engineering, manufacturing, stronger, lighter, better, cheaper, faster* and synonyms. Respondent examples include:

Possibility that can make products that are more stable, more flexible, stronger, less expensive, faster to produce, etc. possibility that can make products that are not possible with other existing technologies.

New materials properties, both physical and chemical, emerging from the ability to control structure at the nanometer length scale.

Benefits include the potential for substituting carbon nano-tubes for metal since it is much lighter and stronger.

Cheap manufacturing

Smaller, lighter, stronger machines self building machines

It should make products lighter, stronger, less expensive.

III. Awareness of applications in consumer goods: This category refers to consumer goods like consumer electronics, fabrics, cosmetics, or self-cleaning products. Respondent examples include:

Electronics industry is going to have biggest advantage of nanotechnology.

Smaller packaging of electronic devices means that we can have every electronic gadget in small sizes too.

New food and cosmetic applications that will allow us to have more nutritious food and more effective cosmetic products including sun protection using fewer chemical inputs.

Benefits seem to wide ranging, I've seen pants that have some kind of nano coating to repel stains. I've read about sunblocks and make-up (cosmetics) that contain nano in some way.

Sunscreen. products that clean or disinfect themselves.
We are already seeing some improved textiles as a result of nanotech. I purchased a vest last winter that had anti-static properties as a result of a nanotechnological fabric treatment.

IV. Awareness of information technology benfits: This category includes references to information technology, computers, or sensors. Respondent examples include:
Being able to do computing faster.
I think that nanotechnology enables the recording of information in an extremely compact way. Information can be used to communicate with other people but also with processes, so that complex instructions can be encoded at the atomic or molecular level.
Could help continue Moore's law--shrinking circuits to improve performance. Get around current technology limitations.
Enhancing ability of data storage units while not enlarging it physical size.

V. Awareness of energy benefits: This category includes references to energy saving or energy-generating devices, including solar or battery uses. Respondent examples include:
Improved battery life energy saving devices
New solar technology applications that could drive down the cost of solar and reduce manufacturing impacts.
I think there are scientists trying to develop a nano-technology that will allow the sun's rays to be converted to electricity, similar to the process of photosynthesis.
Carbon nanotubules offer ideas of more efficient transmission of energy, stronger materials, and possible ways to generate energy as well.

VI. Awareness of environmental benefits: Responses in this category describe uses of nanotechnology that benefit the environment. Respondent examples include:
Clean oil pollution by converting the oil in to something easily collected or harm less.
Nanontechnology can also be used to help repair damage that we have already done to the environment.
Environmental- how food would grow and be harvested.
Potential to keep us healthier by cleaning up our environment, keeping water clean and contaminant free, repairing the damage we are doing to the world, such as repairing the ozone layer.

VII. Awareness of benefits that do not fall into coded categories: Benefit responses in this category are singular and do not fit into the other coding categories. Respondent examples include:
I see it as the next step in science with many different applications of improved technology.
More potential jobs.
Access to new information we have not had before

VIII. Awareness of benefits but did not give example: Respondents in this category reported that they were aware of benefits in the multiple-choice closed-ended question but did not give any examples of benefits in the open-ended follow-up question.

Table 6 presents each category and the percentages of treatment and control group responses that were coded into those categories. Six out of ten respondents described health or medical benefits. The benefit responses were distributed in not significantly different percentages across all eight coding categories for treatment and control groups.

Table 6. Category Percentages in Awareness of Nanotechnology Benefits

Category for *"explain, as best you can, any benefits or potential benefits of nanotechnology."*	**% of Treatment Group (N = 222)**	**% of Control Group (N = 99)**
I. Awareness of health or medical benefits	60%	62%
II. Awareness of benefits related to new materials, structures, etc.	28%	19%
III. Awareness of applications in consumer goods	17%	19%
IV. Awareness of information technology benefits	13%	14%
V. Awareness of energy benefits	14%	6%
V. Awareness of environmental benefits	6%	9%
VII. Awareness of benefits that do not fall into other categories	7%	5%
VIII. Did not give benefit example	8%	10%

RESULTS: AWARENESS OF RISKS OF NANOTECHNOLOGY

Significantly more of the treatment group reported an awareness of risks or potential risks of nanotechnology compared with the control group; however, the two groups did not differ with respect to the kinds of risks they were able to describe.

A set of questions paralleling the above benefit questions were asked about awareness of risks. Respondents were asked via a closed-ended question if they were aware or not aware of any risks or potential risks of nanotechnology. Reported awareness of risks was significantly higher in the treatment group (42%) than in the control group (27%).[25]

In an open-ended question, those who were aware of risks were asked to explain, as best they could, any risks or potential risks of nanotechnology. Ten categories fully describe the data set:

I. Awareness of risks or potential harm to people
II. Awareness of environmental risks
III. References to science fiction type risks
IV. Awareness of potential for unintended consequences
V. Awareness of the field's lack of knowledge about risks
VI. Awareness of a need for regulation or monitoring
VII. Awareness of economic risks
VIII. Awareness of unspecified risks
IX. Awareness of risks that do not fall into other coded categories
X. Awareness of risks but did not give risk example

Each category was coded dichotomously according to whether or not an open-ended response included the category. A full response could be coded into more than one category, but the same text word or phrase could not be included in more than one category. For example, the following response is coded into categories I, II, VI and VII: *Nanoscale objects interact with cells and tissues at similar length scales. Similar to some drugs.*(I) *Small amounts of nanostructured materials can have vast surface areas capable of interacting with the environment. So small amounts of nanomaterials can have big biological and environmental effects.* (II) *Study to understand the interactions of nanomaterials with cells is complex and costly, while pressures to commercialize products is large.* (VII) *Thoughtful regulation at the state and federal levels seems important to balance risks and rewards.* (VI)

[25] χ^2 (1, N=446) = 10.11, p = 0.0015

Each of the ten categories is described below with illustrative verbatim responses:

I. Awareness of risks or potential harm to people: This category captures the respondent's awareness of how nanotechnology harms or might harm the health, safety, security, or privacy of people or living things. Keywords include the following plus their synonyms: *health, medicine, body, skin, lung, cancer, asbestos, inhalation, ingestion, safety, privacy.* Respondent examples include*:*

Nanoparticles which are inhaled or otherwise ingested by humans (and all other animals) may be toxic.

Small size of particles can be an inhalation hazard.

When they enter the body these products may not be processed in the body the way other products are (one example: there is concern that similar to asbestos certain fibers could induce cancer)

Incorrect delivery or blood clots

The destroying of healthy skin.

Using this to invade privacy perhaps?

II. Awareness of environmental risks: This category includes responses that describe potential harm to the environment, referring to land, water, and air pollution or toxicity; disposal of used materials or manufacturing byproducts. Keywords include *environment, ecosystem, air, water, pollutants,* and synonyms. Respondent examples include:

While I find the possibilities for nanotechnology mind-boggling, much more research needs to be done to study the long-term effects on the environment.

Some potential for nano-pollutants that currently can't be filtered out of air and water effluents.

Nano engineered washing machines deliver antimicrobials on silver nano particles and we do not know what silver will do to the ecosystem as it enters the wastewater.

The only potential risk of nanotechnology is in the realm of toxicology and environmental damage, because particles of a very small size may interact differently than would be predicted from their bulk chemical behavior.

Pollution from nanoparticles that conventional waste treatment methods do not address.

Hazards of carbon nanotubes manufacturing of such products

III. References to science fiction type risks: In this category, respondents describe science fiction type risks relating to nano components getting out of control, taking over or destroying. Respondent examples include:

Could we become more "robotic" and "less human", like the Bionic Woman, or the androids of the Terminator movie series? Could they take over???

They could take over the world.

Potential risks could include nanobots with the ability to reproduce themselves using locally found materials, but not being able to shut down. This would end up creating a 'Grey Soup', which could eventually destroy the planet.

From Star Trek, if they started getting out of control, they might become a problem.

IV. Awareness of potential for unintended consequences: This category includes references to instability of materials or products, a lack of control over what is created, or the emergence of unanticipated or inadvertent side effects. Responses in this category are of a general nature and do not identify specific unintended consequences. Respondent examples include:

May result in unstable products.

Unintended consequences of technology - being more effective than planned, changing other variables than planned, too small to find/fix once used.

To me a potential risk would be the control of the nanotechnology way to shut it down in the case things don't go according to plan.

The mechanisms, like anything else, have the potential to break down or malfunction in unintended ways.

V. Awareness of the field's lack of knowledge about risks: Responses in this category refer to the field's lack of knowledge, the field's newness, or general unknowns. Respondent examples include:

Basically, more unknowns than knowns about this technology.

New materials made with nanotechnology can be dangerous because we don't know yet what they're capable of doing.

In my mind, experimenting with unproven sciences/technologies can always create an element of risk as part of the learning curve..

VI. Awareness of a need for regulation or monitoring: Responses in this category recognize the lack of or need for regulation, labeling, monitoring or evaluation. Respondent examples include:

How do we measure the impact in the short, medium, and long-terms? how to regulate and control?

Not enough long-term research done to evaluate the risks of breaking down elements.

VII. Awareness of potential economic risks: This category includes those who describe economic or financial risks associated with nanotechnology. Respondent examples include:

Enormous costs to develop further advances

Economic risks: redefinition of the manufacturing industry

VIII. Awareness of unspecified risks. In this category are included responses that recognize that risks exist but do not identify the specific nature of the risks. Respondent examples include:

I suppose as in most technological advances it could be used for harm as well.

Like other technologies, can be used for good or evil.

IX. Awareness of risks that do not fall into coded categories: Risk responses in this category are singular and do not fit into the other coding categories. Respondent examples include:

There is also the ethical issue--manipulation of structure or form--where will the line be drawn?

X. Awareness of risks but did not give example: Respondents in this category reported that they were aware of risks in the multiple-choice closed-ended question but did not give any examples of risks in the open-ended follow-up question.

Table 7 presents each category and the percentages of treatment and control group responses that were coded into those categories. Most respondents of both groups described risks to people or living things. The risk responses were distributed in not significantly different percentages across all ten coding categories for treatment and control groups.

Table 7. Category Percentages in Awareness of Nanotechnology Risks

Category for *"explain, as best you can, any risks or potential risks of nanotechnology."*	**% of Treatment Group (N = 120)**	**% of Control Group (N = 44)**
I. Awareness of risks or potential harm to people/living things	53%	64%
II. Awareness of environmental risks	23%	18%
III. References to science fiction type risks	13%	11%
IV. Awareness of potential for unintended consequences	10%	16%
V. Awareness of the field's lack of knowledge about risks	12%	11%
V. Awareness of a need for regulation or monitoring	8%	16%
VII. Awareness of potential economic risks	5%	5%
VIII. Awareness of unspecified risks	5%	5%
IX. Awareness of risks that do not fall into coded categories	1%	5%
X. Awareness of risks but did not give example.	11%	7%

RESULTS: AWARENESS OF APPLICATIONS OF NANOTECHNOLOGY

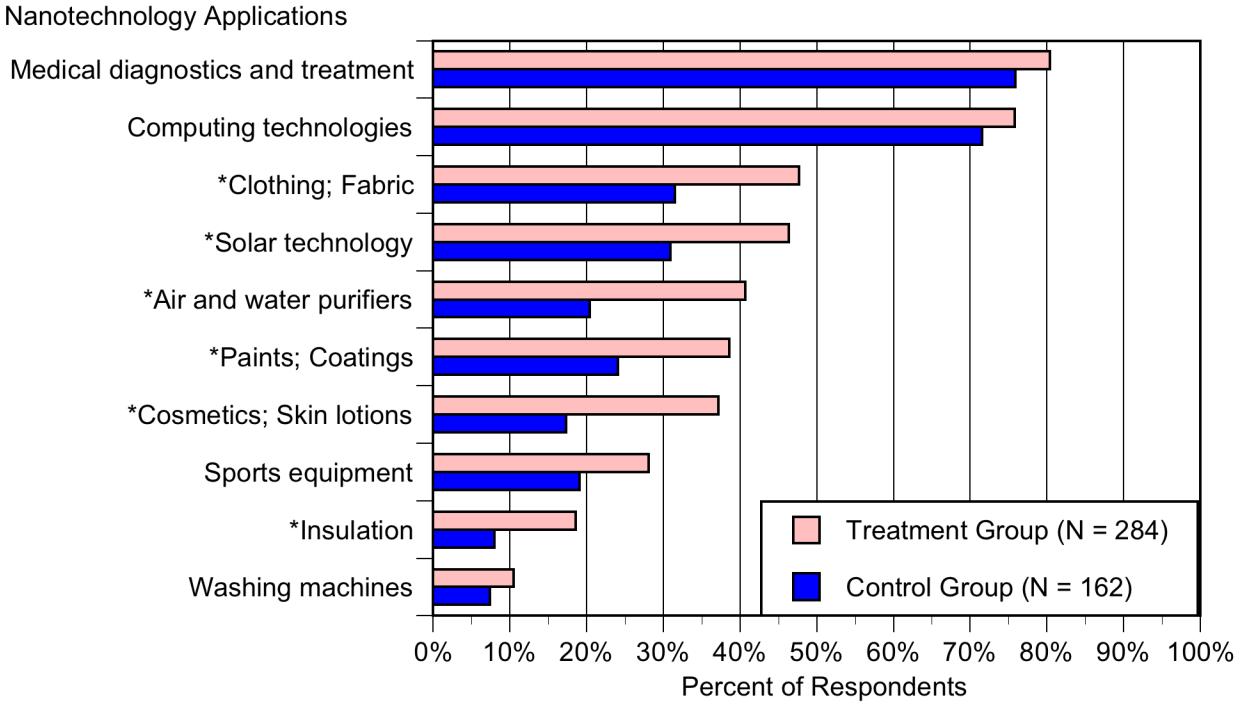
The treatment group respondents were significantly more likely than the control group respondents to have heard of nanotechnology in the following applications: clothing or fabric, solar technology, air and water purifiers, paints or coatings, cosmetics or skin lotions, and insulation. Around three-quarters of both groups felt familiar with medical and computing applications.

To assess respondents' depth of awareness of nanotechnology's dissemination into their lives, they were asked if they had heard of nanotechnology being used in various applications. These applications were mentioned in varying ways by the museum deliverables of Table 1. The applications list was presented in a different random order for each respondent to avoid an order effect. The response alternatives consisted of "yes," "no," and "don't know." A "don't know" alternative was included to make the question more comfortable to answer, because awareness of nanotechnology was assumed to be low; however, for purposes of analysis, "don't know" responses were treated as "no" responses.

Figure 1 on the next page presents the percentages of treatment and control respondents who had heard of nanotechnology being used in the various applications. The most familiar applications for both groups were in medicine and computing with around three-quarters of respondents having heard of applications in these fields. Having heard of nanotechnology in other applications is not independent of group. Significantly more respondents in the treatment group as compared with the control group had heard of nanotechnology being used in clothing or fabric applications[26], solar technology[27], air and water purifiers[28], paints or coatings[29], cosmetics or skin lotions[30] and insulation.[31]

[26] χ^2 (1, N=446) = 10.94, p = 0.0009
[27] χ^2 (1, N=446) = 9.965, p = 0.0016
[28] χ^2 (1, N=446) = 19.44, $p \leq 0.0001$
[29] χ^2 (1, N=446) = 9.522, p = 0.0020
[30] χ^2 (1, N=446) = 19.11, $p \leq 0.0001$
[31] χ^2 (1, N=446) = 9.258, p = 0.0023

Figure 1. Percent of respondents who have heard of nanotechnology being used in applications
*Asterisk indicates significant difference between groups



RESULTS: EXPOSURE TO NANOTECHNOLOGY DELIVERABLES

Most (85%) of the treatment group could identify either hearing about or experiencing one or more of the 39 nano-topic public deliverables, and 59% could describe some personal impact of their exposure. They suggested that the museum deliverable was generally informative, increased their awareness of the term itself, or improved their understanding of nano scale or nano properties.

Although this summative evaluation was not designed to look at the differential influence of deliverable type on awareness of nanotechnology, some significant relationships were found between type of deliverable and categories of associations with nanotechnology, awareness of risks and benefits, and sources of information about nanotechnology.

The museums presented four types of public deliverables with nano content: 11 different programs/presentations/speakers; 24 different activities/demos; 2 different forums; and 2 different exhibits. Survey respondents indicated whether they had heard about or experienced each deliverable that was presented in their respective museum. Table 8 presents the percentages of the treatment group who had heard about or experienced each deliverable type and the percentage who neither heard about nor experienced the deliverable type. All deliverable types were not presented in all museums, so the N is reduced appropriately in Table 8 for programs and exhibits. The rows in Table 8 can add up to more than 100% because an individual, for example, could have "experienced" a program and "heard about" a different program at their museum and thus appear in the same row in more than two columns.

Table 8. Exposure to Nanotechnology Public Deliverables

Public Deliverable Type (# of type)	N	% of Treatment Group		
		Neither heard about nor experienced	Heard about	Experienced
Programs/Stage Presentations/Speakers (11)	234	32%	29%	60%
Activities/Demos (24)	284	52%	32%	30%
Forums (2)	284	70%	14%	18%
Exhibits (2)	115	81%	8%	20%

Of the treatment group, 42 (15%) reported that they had neither heard about nor experienced any of the 39 nanotechnology public deliverables, even though their exposure was observed by museum staff in order to obtain their email address. Of these 42 people who apparently could not recall their nanotechnology exposure, 55% were observed at exhibits; 36% were observed at activity/demo stations; and 10% at programs. A number of explanations are possible for these results; for example, to complete the online survey quickly respondents may have checked off all of the "neither heard about nor experienced" column without reading the list; respondents may not have recognized the titles used in the survey to describe the deliverable; or respondents may

not have had sufficient exposure to the deliverable at the museum in order to recall it. In support of the latter explanation, two respondents whom staff observed as being exposed to an exhibit commented in their open-ended responses on their lack of recall:

Have been to the museum recently but have not seen any exhibits on this subject.
Seems like I heard something about it at the museum.

Those who reported having experienced a deliverable were asked to describe how the experience influenced their awareness of nanotechnology; 59% of the treatment group described some impact of their museum-sponsored exposure to nanotechnology. Of these responses, 10% came from respondents who had experienced more than one type of deliverable and whose response was too vague to attach to a specific deliverable type. The remaining 90% of responses were distributed as follows:

- Of the 140 respondents who reported experiencing programs/stage presentations/speakers, 29% described some impact on their personal awareness of nanotechnology:
  - 10% felt that their program was generally informative; e.g.,
    Learned about nanotechnology.
    Science pub greatly increased my knowledge. I still don't totally understand it, but have a much better grasp of the concepts and some applications.
    The sum of my knowledge of nanotechnology is from those experiences.
  - 9% described the program(s) they saw as a good introduction; e.g.,
    Nano Brothers juggling was excellent intro to the nano world for children and adults.
    The Wheel of the Future program was a great introduction to nanotechnology.
    Good general overview of nanotechnology.
  - 5% felt that their awareness of the term increased; e.g.,
    I learned that it exists.
    Limited influence. It really just brought the term to my awareness.
    Recognition when see name in print.
  - 5% noted that the program influenced their understanding of nano scale or nano properties; e.g.,
    The nanobrothers show/Don Eigler's show taught me how small things are on the nanoscale.
    The game show helped me understand more about a topic I have not read a lot about, but I don't remember a lot of what was presented, except that it deals with very tiny dimensions.
    Clarified some of the impacts from combining different materials with nano tech.

  The remaining presentation attendees provided answers unrelated to a personal increased awareness of nanotechnology:
  - 49% gave no response
  - 16% commented that their program was enjoyable, interesting or entertaining; e.g.,
    Cyborg was entertaining.
    I experienced the treating tumors with gold and I found it to be very interesting.
    My entire family enjoyed the nano brothers juggling show.
  - 8% asserted that their experience had no influence; e.g.,
    To be honest, I didn't get a lot of new information about nanotechnology from these shows and presentations.

Knew about it already.
I should have paid better attention.

- 7% suggested that the presentation was a positive experience for their children; e.g.,
  It was nice to see my daughter light up with excitement that it was fun to learn about science. If she is excited she will learn quicker and more about it.
  The Nano Bros and Don Eigler presentations were FANTASTIC. My 7 year old frequently uses information he learned there to relate to other learning experiences.
  The puppet show helped to teach my daughter what nanotech is.

- Of the 84 respondents who experienced activities, 25% described some impact on their personal awareness of nanotechnology:
  - 12% noted that the activity influenced their understanding of nano scale or nano properties; e.g.,
    We cut measuring tapes down in half until we couldn't cut anymore, so it demonstrated size.
    It showed me how small the particles are.
    Understood how breaking tablets into smaller pieces made the reaction faster. Has to do with surface area, I think.
    It was interesting to see the measurement activity with the water and how the smaller the cup, holes (etc.) would hold the water molecules in place.
  - 7% felt that their awareness of the term increased; e.g.,
    Introduced us to the term.
    Made me aware of what it meant.
    Familiarized me with the term.
  - 6% felt that their activity was generally informative; e.g.,
    They were very informative.
    They broadened my knowledge of nanotechnology and its potential.
    It gave me a better understanding.

  The remaining activity attendees provided answers unrelated to an increased awareness:
  - 54% gave no response
  - 14% suggested that the activity was a positive experience for their children; e.g.,
    I had four or five fourth graders and they loved feeling like a "real' scientist.
    My twins did the experiment and thought it was cool.
  - 7% commented that their activity was fun or interesting; e.g.,
    The one I experienced was very interesting.
    Interesting, fun, engaging activities.
  - 7% asserted that their experience had no influence; e.g.,
    No real impact.
    Although we participated in the experience, I don't recall the use of the word nanotechnology ever being used by the site supervisor.
    Forgot already.

- Of the 50 respondents who experienced forums, 48% described some impact on their personal awareness of nanotechnology:
  - 34% felt that their forum was generally informative; e.g.,
    Gave me an understanding that I didn't have before.

It gave me some exposure and expanded my conception of the idea.
It gave me a lot of background information about nanotechnology and also made me aware of issues surrounding it.

- 14% noted that the forum influenced their understanding of benefits and risks of nanotechnology; e.g.,
  Gave me a better understanding of benefits and risks of nanotechnology.
  More aware of benefits and risks.
  I am very concerned about the pervasive use of nanotechnology within consumer products without warning labels.

The remaining forum attendees provided answers unrelated to an increased awareness:

- 38% gave no response about influence of forums on awareness
- 16% commented that their forum was interesting; e.g.,
  The forum was very interesting.
  Very good and effective
  It was interesting.
- 6% were pleased with the opportunity to discuss nanotechnology topics; e.g.,
  Participated in the discussion forum. I liked the opportunity to discuss, but feel I can do more to help the general public understand the technology.
  Town hall conversations about technology and policy are an important missing link in the way we make community decisions. I would encourage the development of this programming on an even larger scale.
  I attended the forum. While I did not feel I learned much new information about nanotechnology, I did feel that it was a very worthwhile experience to talk with other people about their ideas and opinions about the subject.

- Of the 23 respondents who experienced exhibits, 9% described some impact on their personal awareness of nanotechnology:
  - 9% felt that their activity was generally informative; e.g.,
    Good work explaining some of the basic concepts in nanotech. Useful educational experience for the public and my family.
    Was my first experience with nanotech; the cabbage leaf especially helped me understand it.

  The remaining exhibit attendees provided answers unrelated to an increased awareness:
  - 70% gave no response about influence of exhibits on awareness
  - 13% asserted that their experience had no influence; e.g.,
    I didn't know it was nanotechnology when I did it.
    I didn't learn anything I didn't already know in these cases, although I did not explore them in depth.
  - 9% commented that their activity was interesting; e.g.,
    I thought the butterfly exhibit was interesting, but it left me frustrated. Unfortunately, I don't remember exactly what I was instructed to do at the exhibit, but I do remember that I had trouble getting the results I thought I should after reading the instructions. I remember it being very confusing.
    The one I experienced was very interesting.

The design of this summative evaluation was not intended to look at differential influences of deliverable type on awareness of nanotechnology; however, we can report some significant relationships for the treatment group that merit further study in more focused evaluations.

- Compared to those exposed to other deliverables, those who reported experiencing programs/stage presentations/speakers (n = 140) were significantly
  - more likely to report being aware of benefits or potential benefits of nanotechnology;[32] and
  - less likely to note an association of nanotechnology with science fiction. [33]

- Compared to those exposed to other deliverables, those who reported experiencing activities/demos (n = 84) were significantly
  - less likely to note a benefit or potential benefit of nanotechnology in their top-of-the-mind associations with nanotechnology.[34]

- Compared to those exposed to other deliverables, those who reported experiencing exhibits (n=23) were significantly
  - more likely in their top-of-the-mind associations to note a risk or potential risk of nanotechnology;[35]
  - more likely in their associations to describe nanotechnology as a developing field;[36] and
  - more likely to note reading about nanotechnology on consumer product labels.[37]

- Compared to those exposed to other deliverables, those who reported experiencing forums (n=50) were significantly
  - more likely to report being aware of risks or potential risks of nanotechnology;[38]
  - more likely to note a risk or potential risk of nanotechnology in their top-of-the-mind associations;[39]
  - more likely to report being aware of benefits or potential benefits of nanotechnology;[40]
  - less likely to describe some aspect of nanoscience in their open-ended association responses; [41] and
  - more likely to note reading about nanotechnology in print,[42] the Internet[43] and consumer product labels.[44]

---

[32] χ^2 (1, N=234) = 5.364, p = 0.0206
[33] χ^2 (1, N=234) = 8.668, p = 0.0032
[34] χ^2 (1, N=284) = 6.083, p = 0.0136
[35] χ^2 (1, N=115) = 5.205, p = 0.0225.
[36] χ^2 (1, N=115) = 9.129, p = 0.0025
[37] χ^2 (1, N=115) = 9.072, p = 0.0026
[38] χ^2 (1, N=284) = 47.60, $p \leq 0.0001$
[39] χ^2 (1, N=284) = 14.46, p = 0.0001
[40] χ^2 (1, N=284) = 11.62, p = 0.0007
[41] χ^2 (1, N=115) = 10.55, p = 0.0012
[42] χ^2 (1, N=284) = 9.916, p = 0.0016
[43] χ^2 (1, N=284) = 10.66, p = 0.0011
[44] χ^2 (1, N=284) = 23.10, $p \leq 0.0001$

DISCUSSION

Over four months in 2008, four museums of the Nanoscale Informal Science Education Network presented nano-topic programs, exhibits, forums and activities to increase the museum-going public's awareness of nanotechnology. Utilizing a web-based post-survey, this summative evaluation looked at dependent variables related to breadth and depth of awareness of nanotechnology for differences between a treatment group that was exposed to the nano-topic deliverables and a control group that was not exposed. The treatment and control groups did not differ with respect to distributions of gender, minority status, education, or disability. The treatment group was significantly but not meaningfully younger by two years on average; and, as a result of the recruitment procedure, the treatment group was more likely to have visited the museum within the last six months.

1. *Did exposure influence self-reported awareness of the term "nanotechnology"?*

Those exposed to nano-topic deliverables in the museums were significantly more likely to report having heard more about nanotechnology than those who were random museum members not exposed to the deliverables. Exposure appears to have increased awareness of the term "nanotechnology"; however, the self-selected treatment group could have had a higher awareness of the term prior to exposure. A pre-survey was not administered in this evaluation, so as not to interfere with or bias the visitors' natural museum experience.

2. *Did exposure influence top-of-the-mind verbal associations with the term "nanotechnology"?*

The treatment group was significantly more likely to describe an association with nanotechnology; however, there were no differences between the treatment and control groups as to coded categories of associations. Exposure to nano-topic deliverables appears to increase the museum public's confidence in their awareness rather than influencing the specifics of their awareness. Response associations from both treatment and control groups most frequently indicated an awareness of the nanoscience of nanotechnology and the potential benefits.

3. *Did exposure influence breadth of nanotechnology information sources?*

A majority of both the treatment and control groups who had heard of nanotechnology reported that print and the Internet were information sources for nanotechnology. Significantly more respondents in the treatment group than the control group remember exposure to nanotechnology in science centers, but this result would be expected since the treatment group was recruited at nano-events sponsored by the museums. Significantly more of the treatment group also recall reading about nanotechnology on consumer product labels; exposure to the museum nano-deliverables may have raised their awareness sufficiently to motivate them to check out labels.

4. *Did exposure influence awareness of benefits and risks of nanotechnology?*

Significantly more of the treatment group than the control group reported an awareness of benefits and risks of nanotechnology; however, the treatment group did not differ from the control group with respect to the kinds of benefits and risks they were able to describe. Again, it

would appear that the treatment group is more confident about their awareness but no different in their depth or breadth of awareness of specific benefits and risks.

5. *Did exposure influence awareness of applications of nanotechnology?*
Those exposed to the nano-topic deliverables were significantly more likely than those not exposed to be aware of how nanotechnology applications have filtered into their everyday lives. The treatment group was more likely to have heard of nanotechnology in applications with clothing or fabric, solar technology, air and water purifiers, paints or coatings, cosmetics or skin lotions, and insulation. About three-quarters of both groups felt that they were familiar with medical and computing applications.

6. *How did the treatment group describe changes in awareness as a result of exposure?*
Most (85%) of the treatment group could specifically identify having heard about or experienced one or more of the 39 nano-topic public deliverables. Respondents who could link their museum experience to an impact on their personal awareness of nanotechnology comprised 48% of forum attendees, 29% of those who experienced programs, 25% of those who experienced activities, and 9% of those exposed to exhibits. Respondents described the impact as informative, increasing their awareness of the term itself, or improving their understanding of nano scale or nano properties. Although this evaluation did not focus on the differential influence of deliverable types, significant associations between type of deliverable and some of the dependent variables reinforce the proposition that different kinds of deliverables emphasize different content and modalities and thus influence awareness of nanotechnology in different ways.

The survey research design implemented in this summative evaluation is not an experimental design; thus, we need to consider extraneous variables that may jeopardize the validity of the results. Of the possible threats to validity, the one that applies most to this evaluation is a selection effect. This refers to the idea that the differences between the treatment and control groups is due to self-selection of the treatment respondents to expose themselves to the nano-topic deliverables. For example, those who chose to attend a forum, view a presentation, participate in an activity or exhibit over the four months of the evaluation period might have been more interested, motivated or confident than those who did not. Due to self-selection, there may be other factors affecting the differences between groups other than exposure to the nano-topic deliverables.

While acknowledging that self-selection brings up alternative explanations for the results, exposure to nano-topic deliverables appears to increase the museum public's awareness of and associations with the term "nanotechnology," increase awareness of nanotechnology applications, and increase awareness of the existence of benefits and risks of nanotechnology. The results also give support to a future researchable hypothesis that different kinds of deliverables influence awareness of nanotechnology in different ways.