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

NANOTECHNOLOGY AND THE PUBLIC

Part I of Front-End Analysis in Support of Nanoscale Informal Science Education Network

Final Part I Report for
Nanoscale Informal Science Education Network

by
Barbara N. Flagg, Ed.D.
Director, Multimedia Research
Research Report No. 05-018
November 5, 2005

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 author and do not necessarily reflect the views of the National Science Foundation.

TABLE OF CONTENTS

EXECUTIVE SUMMARY: NANOTECHNOLOGY AND THE PUBLIC

PART I OF FRONT-END ANALYSIS IN SUPPORT OF NISE NETWORK

MULTIMEDIA RESEARCH • NOVEMBER 4, 2005

The Nanoscale Informal Science Education Network (NISE Network) is a national infrastructure that links science museums and other informal science education organizations with nanoscale science and engineering research organizations. The Network's overall goal is to foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology. In support of the NISE Network, this report reviews 20 secondary research documents with a focus on how nanotechnology has penetrated the consciousness of the general adult public.

Highlights:

- Less than half of the industrialized adult population of the U.S., Canada and the U.K. has heard of "nanotechnology" and no more than 20% can provide some sort of definition. Americans are much less aware of nanotechnology than other emerging technologies like stem cell research, biotechnology and genetically modified food.
- Interest in nanotechnology is quite low compared with other emerging and current technologies, but the most appealing aspects are medical applications and the small scale.
- Emotionally, the adult public is mostly positive about nanotechnology, expressing little fear, worry, anger or hopelessness.
- Half of Americans support the use of nanotechnology, even though they may know little about the topic. Exposure and attention to science news in newspapers, television and the web have significant positive relationship to support for nanotechnology.
- Most of the social science research on nanotechnology focuses on people's assessment of potential benefits and risks associated with the field. That benefits outweigh risks is the conclusion drawn by the majority of the populations sampled, particularly when they receive background information. The most favored benefits are medical and environmental. The most feared risks are risks to personal privacy and safety in health and regulation.
- With respect to nanotechnology players, scientists are trusted more than business leaders.
- Half of Americans assess nanotechnology as morally acceptable but concerns about equal access and scientists controlling nature are raised.
- Nanotechnology funding receives high public support.
- Although not really aware of current regulatory systems, half of the public recommends more stringent governmental regulation and increased consumer information.
- Half of the public feels that nanotechnology will improve our way of life in the next 20 years.
- Research has not yet found an influence of nano-related fiction on the public.

INTRODUCTION

The Nanoscale Informal Science Education Network (NISE Network) is a national infrastructure that links science museums and other informal science education organizations with nanoscale science and engineering research organizations. The Network's overall goal is to foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology. The Museum of Science in Boston is the lead institution working in partnership with the Exploratorium in San Francisco and the Science Museum of Minnesota in St. Paul to form the core leadership team for the project. An additional 10 organizational partners, 22+ "thinking partners," 12 advisors, and 2 evaluation firms form the initial fabric of the network.

A front-end analysis to support the NISE Network entails three parts:

I. A review of secondary research materials on the adult public's awareness, interest, knowledge and attitudes relating to nanotechnology;
II. A compilation of past and current projects that attempt to communicate nanoscale issues to the general public, including children;
III. A review of secondary research materials on communicating atomic structure, theory and behavior to a general audience.

The Part I review is presented in this document. It focuses on how nanotechnology has penetrated the consciousness of the general adult public and examines the following questions:

1. How aware of nanotechnology is the public?
2. What does the public know about nanotechnology?
3. What interests them about the field?
4. What emotions does nanotech engender?
5. What is the general support level for nanotechnology?
6. What are the public's attitudes toward
    a. potential benefits and risks of nanotechnology?
    b. morality and ethics of nanotechnology?
    c. governmental funding of nanotechnology?
    d. regulation of nanotechnology?
    e. nanotechnology players (e.g., scientists, business leaders)?
    f. the future of nanotechnology?
7. How does popular fiction relate to public's view of nanotechnology?

To address these questions, the review looks at recent data-based audience research with adults, consisting mostly of large public opinion survey reports; several academic focus group studies and three front-end reports for museum projects. The review addresses the above seven questions. The report appendix presents a paragraph summary of each reference and a longer elaboration of the reference content as it pertains to the NISE Network's goals.

The 20 studies included in this review were identified via scholar.google and google searches; references supplied by NISE Network affiliates; and communications with the study authors themselves. Dr. Susanna Hornig Priest, Assoc. Prof., University of South Carolina, was

particularly helpful in pointing the way to "forthcoming[1]" articles and international data. Reports from Canadian, U.K., and European Union samples are included to represent the international flavor of U.S. museum visitors but also to provide a richer and wider description of the status of adult reactions to the field of nanotechnology. Several studies, as indicated below, analyze the same data in different ways. The studies reviewed are described briefly below:

American samples:

2004 telephone survey of representative national sample of 1536 adults:

- Cobb, M. D. (forthcoming). Framing effects on public opinion about nanotechnology. *Science Communication*.
- Cobb, M. D., & Macoubrie, J. (2004). Public perceptions about nanotechnology: Risks, benefits and trust. *Journal of Nanoparticle Research, 6*, 395-405.

2004 telephone survey of representative national sample of 706 adults:

- Lee, C. , Scheufele, D., & Lewenstein, B. (forthcoming). Public attitudes toward emerging technologies: Examining the interactive effects of cognitions and affect on public attitudes toward nanotechnology. *Science Communication*. Made available by Dietram Scheufele, August 20, 2005.
- Scheufele, D. A., & Lewenstein, B. (forthcoming). The public and nanotechnology: How citizens make sense of emerging technologies. *Journal of Nanoparticle Research*. Retrieved September 9, 2005, from http://www.scholar.google.com

2004 online survey of representative sample of 400 adults:

- GolinHarris. (September 14, 2004). *Press release: U.S. leadership in nanoscience should be a government priority, say survey respondents*. Retrieved May 15, 2005, from Semiconductor Industry Association Web site: http://www.sia-online.org/pre_release.cfm?ID=333

2005 analysis of 12 focus groups of adults in 3 U.S. cities:

- Macoubrie, J. (September 8, 2005). *Informed public perceptions of nanotechnology and trust in government.* Project on emerging technologies at the Woodrow Wilson International Center for Scholars. Retrieved September 8, 2005, from http://www.wilsoncenter.org/index.cfm?fuseaction=events.event_summary&event_id=143410

2004-05 surveys of 495 people aged 7 to 91 in support of *Nanoworld Discovery Center* exhibits:

- Holladay, C. (2005). *A year in review: Internship in nanotechnology museum exhibit design*. Master's Description Paper, University of Wisconsin, Madison, WI. Retrieved November 1, 2005, from www.mrsec.wisc.edu/Edetc/IPSE_exhibits/about/share.html

2002 interviews of 41 adult and teen visitor groups at Museum of Science and Industry, Chicago:

- Gilmartin, J. (2002). *Nanotechnology: Front-end evaluation report.* Museum of Science and Industry: Chicago, IL. Made available by Barry Aprison, Museum of Science and Industry, August 18, 2005.

[1] "forthcoming" articles have been accepted for publication but are not yet available for public distribution. Such articles in this review were offered by authors in final manuscript form. However, some journals do not permit pre-distribution of "forthcoming" articles, and these will be brought to the Network's attention when published in 2006.

Undated survey of 60 teens and adults in support of *Nanozone* exhibit:

- Edu, Inc. (undated). *Windows on research: Front-end research: Evaluating museum visitors' readiness for and interest in learning new science.* Retrieved August 15, 2005, from Nanozone Web site: http://www.nanozone.org/museum.htm

Undated stratified survey of 1500 people aged 6 to 74 in support of *Too Small To See* exhibit:

- Waldron, A. M., Spencer, D., & Batt, C. A. (undated). *Too small to see: The current state of public understanding of nanotechnology.* Made available by Carl Batt, Cornell University, October 7, 2005.

American and Canadian samples:

2005 telephone survey of representative sample of 1200 American and 2000 Canadian adults:

- Canadian Biotechnology Secretariat. (March, 2005). *International public opinion research on emerging technologies: Canada-US Survey Results*. Retrieved September 9, 2005, from http://www.bioportal.gc.ca/english/View.asp?pmiid=524&x=720
- Priest, S. (2005). International audiences for news of emerging technologies: Canadian and U.S. responses to bio- and nanotechnologies. In E. Einsiedel (Ed.), *Unpublished project report to Canadian Biotechnology Secretariat*, University of Calgary. Made available by S. Priest, University of South Carolina, August 20, 2005.

2005 analysis of 24 focus groups of adults in 7 Canadian and 3 U.S. cities:

- Decima Research Inc. (March, 2005). *A Canada-US public opinion research study on emerging technologies*. Report for The Canadian Biotechnology Secretariat Industry Canada. Retrieved September 9, 2005, from http://www.bioportal.gc.ca/english/View.asp?pmiid=524&x=720

American and European samples:

2002 face-to-face interviews of 15,000 EU adults and telephone survey of 850 Americans:

- Gaskell, G., Ten Eyck, T., Jackson, J., & Veltri, G. (2005). Imagining nanotechnology: Cultural support for technological innovation in Europe and the United States. *Public Understanding of Science*, *14*(1), 81-90.

Canadian samples:

2004 telephone survey of representative sample of 1000 adults and analysis of 8 focus groups:

- Pollara Inc. (March, 2004). *Public opinion research findings on emerging technologies*. Report for Biotechnology Assistant Deputy Minister Coordinating Committee (BACC), Government of Canada. Retrieved September 9, 2005, from http://www.bioportal.gc.ca/english/View.asp?x=524&mp=521

U.K samples:

2004 face-to-face interviews of representative sample of 1005 adults and discussion workshops with 40:

- BMRB Social Research (January, 2004). *Nanotechnology: Views of the general public*. (International report 45101666). Retrieved August 15, 2005, from http://www.nanotec.org.uk/Market%20Research.pdf

European Union samples:
2005 face-to-face interviews of representative sample of 33,000 adults:

- TNS Opinion and Social. (June, 2005a). *Eurobarometer 224/Wave63.1: Europeans, Science and Technology*. Retrieved September 9, 2005, from http://europa.eu.int/comm/research/press/2055/pr1306ben.cfm
- TNS Opinion and Social. (June, 2005b). *Eurobarometer 225/Wave63.1: Social Values, Science and Technology*. Retrieved September 9, 2005, from http://europa.eu.int/comm/research/press/2055/pr1306ben.cfm

Internet samples:
2001 Internet survey of 3909 volunteer respondents:

- Bainbridge, W. S. (2002). Public attitudes toward nanotechnology. *Journal of Nanoparticle Research*, 4, 561-570.

2004 book purchasing data from Amazon.com:

- Schummer, J. (2005). Reading nano: The public interest in nanotechnology as reflected in purchase patterns of books. *Public Understanding of Science, 14* (2), 163-183.

All of the above reports use only the term "nanotechnology" in their explorations with the public. Because public awareness of the term itself is currently quite low, most research protocols eventually define it for their respondents. Base definitions that are reported in the above documents include the following:

> "…nanotechnology, which works at the molecular level atom by atom to build new structures, materials, and machines." (Bainbridge, 2002, p. 561).
>
> "Nanotechnology is the process of manipulating materials at the minuscule level of atoms and molecules. Another way to say this is that nanotechnology refers to the manipulation of living and non-living matter at the level of the nanometer, one billionth of a meter." (Cobb, forthcoming; also used in Cobb & Macoubrie, 2004)
>
> "Nanotechnology is an emerging field of technology that is developing out of the science of the very small (one billionth of a meter) – the world of atoms and molecules, the building blocks of all physical things. Note: A nanometer is one billionth of a meter; a molecule is about 1 nanometer is size. Tools that can be used to see, pick up, and move atoms allow us to build nano-sized structures and devices with unprecendented capacities for information processing and storage, electrical conductance, and bio- and chemical- sensing." (Gilmartin, 2002, p. 6)
>
> "…involving the study, manipulation, and manufacturing of ultra-small structures and machines made of as few as one molecule, with applications in industry, health, and the environment." (Pollara, 2004, p. 6)
>
> "Recently there has been a lot of talk about new technologies that allow scientists to manipulate materials at the level of tiny molecules. This could lead to the development of extremely small computers, or the improvement of existing materials. This is usually referred to as "nanotechnology." (Scheufele & Lewenstein, forthcoming, p. 20 in pre-publication manuscript; also used in Lee, Scheufele & Lewenstein, forthcoming)
>
> Macoubrie's (2005) focus groups read 4-5 background pages on nanotechnology and applications.

AWARENESS OF NANOTECHNOLOGY

Lots of products but little awareness

Nanotechnology is rapidly penetrating the public marketplace mostly in the sports arena through such products as tennis rackets and balls, ski wax, sunscreen, foot warmers, clothing, golf drivers and golf balls.[2] The term "nano" is also breaking into common parlance, inaccurately through products like Apple's iPod nano[3] and kids' toys like Nano Bloks™[4] and even on bottle labels like A1 Steak Sauce's: "Place bottle upside down so you can get the last drop. Or half drop. Or nano-fraction of a half drop."[5] Nanomaterial products are arriving daily, yet recent international and national polls indicate that the general public is largely unaware of nanotechnology.

Surveys of representative samples of adults in the U.S., Canada and the U.K. find that as recently as the winter of 2005 less than half of this industrialized population has heard of "nanotechnology" (BMRB Social Research [BMRB], 2004; Canadian Biotechnology Secretariat [CBS], 2005; Cobb & Macoubrie, 2004; Pollara Inc., 2004; Scheufele & Lewenstein, forthcoming; Waldron, Spencer & Batt, n.d.). In fact, awareness is so low that some survey studies provide a definition in order to assess familiarity.

Americans are less aware of nanotechnology than other emerging technologies (CBS, 2005):

- 83% say they are "very" or "somewhat" familiar with stem cell research (after being read a definition);
- 66% say they are "very" or "somewhat" familiar with biotechnology (no definition given)
- 66% say they are "very" or "somewhat" familiar with genetically modified food (no definition given)
- 42% say they are "very" or "somewhat" familiar with nanotechnology (after being read a definition)

A few survey studies analyzed subgroups to reveal that awareness is significantly higher among men (BMRB, 2004; Pollara Inc., 2004); among those with higher socioeconomic status (BMRB, 2004); and among younger respondents (<55 years; BMRB, 2004). Waldron et al (n.d.) finds that 71% of college age respondents (18-22 years) say they have heard of "nanotechnology" compared with 50% of those in the 14-59 year bracket and about 33% of those 60 years and over.

Studies conducted in support of the development of U.S. museum projects find lower awareness of nanotechnology in adults and teens than the above surveys of larger more representative audiences (Edu, inc, n.d.; Gilmartin, 2002; Holladay, 2005).

[2] http://www.forbes.com/investmentnewsletters/2005/01/12/cz_jw_0112soapbox.html
[3] http://www.apple.com/ipodnano/
[4] http://www.megabloks.com/en/products/browse.php?level=2&level2=1&subCat=21&lId=0
[5] Example submitted by Pamela Winfrey, Senior Artist, The Exploratorium

KNOWLEDGE OF NANOTECHNOLOGY

Low awareness, even lower knowledge

American, Canadian and U.K. citizens are mostly unable to define nanotechnology. About 20% of the population can provide some sort of definition (BMRB, 2004; Holladay, 2005; Macoubrie, 2005). About one-quarter knows that nanotechnology is anticipated to be the next "big thing" (Macoubrie, 2005; Decima Research Inc., 2005). In terms of subgroup differences, men and those aged 35-54 are more likely to give some definition (BMRB, 2004).

Gilmartin (2002) finds in open-ended interviews that 10% of museum visitor groups can correctly explain the term "nanotechnology," typically referring to applications. Some relate nanotechnology to time, as in nanoseconds. The evaluation reports that "visitors could talk about atoms and molecules, but not with ease or confidence (p. 9). The phrase "the building blocks of all physical things" is less discomforting. Comparing nano size to human hair is successful in helping visitors understand the small scale, but visitors have difficulty grasping the physical structure of a nanoscale object.

Members of the public with some nanotechnology knowledge can describe current or potential medical or electronic applications. BMRB (2004) notes that the most common respondent definition of nanotechnology focuses on miniaturization or technology on a small scale. The second most common definition depicts potential applications in computing, electronics or medicine. Canadian-U.S. focus group participants understand that nanotechnology involves "tiny machines" but beyond that, specifics are not known (Decima Research Inc., 2005). Applications most often recalled in focus group discussion include an ingestible camera; implantable devices to regulate drugs; implantable tracking monitors; and less invasive surgery (Decima Research Inc., 2005). Museum visiting groups are most familiar with applications of high-speed computer chips, nanobots and biosensors, although some are uncertain whether the application they note is actually a nanotech application (Gilmartin, 2002).

To obtain more detailed knowledge estimates, two studies tested with true-false statements. In Scheufele & Lewenstein (2004), Americans answer correctly an average of four of six true-false nanotechnology statements. Respondents cannot accurately recognize scale facts about nanotechnology in the T/F statements of "a nanometer is a billionth of a meter" or "a nanometer is about the same size as an atom." However, they are aware (beyond chance) that "nanotechnology involves material not visible to the naked eye;" that it "allows scientists to arrange molecules in a way that does not occur in nature;" that it is "the next industrial revolution;" and that nanotech "products are sold today." In the second study that used T/F statements, respondents answer correctly, on average, one of three statements presented at the end of a telephone survey (Cobb & Macoubrie, 2004). Specific percentage responses and statistical analyses are not given for the T/F statements: "Nanotechnology involves materials that are barely visible to the naked eyes"; "Industry is already using nanotechnology to make products sold today"; "Nanotechnology is predicted to be the next industrial revolution of the U.S. economy."

Waldron et al. (n.d.) also finds low knowledge of nanoscale facts in a survey 1500 non-random respondents aged 6-74: 1% of their respondents could define "nano" as one-billionth or "nanotechnology" as "manipulation of matter at length scales of less than 100 nanometers." 'Nano' was defined as 'small' or 'really small' and sometimes interpreted as "an acronym, a Spanish word, or a term for grandmother" (p. 6); whereas 'nanotechnology' "was making tiny things, science, or a type of computer technology" (p. 6). As the smallest thing they could think of, nanoscale objects like proton, atom, and molecule were offered most often by college age students (58%) and next often by 40-59 year olds (48%). Holladay (2005) also asked a non-random sample of 495 Wisconsin residents about the smallest thing they could think of and found that responses of nanoscale objects increased with age and/or education: 5% for 2nd-5th grade; 1% for 6th-8th grade; 21% for 9th-12th grade and 43% for college and beyond.

Most commonly noted sources of knowledge about nanotechnology by Macoubrie's (2004) American focus groups are public TV, public radio, magazines and talking with another person. Sources for nanotechnology for Holladay's (2005) Wisconsin sample included TV, magazines and newspapers. Americans in Waldron's (n.d.) sample say they learn about nanotechnology "because they are avid readers, science enthusiasts, NPR listeners, or investors" (p.6).

INTEREST IN NANOTECHNOLOGY

Low interest relative to other technologies but most appealing are medical applications and the small scale

Survey research finds that interest in nanotechnology is very low when compared with other emerging and current technologies, but this low interest likely correlates with low awareness and knowledge. European Union residents, who are very or moderately interested in either "new inventions and technologies" or "scientific discoveries," were asked which of seven science and technology developments they are most interested in. Nanotechnologies comes in lowest with only 8% expressing interest, but this 2005 percentage is reportedly double what was measured in 2001. Men express more interest than women, and those with higher education express more interest. The more interesting technology fields are medicine (61%), environment (47%), humanities (30%), Internet (29%), economics and social sciences (24%), astronomy and space (23%) and genetics (23%) (TNS Opinion and Social, 2005a).

More open discussion with small samples of the public in support of museum exhibits concludes that most are interested in medical applications and the small scale of nanoscience. Visitors to the Chicago Museum of Science and Industry are most interested in the small scale of science, personal benefits of technology applications and the cutting-edge nature of nanotechnology. (Gilmartin, 2002). More knowledgeable visitors are interested in applications, current developments and learning about how devices are made. Less knowledgeable visitors are interested in medical applications. The small scale of nanoscience intrigues both groups. Moreover, Edu, inc (n.d.) notes that 60% of teen and adult respondents surveyed in upstate NY are "very interested" or "interested" in how scientists move individual atoms, although respondents have difficulty articulating the concept of an atom.

After hearing about potential nanotechnology applications in medicine, information technology, materials, sensors and cosmetics, U.K. discussion group participants are most interested in creation of new materials and possible medical applications that might improve their quality of life. (BMRB, 2004).

EMOTIONS ABOUT NANOTECHNOLOGY

Mostly positive emotions

The few researchers studying affect report that fear, worry, anger and hopelessness is minimal relative to nanotechnology. After hearing a definition of nanotechnology, 83% of Americans are very or somewhat hopeful about nanotechnology, 82% are not angry and 74% are not worried (Cobb, forthcoming). Lee, Scheufele and Lewenstein (forthcoming) asked American respondents to rate their fear of potential effects of scientific research and their worry about nanotechnology. On average, both fear and worry are relatively low on a ten-point scale. Women, older people, and ethnic minorities are significantly more likely to feel negative toward nanotechnology than their counterparts. Also, there is a strong link between people's fear of potential effects of scientific research and their worry about nanotechnology (Lee at al, forthcoming).

Additionally, providing information about nanotechnology appears to have some influence on respondent feelings. After hearing a definition of nanotechnology and then more information about health benefits, anger about nanotechnology tends to decrease, whereas after hearing more information about health risks, hopefulness tends to decrease; however, the changes, although significant, are small at 9 - 10% (Cobb, forthcoming). Macoubrie (2005) finds that prior to reading about nanotechnology, 21% of American focus group participants are "quite" or "mostly" positive about nanotechnology but 41% answer "don't know." After reading and discussion of nanotechnology basics, applications, and regulation, the "don't know" responses decrease and those feeling positive about nanotechnology increase to 50%.

GENERAL PUBLIC SUPPORT LEVEL FOR NANOTECHNOLOGY

Moderate public support

Half of surveyed Americans say they "support the use of nanotechnology" (Scheufele & Lewenstein, forthcoming). After hearing a definition and specific applications, three-quarters of surveyed Canadians are supportive of nanotechnology (Pollara Inc., 2004). Canadian men show a higher level of support than women, and support is higher among respondents who are familiar with the term (Pollara Inc., 2004). However, Scheufele & Lewenstein (forthcoming) find that knowledge about nanotechnology is not significantly predictive of "support," after other demographic and background variables are statistically controlled for. The authors suggest that increases in factual knowledge about nanotechnology will not necessarily lead to higher levels of public support.

Studies about American support for nanotechnology look at factors influencing that support. They conclude that science media exposure and negative sentiments about nanotechnology have significant influence on support. For example, Scheufele & Lewenstein (forthcoming) reveal that heavier users of science media are more supportive of nanotechnology than light users. Exposure and attention to science news in newspapers, television and on the web have a significant positive relationship to nanotechnology support. The researchers suggest that supporters of nanotechnology need to frame their messages in mainstream media to influence public support. Lee et al (forthcoming), analyzing the same survey data as Scheufele & Lewenstein, looked at separate and combined effects of cognitive and affective factors on support of nanotechnology. They find a significant interaction effect: For respondents who are worried about nanotech, knowledge of nanotech has a weaker effect on their general support than for respondents who are not so worried. To interpret this in non-statistical terms, the finding means that giving people information works better to build support when they are not worried than when they are worried. The authors point out that this finding highlights the importance of controlling the emotional involvement of participants in public forums, since new information may be ineffective if processed through strong emotional heuristics.

ATTITUDES TOWARD NANOTECHNOLOGY BENEFITS AND RISKS

Benefits favored over risks
Most favored benefits: Medical and environmental
Most feared risks: Privacy and safety

Most of the social science research on nanotechnology focuses on people's assessment of potential benefits and risks associated with nanotechnology. That benefits outweigh risks is the conclusion drawn by the majority of the population sampled, particularly when they have background information about the field.

Benefits vs. Risks

In spite of knowing next to nothing about nanotechnology, nine out of ten Americans give ratings that nanotechnology research is of benefit to society, with one-third seeing "substantial benefit." On the other side of the coin, five out of ten Americans agree there are risks of nanotechnology but only 14% see "substantial" or "some" risks (CBS, 2005).

Using agree/disagree statements about benefits and risks, Bainbridge (2002) finds that almost six of ten volunteer respondents to a 2001 Internet survey agree that humans will benefit from nanotechnology, defined as "working at the molecular level atom by atom to build new structures, materials, and machines." More men than women agree with the benefit statement. Less than one out of ten agree that 21st century technologies, including nanotechnology, are threatening to make humans an endangered species (Bainbridge, 2002). Scheufele & Lewenstein (forthcoming) also use agree/disagree statements to reveal that in 2004 the majority of Americans are optimistic about nanotechnology, and those more aware of the field are significantly more positive than those with less awareness.

Comparing benefits to risks, Cobb & Macoubrie (2004) find that four out of ten surveyed Americans agree that potential benefits of nanotechnology outweigh risks, and four out of ten say benefits equal risks. Those most likely to agree that benefits outweigh risks are white, more educated, more familiar with nanotechnology, more hopeful, less worried and more positive about science overcoming problems.

Benefits

Of benefits described to the American public, most favored are those in medicine. For example, Cobb & Macoubrie (2004) report that 57% of Americans feel "new ways to detect and treat human diseases" is the most important benefit to achieve among five presented. Scheufele & Lewenstein (forthcoming) note that 74% of Americans agree with the statement that "nanotech may lead to new and better ways to treat and detect human diseases," and 62% agree that "nanotech may give scientists the ability to improve human physical and mental abilities." In national focus groups, benefits of most interest in discussion are medical applications and consumer products (Macoubrie, 2005).

The second more favored nanotechnology benefit described to the public is cleaning up the environment. Cobb & Macoubrie (2004) indicate that 16% of Americans feel "new ways to clean the environment" is the most important benefit to achieve among five presented. Scheufele & Lewenstein (forthcoming) report that 62% agree with the statement that "nanotech may lead to new and better ways to clean up the environment."

Participants in 2005 Canadian-U.S. focus groups feel that nanotechnology will bring jumps in both health and environmental benefits. After hearing about health benefits, participants feel that benefits outweigh risks; however, for the environment, participants mainly ask "where do these nanomolecules go" (Decima Research, 2005).

A 2004 Canadian telephone survey reinforces the American findings that medical and environmental benefits are supported by most of the public (Pollara, 2004):

- 92% see as beneficial "a tiny wireless 'lab on a chip' that can be placed into the eardrum of deaf people that will enable them to hear."
- 83% see as beneficial "the use of molecules that have magnetic properties to extract heavy metals in water treatment facilities."
- 83% see as beneficial "the use of light-sensitive molecules that have the ability to detect pollutants in water and air, by the amount of light they emit."
- 73% see as beneficial "advanced drug 'labs on a chip,' that would be placed in/on the body that would automatically monitor levels of drugs in the body and automatically administer treatments as needed."
- 69% see as beneficial "the use of 'nanocatalysts' in oil sands development, which are molecules that separate the sand from the oil, that substitute for the energy intensive separation processes that are currently used."

Risks

Of risks described for the public, the most feared is loss of personal privacy. Cobb & Macoubrie (2004) reveal that 32% of Americans say "losing personal privacy" is the most important risk to

avoid among five presented. Data from the survey of Scheufele & Lewenstein (forthcoming) support privacy as critical to the public: 60% of Americans agree with the statement that "nanotech may lead to a loss of personal privacy because of tiny new surveillance devices." Decima Research (2005) says that the main negative spontaneously brought up in focus groups related to potential privacy concerns, particularly for U.S. participants in light of the Patriot Act.

The "risk of an arms race" is second in the public's mind but is much less feared compared with loss of personal privacy (Cobb & Macoubrie, 2004; Scheufele & Lewenstein, forthcoming). The public rates the idea of an "uncontrollable spread of nano-robots" at the bottom of Cobb & Macoubrie's (2004) list of five foreseeable risks and Scheufele & Lewenstein's (forthcoming) list of four potential risks.

Open-ended discussion elicits concerns about safety issues related to health and regulatory control, which were not asked about in closed-ended questions in the previously mentioned survey studies. Macoubrie's (2005) American focus group discussions indicate that risks of most concern are unpredictable outcomes, health risks and regulation. Groups visiting Chicago's Museum of Science and Industry see only positive benefits to nanotechnology but some express general fears associated with any emerging technology. Issues raised concern privacy, medical side effects, and regulatory control (Gilmartin, 2002). In U.K. discussion groups, participants are also positive about nanotechnology applications but are concerned about privacy and safety (e.g., side-effects, long-term use effects, reliability) as well as environmental impacts about disposability and use of fewer resources (BMRB, 2004). Canadians in focus groups are most positive if an application provides personal benefit and are most concerned about long-term risks to human health and the environment (Pollara, 2004).

Influence of information

The influence of information on the public's assessment of benefits and risks appears variable depending upon how the study is designed:

- Using focus groups, Macoubrie (2005) finds that 65% of Americans are uncertain about the risk-benefit equation. After reading a short document about nanoresearch basics, applications, and roles of regulatory agencies, the "don't know" responses decrease as participants take more informed positions. Prior to reading, 16% say benefits will exceed risks, and after reading, 41% agree.

- Cobb's (forthcoming) respondents heard extra description to assess the influence of differing frames of information on attitudes. Those who hear about potential risks to health or to other areas feel that nanotechnology will be more risky but still not outweigh its benefits. Information about health benefits tends to increase responses that nanotechnology is beneficial, but still only five of ten of this group favor benefits over risks. Exposure to positive and negative information frames results in, at most, a minimal 10% change in attitudes.

- Lee et al (forthcoming) use 2004 national telephone survey data about perceptions of risks and benefits of nanotechnology to test a model of decision-making about emerging technologies. Those likely to perceive more benefits than risks fall in the higher levels of

education, income, science media use, general science knowledge and trust of scientists. Those who perceive more risks than benefits for nanotechnology are women and those showing higher levels of negativity toward nanotech and science in general. The regression analysis yields a significant interaction effect: Knowledge about nanotechnology has a significantly stronger influence on rating benefits over risks for respondents who show low levels of negative emotion toward nanotechnology than for those who show high levels of negative emotion.

ATTITUDES TOWARD NANOTECHNOLOGY PLAYERS

Scientists trusted more than business leaders

On the whole, the American public trusts scientists but is not so sure about trusting business leaders. Trust appears dependent less on knowledge and more upon one's values and beliefs. In any case, the public would like to be informed about risks and benefits and make their own decisions about products.

Nanotechnology is considered to be "in safe hands" with scientists by three-quarters of surveyed Americans (CBS, 2005). The majority of participants in Canadian-U.S. focus groups also express a high level of trust in scientists, although people note some fear of scientists going "too far;" fear of amoral science; and fear of negative corporate influences. (Decima Research Inc., 2005). In contrast, half of surveyed Americans do "not much trust" business leaders within the nanotechnology industry to minimize potential risks to humans. Given extra information about non-health risks of nanotechnology decreases trust significantly, so that three-quarters of respondents express low trust toward business leaders (Cobb, forthcoming).

In terms of decision-making, about seven of ten Americans feel that decisions about nanotechnology should be based on expert advice and on scientific evidence of risk and benefit; however, authorities should inform people about nanotechnology and let them decide for themselves about product usage (CBS, 2005). Priest's (2005) statistical reanalysis of the CBS data yields five subgroups of respondents, based on their decision-making preferences. For example, "true believers" see technology as more beneficial than risky and believe experts should make decisions about policy based on risks and benefits; whereas "ethical populists" believe that lay people should decide on the basis of morality or ethics. In the U.S. data, "true believers" comprise 35% of the sample and "ethical populists," 14%. In the Canadian data, the distribution is 26% and 15%. Subgroup differences appear in analyses of respondents' level of trust in a variety of information sources. For example, "true believers" believe information from the scientific community; whereas "ethical populists" are more likely to trust information from non-scientific sources – religious, political and environmental (Priest, 2005).

ATTITUDES TOWARD MORALITY AND ETHICS OF NANOTECHNOLOGY

Concerns about equal access and controlling nature are raised but intensity of feeling depends upon attitudinal predisposition toward technology

Exploration of the morality and ethics of nanotechnology is not a strong component in the body of social research studies so far. Issues raised in focus groups include concerns about equal access to nanotechnology's benefits and the morality of scientists' changing nature at an atomic level. Attitudes appear to reflect underlying values and beliefs.

In Canadian-U.S. focus groups, ethical issues are rarely raised for applications, although participants bring up the issue of equal access, which is typically on people's minds for all emerging technologies (Decima Research, 2005). In U.K. discussion groups, participants raise ethical implications of scientists controlling nature at the atomic levels and whether such outcomes are morally desirable (BMRB, 2004).

A telephone survey reveals that about half of Americans and half of Canadians assess nanotechnology as "morally acceptable." Half of Americans trust that authorities will ensure that nanotechnology research will follow ethical guidelines (CBS, 2005). In a reanalysis of the CBS survey data, Priest (2005) concludes that attitudes reflect, not knowledge, but underlying differences in values and beliefs. For example, respondents were asked if nanotechnology has or has not been carried out in consideration of their interests, values and beliefs. Affirmative answers are given by 50% overall, but by 70% of the subgroup identified as "true believers" and by 25% of the subgroup described as "ethical populists." Compared with responses to the same question about biotechnology, "…the pattern [of subgroup differences] is even clearer for nanotechnology, arguably reflecting the relative importance of attitudinal predispositions in a newer area of technology for which a lower percentage of the public had had the opportunity to become informed about the technology" (p.9).

ATTITUDES TOWARD GOVERNMENTAL FUNDING

High public support of nanotechnology funding

National surveys indicate relatively high support by both Americans and Canadians of governmental funding of nanotechnology research. In 2005, about three-quarters of Americans (who were read a definition of nanotechnology) say that government should be involved in funding nanotechnology research: 32% support "active" involvement and 46% support "moderate" involvement (CBS, 2005). In Scheufele & Lewenstein's 2004 study, 42% of Americans (who were read a definition of nanotechnology) support federal funding of

nanotechnology.[6] Those who said they are aware of nanotechnology express significantly higher support (49%) than those unaware (22%); however, Scheufele & Lewenstein's statistical analyses conclude that knowledge about nanotech is not statistically related to attitudes about funding.

In a 2004 online survey, nine of ten respondents, representative of the general U.S. population, agree that "continued U.S. global leadership in technology is important to the nation's economy," and almost eight of ten believe that "funding for research into the new fields of nanoscience and nanotechnology should be a priority of both federal and state governments." Six of ten say, "the government should increase current funding levels for nanotechnology research" (GolinHarris, 2004).

For the Canadians, three-quarters of those surveyed believe that nanotechnology is important for Canadian economy and society and believe it should be supported. They hope that experts will make decisions about support based on individual applications (Pollara Inc., 2004).

ATTITUDES TOWARD NANOTECHNOLOGY REGULATION

Moderate support of more regulation

Nano size and unexpected properties of nanomaterials present challenges to regulatory systems. At this point in the public's perceptions and understandings of nanotechnology, about half of Americans and three-quarters of Canadians feel that more governmental and not voluntary regulation of the industry is called for (CBS, 2005; Macoubrie, 2005; Pollara Inc., 2004). Moreover, most Americans feel that a ban on nanotechnology until further study is an overreaction (Macoubrie, 2005).

However, participants in 2005 Canadian-U.S. groups raise concerns about stringency of current regulatory systems. Their confidence in such systems is low to moderate in general (Decima Research, 2005). In fact, of six regulatory agencies assessed for their potentially effective management of nanotechnology risks, the Centers for Disease Control receives the highest level of trust but only at 50% (Macoubrie, 2005). Recommendations for increasing public trust include increased safety tests before market and more consumer product information (Macoubrie, 2005).

In the U.K. discussion groups, scientists presented nanotech facts and applications. Afterward, participants ask about financial advantages and disadvantages to the government and to the individual. They raise the issues of social and political impacts on employment, control over society by government and corporations, and positioning of developing nations vis-à-vis industrialized nations. Participants mention the issues of controlling and regulating nanotechnology on national and international levels and how the public might be involved in such activity (BMRB, 2004).

[6] These two studies ask different funding questions of different samples so the difference in percentages cannot be interpreted validly as an increase over time.

ATTITUDES ABOUT THE FUTURE OF NANOTECHNOLOGY

Improved way of life predicted by half

Fairly consistently, the surveys of Americans, Canadians and Europeans find that half of the population thinks that nanotechnology will improve our way of life in the next 20 years (BMRB, 2004; CBS, 2005; Gaskell, Ten Eyck, Jackson & Veltri, 2005; TNS Opinion and Social, 2005b).

Other technologies, of which respondents are more aware, are seen as more likely to improve future life than nanotechnology (e.g., hybrid cars; computers; biotech; stem cell research). However, in a different phrasing of the future scenario, eight of ten respondents agree with the statement: "nanotechnology research represents the next frontier of human endeavor, a frontier that will lead to significant quality of life benefits for all Americans" (CBS, 2005). Americans are also significantly more optimistic than Europeans about the impact of other more familiar technologies. The authors conclude that the U.S. respondents "assimilate nanotechnology within a set of pro-technology cultural values" (Gaskell, Ten Eyck, Jackson & Veltri (2005), p. 81).

Changes from 2001 data to 2005 data about European Union members indicate increased familiarity and movement toward a more positive viewpoint. In 2005, the EU public was interviewed as to whether nanotechnology will have "a positive effect, negative effect or no effect on our way of life in the next 20 years." About half say a positive effect and 40% say, "don't know." A similar question, asked of EU members in 2001, yielded 29% positive and 53% "don't know." "Don't know" responses have decreased and optimism about the field has increased (TNS Opinion and Social, 2005b).

POPULAR FICTION AND NANOTECHNOLOGY

No meaningful relationship found yet

Nanotechnology made appearances in popular fiction in the late 1980's. Several hundred fiction books are identified as having nano-related content.[7] Best known is possibly Michael Crichton's 2002 book *Prey*, in which a swarm of self-replicating nanoscale entities are the bad guys. Nanotechnology even plays a malevolent part in teen spy literature as "nano shells" injected into children with routine inoculations.[8] Yet the few social science studies that have looked into the influence of fictional nanotechnology on people's attitudes toward real nanotechnology have not yet found a meaningful relationship.

[7] See http://www.geocities.com/asnapier/nano/n-sf/ for a listing of Nanotechnology in Science Fiction by Anthony Napier

[8] See *Scorpia: An Alex Rider Adventure* (2005) by Anthony Horowitz, author of teenage spy books. I'm grateful to Pamela Winfrey, Senior Artist, The Exploratorium, for this example.

Cobb & Macoubrie (2004) find that 8% of American surveyed respondents have read or talked about the novel *Prey*, but exposure is not significantly predictive of people's perceptions of risks versus benefits of nanotechnology. In a different study, 16% of surveyed Americans agree with the statement that "nanotech may lead to the uncontrollable spread of very tiny self-replicating robots" (Scheufele & Lewenstein, forthcoming). In a unique analysis of co-purchase book data from Amazon.com, Schummer (2005) concludes that readers of popular nanotechnology books are not inspired to buy nano-science fiction or vice versa. In the specific case of *Prey*, Schummer finds no direct link to any non-fiction book in co-purchase patterns.

Finally, in a pre-*Prey* Internet survey, Bainbridge (2002) finds that agree/disagree responses to benefit/risk statements have zero correlation with responses to two statements about pseudoscience ("Some scientific instruments [e.g., e-meters, psionic machines, and aura cameras] can measure the human spirit." "Perpetual motion machines, anti-gravity devices, and time travel machines are physically impossible."). Responses in favor of nanotechnology's benefits correlate significantly with agreement in support of the space program, nuclear power and cloning research. Bainbridge concludes that "nanotechnology has no measurable connection with pseudoscience in people's minds, even as they connect it strongly with other kinds of genuine technology." (p. 564). Bainbridge's survey also finds that less than one out of ten agree that 21st century technologies, including nanotechnology are threatening to make humans an endangered species.

REFERENCES

Bainbridge, W. S. (2002). Public attitudes toward nanotechnology. *Journal of Nanoparticle Research*, *4*, 561-570.

BMRB Social Research (January, 2004). *Nanotechnology: Views of the general public*. (International report 45101666). Retrieved August 15, 2005, from http://www.nanotec.org.uk/Market%20Research.pdf

Canadian Biotechnology Secretariat. (March, 2005). *International public opinion research on emerging technologies: Canada-US Survey Results*. Retrieved September 9, 2005, from http://www.bioportal.gc.ca/english/View.asp?pmiid=524&x=720

Cobb, M. D. (forthcoming). Framing effects on public opinion about nanotechnology. *Science Communication*.

Cobb, M. D., & Macoubrie, J. (2004). Public perceptions about nanotechnology: Risks, benefits and trust. *Journal of Nanoparticle Research, 6*, 395-405.

Decima Research Inc. (March, 2005). *A Canada-US public opinion research study on emerging technologies*. Report for The Canadian Biotechnology Secretariat Industry Canada. Retrieved September 9, 2005, from http://www.bioportal.gc.ca/english/View.asp?pmiid=524&x=720

Edu, inc. (undated). *Windows on research: Front-end research: Evaluating museum visitors' readiness for and interest in learning new science.* Retrieved August 15, 2005, from Nanozone Web site: http://www.nanozone.org/museum.htm

Gaskell, G., Ten Eyck, T., Jackson, J., & Veltri, G. (2005). Imagining nanotechnology: Cultural support for technological innovation in Europe and the United States. *Public Understanding of Science*, *14*(1), 81-90.

Gilmartin, J. (2002). *Nanotechnology: Front-end evaluation report.* Museum of Science and Industry: Chicago, IL. Made available by Barry Aprison, Museum of Science and Industry, August 18, 2005.

GolinHarris. (September 14, 2004). *Press release: U.S. leadership in nanoscience should be a government priority, say survey respondents*. Retrieved May 15, 2005, from Semiconductor Industry Association Web site: http://www.sia-online.org/pre_release.cfm?ID=333

Holladay, C. (2005). *A year in review: Internship in nanotechnology museum exhibit design*. Master's Description Paper, University of Wisconsin, Madison, WI. Retrieved November 1, 2005, from www.mrsec.wisc.edu/Edetc/IPSE_exhibits/about/share.html

Lee, C. , Scheufele, D., & Lewenstein, B. (forthcoming). Public attitudes toward emerging technologies: Examining the interactive effects of cognitions and affect on public attitudes toward nanotechnology. *Science Communication*. Made available by Dietram Scheufele, August 20, 2005.

Macoubrie, J. (September 8, 2005). *Informed public perceptions of nanotechnology and trust in government.* Project on emerging technologies at the Woodrow Wilson International Center for Scholars. Retrieved September 8, 2005, from Woodrow Wilson International Center for Scholars Web Site: http://www.wilsoncenter.org/index.cfm?fuseaction=events.event_summary&event_id=143410

Pollara Inc. (March, 2004). *Public opinion research findings on emerging technologies*. Report for Biotechnology Assistant Deputy Minister Coordinating Committee (BACC), Government of Canada. Retrieved September 9, 2005, from http://www.bioportal.gc.ca/english/View.asp?x=524&mp=521

Priest, S. (2005). International audiences for news of emerging technologies: Canadian and U.S. responses to bio- and nanotechnologies. In E. Einsiedel (Ed.), *Unpublished project report to Canadian Biotechnology Secretariat*, University of Calgary. Made available by S. Priest, University of South Carolina, August 20, 2005.

Scheufele, D. A., & Lewenstein, B. (forthcoming). The public and nanotechnology: How citizens make sense of emerging technologies. *Journal of Nanoparticle Research*. Retrieved September 9, 2005, from http://www.scholar.google.com

Schummer, J. (2005). Reading nano: The public interest in nanotechnology as reflected in purchase patterns of books. *Public Understanding of Science, 14* (2), 163-183.

TNS Opinion and Social. (June, 2005a). *Eurobarometer 224/Wave63.1: Europeans, Science and Technology*. Retrieved September 9, 2005, from http://europa.eu.int/comm/research/press/2055/pr1306ben.cfm

TNS Opinion and Social. (June, 2005b). *Eurobarometer 225/Wave63.1: Social Values, Science and Technology*. Retrieved September 9, 2005, from http://europa.eu.int/comm/research/press/2055/pr1306ben.cfm

Waldron, A. M., Spencer, D., & Batt, C. A. (undated). *Too small to see: The current state of public understanding of nanotechnology.* Made available by Carl Batt, Cornell University, October 7, 2005.

For access to the 40 page Appendix, please contact Barbara Flagg at FlaggB@aol.com.