

The public and nanotechnology: How citizens make sense of emerging technologies

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Abstract

We report findings from a national telephone survey on levels of knowledge about and attitudes toward nanotechnology that demonstrate how people make decisions about emerging technologies. Our findings confirm previous research that suggests that people form opinions and attitudes even in the absence of relevant scientific or policy-related information. In fact, our data show that cognitive shortcuts or heuristics – often provided by mass media – are currently a key factor in influencing how the public thinks about nanotechnology and about its risks and benefits, and in determining the level of support among the public for further funding for research in this area.

The societal dimensions of nanotechnology have been a concern since the establishment of the National Nanotechnology Initiative. The 2001 NSET Workshop on this topic was dominated by visions of applications of nanotechnology in industries running the gamut from automobiles to space exploration. Among this volume of speculation, a number of commentators identified ‘social acceptance’ of nanotechnology as critical to its future development (Roco & Bainbridge, 2001).

Ironically, public acceptance and public understanding of nanotechnology as an emerging scientific issue are chronically understudied (Roco, 2003). There are exceptions, of course (e.g., Bainbridge, 2002; Cobb & Macoubrie, 2004; Gaskell et al., 2004), but researchers in the social and natural sciences are only now beginning to see the importance of developing a thorough understanding on public opinion formation surrounding nanotechnology. In fact, many of these earlier studies focused

mostly on descriptive analyses of media coverage (Gaskell et al., 2004) or of perceptions of risks and benefits of nanotechnology (Bainbridge, 2002; Cobb & Macoubrie, 2004) and did not examine the relatively complex influences of many of these variables on general attitudes toward nanotechnology and nanotech funding.

It could be argued, of course, that a systematic assessment of public attitudes toward nanotechnology and their antecedents is not possible at this point, given the relatively low levels of awareness of the issue among the general public. This conclusion, of course, is somewhat simplistic. In fact, public opinion research has struggled for decades with the question of how to systematically measure opinions of a public that is largely uninformed, not just about scientific issues but also about most issues and problems related to politics and current events (for an overview, see Page & Shapiro, 1992). More importantly, however, an exclusive focus on

scientific literacy when examining public opinion on nanotechnology will likely lead to an artificially narrow understanding of how people develop opinions and attitudes about this emerging technology.

Explaining Attitudes Toward Emerging Technologies: The Scientific Literacy Model vs. The Cognitive Miser Model

Acknowledging the shortcomings of exclusively cognitive models of information processing, research in social psychology (Fiske & Taylor, 1991) and political science (Popkin, 1994) suggests that people are 'cognitive misers' or 'satisficers' who will only collect as much or as little information about a given issue as they think is necessary to make a decision. And in most cases, this means that they will make decisions with little or at least insufficient amounts of information (Kunreuther, 2001).

In contrast to traditional scientific literacy models, however, which are mostly concerned with informational deficits among the general public (Bauer & Schoon, 1993; Miller, 1998), the cognitive miser model assumes that making decisions based on little or no information is not just part of human nature but may in fact make rational sense (Fiske & Taylor, 1991). Popkin (1994) explains the same behavior using the term 'low-information rationality'. Citizens, he argues, are public consumers and invest efforts in information seeking only if they see a reasonable pay-off. For issues, such as nanotechnology, where developing an in-depth understanding would require *significant* efforts on the part of ordinary citizens, the pay-offs in terms of being able to make informed policy judgments may simply not be enough. As a result, it makes perfect sense for citizens to rely on the judgment of regulatory bodies or interest groups, and – most importantly – on media portrayals of the issue.

In sum, what we label the cognitive miser model of information processing is based on two key assumptions. First, people do not use all available information to make decisions about issues, including new technologies or scientific discoveries (Fiske & Taylor, 1991). Rather, they rely on heuristics or cognitive shortcuts, such as ideological predispositions, religious beliefs, and media portrayals, in

order to form judgments about issues, such as nanotechnology, that they know little or nothing about. The second assumption is that the idea of human beings as cognitive misers is a model, i.e., it describes overall social patterns. This, of course, also means that some groups will not follow the cognitive miser model. This includes audiences that are highly interested in scientific topics, scientific decision makers, members of interest groups, and various other groups in society. For the vast majority of the public, however, the cognitive miser model is an excellent explanatory model for decision making with sub-par levels of information (Fiske & Taylor, 1991).

Framing Nanotechnology – Mass Media as a Key Heuristic

Especially in the area of emerging technologies where most citizens have little or no direct experience, media coverage of these technologies provides a key heuristic to audiences (Nisbet et al., 2003; Nisbet & Lewenstein, 2002). Recent research has suggested that some of the strongest effects of media coverage are not based on the valence of content, i.e., journalists taking explicit stances on the pros or cons of specific technologies, but rather on more subtle differences with respect to how news content is presented. This is often referred to as media framing (Iyengar, 1996; Scheufele, 1999, 2000).

Media framing is based on the idea that how audiences interpret news coverage depends heavily on how a given news item is presented by journalists (Scheufele, 1999). In other words, two news stories that present the exact same content may be interpreted differently by audiences, simply based on their mode of presentation. Specifically, framing can rely on visual or terminological tools. A crime story in the local paper using the picture of an African-American suspect, for instance, will be interpreted very differently by audiences than a story without the picture. Framing can also rely on terminological tools, i.e., different labels for the same issue stance or political actor. The recent battle in the U.S. political arena over labels, such as 'death tax' versus 'estate tax' or 'tax cuts' versus 'tax relief,' are good examples. The different reactions evoked by such opposing frames are largely a function of different interpretive schema being

activated in people's minds by each frame (Price & Tewksbury, 1997).

In short, media frames provide audiences with cognitive shortcuts or heuristics for efficiently processing new information, especially for issues that audiences members are not very familiar with. Greenpeace's attempt to reframe the debate about genetically-modified organisms around the 'Frankenfood' label, for example, was directly based on this assumption. Even for citizens who knew little about the scientific facts underlying the debate, the 'Frankenfood' label provided a convenient interpretive device (or frame) that allowed them to form opinions, even in the absence of information.

Previous research on public opinion on nanotechnology highlights two important facts related to framing. First, it seems that U.S. media coverage of nanotechnology – at this point – is framed in much more positive terms than in the U.K., for instance, with a heavier emphasis in the U.S. on potential benefits of this new technology (Gaskell et al., 2004). The nature of media coverage is also reflected in how the public thinks about this issue. In separate surveys, both Bainbridge (2002) and Cobb and Macoubrie (2004) showed that perceived benefits of nanotechnology – at this stage of the issue cycle – far outweigh the perceived risks and that overall opinions toward this new technology are very positive.

Nanotechnology, therefore, is an ideal issue for studying public understanding of emerging scientific issues and the various factors influencing it. As we outline later, levels of awareness of nanotechnology as an issue and levels of perceived knowledge are still very low. The fact that citizens perceive themselves to be uninformed about the issue, however, does not mean that they do not make decisions or judgments about nanotechnology. Rather, their opinions will be influenced by factors *other* than information, such as ideological predispositions (Converse, 2000), the way mass media frame issues (Scheufele, 1999, 2000), or their levels of general scientific literacy (Miller, 1998). The goal of the study presented here was to explore these processes further. In particular, we were interested in two key research questions:

RQ1: Do people form a scientific literacy model or a cognitive miser model when forming judgments about nanotechnology as an emerging technology?

RQ2: What is the role that media play in shaping public attitudes toward nanotechnology?

By answering these questions, we will also present a snap shot of public opinion at the outset of the emerging public debate and identify the forces – other than nanotech literacy – that will influence public opinion on nanotech in the long run.

Methods

In the fall of 2004, we conducted a representative national telephone survey with a sample size of $N = 706$. The cooperation rate (based on standard definitions developed by the American Association for Public Opinion Research) was 43% (AAPOR definition CR-1). The survey was based on a carefully constructed probability sample that minimizes sampling and non-response biases. In this survey, we were particularly concerned about systematic non-response as a result of the scientific nature and novelty of the survey topic. In other words, it is possible that the people who chose to respond to our survey are overall more interested in nanotechnology and related issues and that people who were less aware or less interested in the issue refused to participate in the survey. This would not only skew our descriptive statistics, but potentially also introduce biases in the multivariate relationships reported here. We therefore invested significant amounts of resources in multiple call-backs for non-contacts and initial refusals in order to minimize non-response potentially due to the survey topic.

Our analyses included general attitudes toward nanotechnology, risk-benefit assessments, nanotech literacy, and different types of science media use. The specific question wording for the most important findings presented here can be found in Appendix 1. The measures of demographics were relatively straightforward and relied on standard survey wording. We included four types of demographic controls: age ($M = 50.0$, $SD = 17.72$), gender (58% females), formal education (median: some college education), and income (median household income between \$30,000 and \$50,000).

Our measures of media use relied on multi-item measures of science media use in newspapers, on television, and online. Newspaper science news use was constructed as a summative index of six items

($M = 24.34$, $SD = 16.95$, Cronbach's $\alpha = 0.95$). Television science news use was a summative index of four items ($M = 12.57$, $SD = 7.94$, Cronbach's $\alpha = 0.97$). Web science news use was also a four-item summative index ($M = 8.70$, $SD = 9.46$, Cronbach's $\alpha = 0.93$).

Perceptions of risk and benefit frames were measured using a total of eight items, each measured on a ten-point scale. Both perceived benefits and perceived risks were measured as summative indices of four items each, with a mean of 26.26 ($SD = 8.75$) for perceived benefits and a mean of 18.90 ($SD = 8.41$) for perceived risks.

Nanotech literacy was constructed as an additive index of six factual knowledge questions ($M = 3.90$, $SD = 1.55$, Cronbach's $\alpha = 0.56$). General support for nanotechnology was measured on a ten-point scale ($M = 5.98$, $SD = 2.67$).

Results

The results of our survey suggest that people's level of awareness of the issue was overall low. Even after having the issue explained to them by the interviewer, about a quarter of all respondents reported that they had never heard of the issue at all.

Interestingly enough, however, people knew more than they thought they knew. While only about 16% of all respondents felt at least somewhat informed about nanotechnology, they had at least some knowledge about the current economic impact of nanotechnology. Figure 1 shows the percentage of respondents who answered any of six factual knowledge-questions correctly. It depicts answers as deviation from 50%, i.e., the probabilities if every respondent guessed his or her answer. As Figure 1 shows, knowledge levels were highest for questions related to current economic relevance of nanotechnology and more general questions about the nature of nanotechnology. For all of these questions, the sample average differed significantly from what could have been expected by chance. Answers did not differ significantly from 50% for specific technical knowledge related to the size of a nanometer, for example, or other scientific details.

Nanotech awareness and optimism about potential benefits

Our data also show, however, that there are significant differences between those in the population who are already aware of nanotechnology as

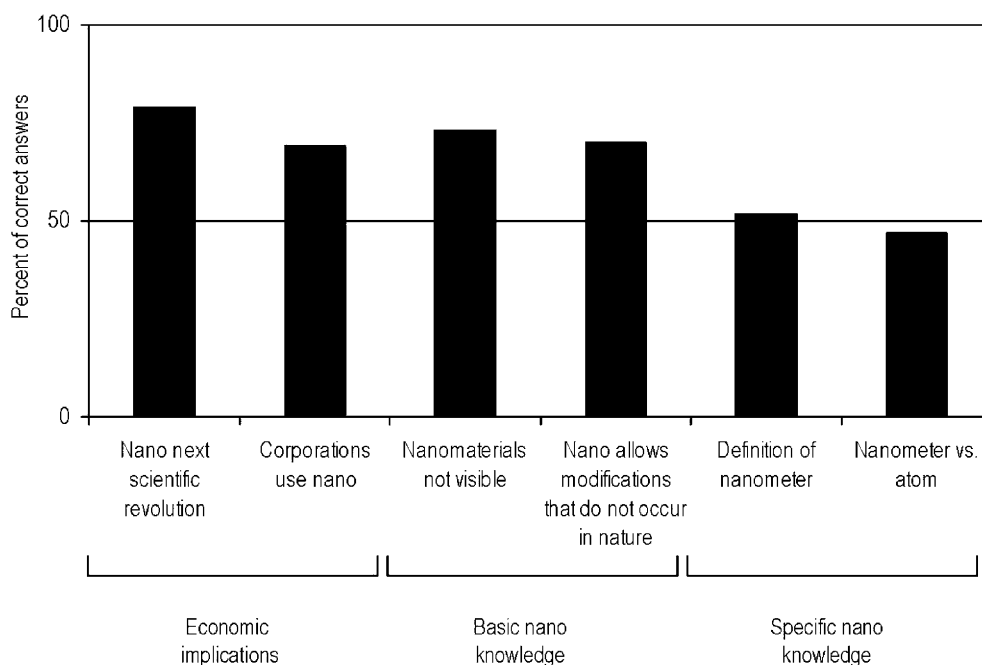


Figure 1. Knowledge levels about nanotech-related issues.

an emerging technology and those who are not. Fifty-five percentage of all respondents who indicated that they were aware of the issue of nanotechnology expressed overall support for nanotech, compared to only 28% of the unaware group. This is compared to 52% support and 48% opposition in the total sample. Similarly, 49% of the aware respondents supported more increased financial support for nanotech research, compared to 22% of the unaware group. In the total sample, the breakdown was 42% in favor of increased funding and 58% opposed to increased funding.

Where do these more favorable attitudes among the aware group come from? Our data suggest very strongly that more aware respondents also held significantly more favorable views of the potential benefits of nanotechnology (see Table 1).

As Table 1 shows, the more favorable attitudes toward nanotechnology are mostly a function of higher levels of optimism among aware respondents rather than their concerns about the potential risks connected with this new technology. Specifically, we found no or only small differences between aware and unaware respondents for most of the concerns listed in Table 1, such as worries about surveillance devices, self-replicating robots or loss of U.S. jobs. It is important to mention, however, that almost two-thirds of all respondents did express concerns about a potential loss of privacy due to small surveillance devices.

However, the differences in attitudes toward nanotechnology between aware and unaware groups – at this time – seem to be a function of aware respondents having a much more optimistic view of the potential positive effects of this new technology. Two-thirds to three-quarters of all respondents who reported having been aware of the issue before the survey also agreed that nanotechnology has potential benefits in the areas of health and medicine, environmental policy, and national defense. Only about half of all respondents who reported being unaware of the issue agreed with this assessment.

The role of mass media

These findings are consistent with previous research news coverage of scientific controversies. Nisbet and Lewenstein (2002) for instance, demonstrated that the issue of biotechnology first emerged in science media and science sections of mainstream media, framed mostly around the potential benefits of the new technology. We found similar patterns for nanotechnology. Directly addressing Research Question 2, our survey showed that attention to mass media was in fact one of the strongest predictors of attitudes toward nanotechnology. Ordinary-least-squares (OLS) multiple regression models showed that – after simultaneous controls for personal predisposition

Table 1. Perceptions of potential risks and benefits of nanotechnology

	Total sample (<i>N</i> = 706) (%)	Aware of nanotech (<i>N</i> = 519) (%)	Unaware of nanotech (<i>N</i> = 187) (%)	Significant δ
Nanotech may lead to the loss of personal privacy because of tiny new surveillance devices	60	62	53	n.s.
Nanotech may lead to the uncontrollable spread of very tiny self-replicating robots	16	17	16	n.s.
Nanotech may lead to an arms race between the U.S. and other countries	37	37	38	n.s.
Because of nanotech we may lose more U.S. jobs	34	33	40	$p \leq 0.05$
Nanotech may lead to new and better ways to clean up the environment	62	67	48	$p \leq 0.01$
Nanotech may lead to new and better ways to treat and detect human diseases	74	80	57	$p \leq 0.01$
Nanotech may help us develop increased national security and defensive capabilities	64	68	49	$p \leq 0.01$
Nanotech may give scientists the ability to improve human physical and mental abilities	62	67	46	$p \leq 0.01$

and demographic variables – attention and exposure to science and technology news in newspapers, on television, and on the web had a consistent significant positive impact on attitudes toward nanotechnology. There are two possible explanations for this that are illustrated in Figure 2.

The first explanation is based on a scientific literacy model and potential learning effects of attention to mass media. In other words, it is based on the assumption that increases in nanotech literacy will also lead to higher levels of public support for nanotechnology. This explanation, however, was not supported by our data.

In fact, after controlling for demographic predispositions and information seeking in mass media, knowledge levels about nanotechnology were largely unrelated to attitudes toward nanotechnology in general or toward increased funding for nanotechnology. Interestingly enough, knowledge about nanotechnology is significantly related to support for nanotechnology ($r = 0.17, p < 0.01$) at the zero-order level, i.e., *without* controlling for other demographics, media use variables, and risk/benefit perceptions. At this stage of the issue cycle, however, this relationship is largely spurious. In other words, higher levels of information about nanotechnology are probably indicative of higher levels of interest in scientific issues overall. As a result, these respondents are also more likely to be exposed to news coverage about nanotech, which – at this point – frames the issue mostly in terms of potential benefits (Gaskell et al., 2004). As a result, the impact of nanotech literacy in our multivariate OLS regression models was not significant (see Table 2).

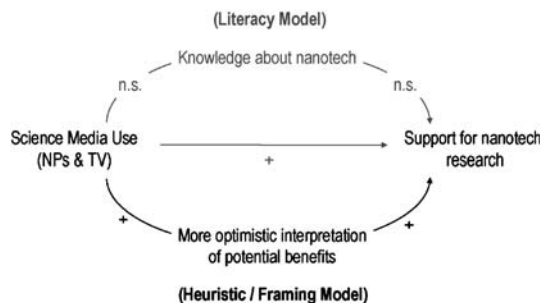


Figure 2. Science Literacy and Heuristic Models of Attitude Formation.

If the science literacy model applies to nanotechnology, of course, we should also see a mediation of the total effects of science media use (represented by the before-entry betas in the first column of coefficients in Table 2) by nanotech literacy. In other words, if the introduction of nanotech literacy into the equation reduces the strength of the coefficients for media use, it is likely that media influences on attitudes work largely through increased knowledge. This was not the case. In fact, the introduction of nanotech knowledge made no difference at all with respect to the strength of the coefficients for media use.

The second explanation for the link between media use and attitudes toward nanotechnology is based on the cognitive miser or heuristic model and focuses on the mode of presentation of scientific issues in mass media. As outlined earlier, mass media can influence attitudes toward issues, such as nanotechnology, by presenting or ‘framing’ information in certain ways or by emphasizing or ‘priming’ certain aspects of issues over others. As a result, heavy users of science media may be more supportive of nanotechnology, simply because media coverage of nanotech – at this point – focuses mostly on the potential benefits of this new technology rather than its risk or its ethical implications. Our data suggests that this is indeed

Table 2. Predicting support for nanotech

	Before-entry β	Final β
<i>Demographics</i>		
Age	−0.07*	−0.03
Sex (f)	−0.14**	−0.11**
Education	0.17**	0.04
Income	0.16**	0.03
Incremental R-square	9.0**	
<i>Science media use</i>		
NP Science news use	0.25**	0.09*
TV Science news use	0.31**	0.17**
WWW Science news use	0.16**	0.02
Incremental R-square	10.1**	
<i>Risk/Benefit frames</i>		
Perceived benefits	0.35**	0.41**
Perceived risks	0.00	−0.16**
Incremental R-square	13.4**	
<i>Nano literacy</i>		
Nano literacy	0.02	0.02
Incremental R-square	0.00	
Total Model R-square	32.5**	

Note: ** $p < 0.01$. * $p < 0.05$.

the case. About 35% of frequent readers of science news in newspapers for example, indicated that the benefits of nanotechnology outweighed the risks. Among respondents who do not read science news frequently, only 25% thought that the benefits outweighed the risks. As Table 2 shows, the introduction of the risk and benefit frames into the equation significantly reduced the strength of the coefficients for all types of media use. This suggests that media influences on attitudes toward nanotechnology – at this stage of the issue cycle – work in part by emphasizing positive frames over negative ones and therefore indirectly influencing public attitudes toward this new technology. This, of course, provides direct support for the cognitive miser model outlined in Research Question 1.

Conclusions

As our data show, nanotech coverage – at this stage of the issue cycle – is focused mostly on the scientific and economic aspects of this new technology. This focus on the scientific and market potential makes perfect sense if we look at the writers and reporters who contribute the majority of nanotech-related articles in U.S. elite print media. At this point, the majority of nanotech reporting at the *Washington Post* is one by science reporter Rick Weiss. At the *New York Times* a majority of the writing on nanotechnology is done by business reporter Barnaby J. Feder.

This is not to say, of course, that science and business media do not play an informational role. But our data strongly suggest that the people who pay attention to nanotech coverage in these outlets at this point are highly informed already. As a result, the strongest media effects are not necessarily informational but rather a function of more positive framing of new technologies in science and business media. In other words, these media outlets likely emphasize the potential benefits of nanotechnology and offer a more positive framing of the issue overall.

Most likely, however, this will change over time as the issue of nanotech is picked up by mainstream media, which traditionally focus more on controversy than scientific discourse in their coverage (Nisbet et al., 2003). As a result, we will see more and more of a ‘war of words,’ i.e., a competition over which frames will dominate public

discourse over nanotech. Interest groups, policy makers, scientists, and mass media will struggle to get their voices heard and establish their way of ‘framing’ the debate. Some of the frames that may emerge will focus on toxic qualities of nano particles, others will emphasize the potential for contamination. Can Britta filters catch nano particles, for instance? And are nano particles in our drinking water already? At this stage of the issue cycle, the public has not begun to ask, let alone think about, these questions. As soon as the issue is picked up by mainstream media and local news, however, this will change. As outlined earlier, a broad, scientifically-based public discussion will not take place. Rather public opinion will form around frames offered by interest groups, policy makers, scientific media, and other actors in the policy arena.

As a result, we need social science more than ever to answer the most urgent questions related to public perceptions of nanotech: What frames are out there and what frames are likely to appear in the public area in the near future? How do these frames get onto the media agenda? What role can scientists and science writers play in influencing these dynamics? What are the dynamics that link frames to public opinion and public decision making? And most importantly, how will public opinion develop in the long-run? This article has provided some answers about the early stages of the issue cycle of nanotechnology. Providing answers to the questions we left unanswered will be critical for understanding how the public thinks about nanotech and how nanotechnology will emerge as a public issue in the long run.

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Appendix 1: Question Wording

Awareness and perceived level of information

Now let’s turn to a different issue. 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.'

- Let's use a ten point scale with one being 'not at all' and ten being 'very much.' Which number between 1 and 10 would best represent how much you have heard, read or seen about this issue?
- Using a scale from 1 to 10, with one being 'not informed at all' and ten being 'very well informed,' how well informed would you say *you* are about nanotechnology?

General attitudes toward nanotech and nanotech funding

Here's a list of statements people have made about nanotechnology and its potential impact. For each of these statements, could you tell me how much you agree or disagree on a ten-point scale with one being 'not at all' and ten being 'very much?'

- Overall, I support the *use* of nanotechnology.
- Overall, I support *federal funding* for nanotechnology.

Nanotech literacy

Next, I am going to read a few statements about nanotechnology. For each one, please tell me if you think the statement is true or false. [order randomized]

- Nanotechnology involves materials that are not visible to the naked eye.
- U.S. corporations are not using nanotechnology yet to make products sold today.
- Experts consider nanotechnology to be the next industrial revolution of the U.S. economy.
- A nanometer is a billionth of a meter.
- Nanotechnology allows scientists to arrange molecules in a way that does not occur in nature.
- A nanometer is about the same size as an atom.

Perceptions of risks and benefits

Now, for each of these statements, could you tell me how much you agree on a ten-point scale with

one being 'not at all' and ten being 'very much?' [order randomized]

- Because of nanotech we may lose more U.S. jobs.
- Nanotech may lead to an arms race between the U.S. and other countries.
- Nanotech may lead to new and better ways to treat and detect human diseases
- Nanotech may help us develop increased national security and defensive capabilities.
- Nanotech may lead to new and better ways to clean up the environment.
- Nanotech may lead to the loss of personal privacy because of tiny new surveillance devices.
- Nanotech may lead to the uncontrollable spread of very tiny self-replicating robots.
- Nanotech may give scientists the ability to improve human physical and mental abilities.

Science Media Use

On a scale from 1 to 10, where 1 means 'never' and 10 means 'all the time,' how often do you read the following types of newspaper content?

- Stories related to science and technology
- Stories about specific scientific developments, such as nanotechnology
- Stories about the investment and market potential of specific technologies

Now using another scale from 1 to 10, where 1 means 'little attention' and 10 means 'very close attention,' please tell me how much attention you pay to the following kinds of stories when you read the newspaper:

- Stories related to science and technology
- Stories about specific scientific developments, such as nanotechnology
- Stories about the investment and market potential of specific technologies

How often do you watch the following type of TV programs? Here one means 'not very often' and ten means 'all the time.'

- Stories related to science and technology
- Stories about specific scientific developments, such as nanotechnology
- Science documentaries on stations such as PBS, the Learning Channel, or Discovery Channel?

Using the same scale from 1 to 10, where 1 means 'little attention' and 10 means 'very close attention,' please tell me how much attention you pay to the following kinds of programs on television:

- Stories related to science and technology
- Stories about specific scientific developments, such as nanotechnology
- Science documentaries on stations such as PBS, the Learning Channel, or Discovery Channel?

[Only asked for regular Web users] Now using a scale from 1 to 10, where 1 means 'never' and 10 means 'all the time,' please tell me how often you go online for:

- For information related to science and technology
- For information about specific scientific developments, such as nanotechnology
- For information about scientific studies in new areas of research, such as nanotechnology
- For information about the investment and market potential of specific technologies

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