Leading U.S. nano-scientists' perceptions about media coverage and the public communication of scientific research findings

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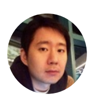

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RESEARCH PAPER

Leading US nano-scientists' perceptions about media coverage and the public communication of scientific research findings

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Abstract Despite the significant increase in the use of nanotechnology in academic research and commercial products over the past decade, there have been few studies that have explored scientists' perceptions and attitudes about the technology. In this article, we use survey data from the leading U.S. nano-scientists to explore their perceptions about two issues: the public communication of research findings and media coverage of nanotechnology, which serves as one relatively rapid outlet for public communication. We find that leading U.S. nano-scientists do see an important connection between the public communication of research findings and public attitudes about science. Also, there is a connection between the scientists' perceptions about media coverage and their views on the timing of public communication; scientists with positive attitudes about the media are more likely to support immediate public communication of research findings, while others believe that communication should take place only after research findings have been published through a peer-review process. We also demonstrate that journalists might have a more challenging time getting scientists to talk with them about nanotechnology news stories because nano-scientists tend to view media coverage of nanotechnology as less credible and less accurate than general science media coverage. We conclude that leading U.S. nano-scientists do feel a sense of responsibility for communicating their research findings to the public, but attitudes about the timing and the pathway of that communication vary across the group.

Keywords Nanotechnology · Perceptions · Scientist attitudes · Media coverage · Public communication · Survey data collection · Societal implications · ELSI

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Nanotechnology is one of the key enabling technologies of the twenty-first century (Anderson et al. 2005). As it becomes more prevalent in commercial products, scholars are calling for a detailed discussion of a regulatory framework for the technology (Wardak et al. 2007; Reinert et al. 2006; Tyshenko et al. 2010; Marchant et al. 2007, 2009; Marchant and Sylvester 2006; Pitkethly 2009; Corley et al. 2009; Powell et al. 2008). While this discussion moves forward, decision-makers look to public perceptions and expert opinions about the risks, benefits, communication, and regulation of nanotechnology to make policy decisions. But what are the perceptions and opinions of the public and experts regarding nanotechnology? Social scientists have started painting this picture of public and scientist perceptions about nanotechnology, but the full landscape of perceptions is still incomplete, particularly in the area of scientists' perceptions.

Our goal in this article is to use survey data from the leading U.S. nano-scientists to explore their perceptions about the public communication of research results, as well as science and nanotechnology media coverage, which is one prevalent outlet for public communication of research findings (Mathews et al. 2005; McInerney et al. 2004). As McInerney et al. (2004) outline, media coverage of science is often based on press releases that scientists issue through university public relations departments to help increase the awareness of particular scientific issues. Since the public communication of research findings is often linked with media coverage of scientific topics, we explore scientists' perceptions about these two linked topics in this article. Before delving into the details of our data collection and results, we will first present our research questions and hypotheses within the context of the existing literature.

Scientists' underlying motivations for engaging in public communication

Some scholars have argued that scientists have an ethical obligation to communicate their scientific findings with the public in the name of democracy (Dibella et al. 1991; Weigold 2001; Petersen et al. 2009). In particular, Bentley Glass, a former president of the American Association for the Advancement of Science (AAAS), outlined this obligation in writing (Glass 1993). On the other hand, there are a variety of barriers that have been identified by scientists as reasons why they avoid communicating with the public, including a lack of time, lack of credit toward tenure, professional stigmatization, low knowledge levels about potential public communication opportunities, and a lack of communication skills (Mathews et al. 2005; Gascoigne and Metcalfe 1997; Dibella et al. 1991; Weigold 2001; Dunwoody and Ryan 1983; Gunter et al. 1999; Maille et al. 2010; Petersen et al. 2009).

Scientists are often concerned with the potential misinterpretation of their findings by the media or public (Mathews et al. 2005; Frewer et al. 2003; Davies 2008; Petersen et al. 2007; Berube 2008; Nelkin 1996; Hartz and Chappell 1997; Moore and Singletary 1985; Petersen et al. 2009) and, as a result, they might resist communicating research findings with the public until they have been peer-reviewed and formally published by a scholarly journal (Mellor 2010; Geller et al. 2005). For example, previous studies have found that scientists believe that journalists leave important facts and methodological details out of media stories (Moore and Singletary 1985; Maille et al. 2010).

These skeptical approaches to the public communication of scientific research could be driven by thinking that fits into the "deficit model" (Davies 2008; Kurath and Gisler 2009), which argues that the public would understand the risks of technology only if they fully understood the scientific information that experts have uncovered. This deficit model often leads to the public communication of research findings that is one way—i.e., from scientists to the public. In recent years, however, multiple scholars have demonstrated the weaknesses of one-way risk communication and the deficit model (Nisbet and Scheufele 2009; Davies 2008; Brown 2009; Kurath and Gisler 2009; Bostrom and Lofstedt 2010; Pidgeon and Rogers-Hayden 2007).

Even though we would argue that the deficit model is not an effective way of thinking about the public communication of scientific findings, it is not our goal in this article to propose a model of risk communication that *should* be used. Rather, our goal is to describe the way leading U.S. nano-scientists perceive the public communication of research findings, both generally and through media coverage. The nature of our data makes our focus in this study descriptive rather than prescriptive. As Mathews et al. (2005) outline, one important first step in developing effective strategies to increase scientist involvement in public communication is to understand their perceptions about the process.

Since the illumination of scientists' perceptions about public communication of research findings (including media coverage of science and nanotechnology) is our goal in this study, our first research question is "What are the perceptions of the leading U.S. nano-scientists about the public communication of their research findings?" To answer this research question, we analyzed survey data for three perception areas about the public communication of research results: the timing of public communication, the types of information that should be included in public communication, and the groups that should be responsible for the public communication. Based on the existing studies that we outlined above, we have developed our first hypothesis about the timing of public communication.

Hypothesis 1 Leading U.S. nano-scientists will prefer to communicate research results with the public after they are published rather than before publication.

Since we are not aware of any existing studies focused on the other two aspects of scientists' perceptions about public communication (i.e., the types of information and the groups that should be responsible for the communication), we did not develop formal hypotheses about these results. We speculate, however, that scientists will think that two types of information are most important for public communication: the risks/benefits of nanotechnology and the scientific processes being used in nanotechnology research. This speculation is based solely on the issues that we expect the scientists to rate as most important based on their own role in nanotechnology research. We also speculate that our sample will believe that university scientists should be the group most responsible for communicating research results with the public. Again, we develop this based only on the perspective of the respondents—i.e., they are scientists so they probably think that they should be responsible for communicating their own results with the public. Now we turn to a discussion of scientists' perceptions about the media coverage of science while presenting our second and third research questions.

Scientists' evaluations of existing public communication through media

Media coverage is one common mechanism that can be used to communicate the results of scientific studies to the public (Lievrouw 1993; Suleski and Ibaraki 2010; Nisbet et al. 2002; Nelkin 1996; Geller et al. 2005). In fact, Mathews et al. (2005) found that U.S. geneticists argued that the media was the best way for scientists to communicate with the public about scientific findings. On the other hand, Suleski and Ibaraki (2010) have demonstrated quantitatively that using media coverage as a main conduit of science communication with the public is not always effective and can actually lead to declining science knowledge levels among the public if it is used as the only mechanism for the public communication of scientific results. There have been many studies that have debated the pros and cons of using media coverage as a tool for the public communication of scientific findings (for example, Suleski and Ibaraki 2010; Phillips et al. 1991; Treise and Weigold 2002), and therefore, this is not our focus for this study. Rather we are interested in providing an updated view of how nano-scientists think about the public communication of scientific research findings. As we mentioned earlier, we explore their perceptions about science media coverage because this is one common mechanism that scientists use to communicate research findings with the public (Dibella et al. 1991; McInerney et al. 2004; Phillips et al. 1991).

Even though there are several previous studies focused on scientists' perceptions about general science media coverage, there are not many studies focused specifically on scientists' perceptions about nanotechnology media coverage. Petersen et al. (2009) captured this when they said "little is known about how scientists currently perceive and interact with the media where these issues are concerned, and how they see the media contributing to the formation of public knowledge on nanotechnologies."

To provide some context for our results, however, we will briefly highlight the previous work in this related area (for both general science media coverage and nanotechnology media coverage). As we will demonstrate, several of the existing studies have shown that there is often a tense relationship between scientists and journalists (Gunter et al. 1999; Dunwoody and Scott 1982; Nelkin 1996; Ruth et al. 2005; Geller et al. 2005; Maille et al. 2010).

Attributes of media coverage: perceptions of accuracy, hostility, and comprehensiveness

Previous studies on scientists' perceptions of media coverage have concluded that scientists do not have favorable opinions about the media coverage of science or about the journalists that produce the media materials (for example, Dunwoody and Scott 1982). This can lead scientists to avoid talking with journalists and to hesitate in sharing their research results with the public outside of peer-reviewed journal outlets. For example, a survey by Rabino (1998) indicated that only 29% of U.S. biotechnology researchers have talked to the media about their research.

Some of the scientists' hesitation about sharing their research results with the media and journalists can be attributed to their perceptions about media coverage of science in general. For example, Mellor (2010) studied the way that astroid scientists perceived media coverage of scientific findings. She concluded that astroid scientists tend to be concerned about how media coverage of their results might undermine their authority, viewing media coverage largely as a negative process. She also found that this perception on the part of scientists can result in their need to have more control over the media coverage of the scientific issue.

Scientists are also concerned with the way journalists interpret or translate their scientific results for the public. For example, Mathews et al. (2005) conducted a series of interviews with U.S. geneticists and found that they expressed mixed opinions about the way news outlets present scientific results in the media. In particular, some of the geneticists' most significant concerns were associated with the way the news media interpreted or translated scientific terminology and jargon. One of the scientist interviewees outlined that ''… to a certain extent, one has to be very careful about one's wording and how one presents things; but even then, there's a lot of misconception… for example: cloning. The word 'cloning' means different things to different people'' (Mathews et al. 2005).

One of the more common perceptions that scientists have about journalistic interpretation of their research is that journalists make the story sensationalistic. For example, Hartz and Chappell (1997) found in their research that roughly 76% of U.S. scientists think that journalists are more interested in creating sensationalistic stories than they are in providing the truth about scientific findings in media coverage. This attitude seems to occur in other countries as well. Gunter et al. (1999) demonstrated that British scientists perceive that media coverage of biotechnology is "overly dramatic and sensational, with many also saying that such stories tend to be speculative and to place too much emphasis on risks." They found that British scientists tended to think that biotechnology media stories were largely inaccurate, not balanced, and not very informative. The scientists in their study were also likely to believe that media coverage of biotechnology does not increase public understanding of the technology and that the news media do not effectively present scientists' views.

Petersen et al. (2009) also explored this perception about sensationalistic journalism by conducting a qualitative study of scientists' perceptions about media coverage in the field of nanotechnology within the UK. Even though their study design is different from ours (i.e., they conducted interviews and an email survey with 37 nano-scientists in the UK), they found some interesting results that we build on for our own study. This is particularly true since it is one of the only existing studies in the area of scientists' perceptions about nanotechnology media coverage. Petersen et al. (2009) concluded that UK scientists have a high level of dissatisfaction with the way nanotechnology is covered by the media, and that half of the scientists described media coverage of nanotechnology as inaccurate and about three-fourths stated that media coverage was sensationalized.

These overall negative impressions of media coverage can play out in the scientists' actions when dealing with press coverage of scientific results. For instance, several research studies have shown that there might be a relationship between scientists' perceptions about sensationalistic journalism and their desire for control over the editing process before the final story is published. As we mentioned earlier, Gunter et al. (1999) demonstrated that British scientists perceive that media coverage of biotechnology is "overly dramatic and sensational." In this same study, they reported that out of the 30 scientists they studied, 28 of those respondents believed that they should be able to check the copy of a media story they were interviewed for before the story is published.

In some cases, scientists' perceptions about general science media coverage might differ from their perceptions about media coverage in their own disciplines. For example, Ruth et al. (2005) found that U.S. agricultural scientists have more positive perceptions about media coverage of general science than about media coverage of their specific disciplinary field; they also demonstrated that agricultural scientists tend to be more positive about local news coverage than national news coverage of scientific topics. Yet, they speculated that this discrepancy might be due to the fact that scientists could feel more control over local news stories because they have more access to the journalists (due to their physical proximity).

In this section, we have outlined several key attributes of media coverage that might inform scientists' motivations for engaging in the public communication of their research results through media stories. Based on our analysis of these studies, we have developed our second research question: "What are the perceptions of the leading U.S. nano-scientists about media coverage of scientific topics (in general) and nanotechnology topics (in particular)?" Based on the existing studies that we outlined above, we have developed our second, third, and fourth hypotheses that are focused on scientists' perceptions about media coverage of science and nanotechnology.

Hypothesis 2 Leading U.S. nano-scientists are more likely to have negative perceptions of general science media coverage (i.e., that it is inaccurate and hostile) than positive perceptions (i.e., that it is credible and comprehensive) of general science media coverage.

Hypothesis 3 Leading U.S. nano-scientists are more likely to have negative perceptions of nanotechnology media coverage (i.e., that it is inaccurate and hostile) than positive perceptions (i.e., that it is credible and comprehensive) of nanotechnology media coverage.

Hypothesis 4 Leading U.S. nano-scientists are more positive about media coverage of general science than they are about media coverage of nanotechnology.

Now we will introduce our final research question. Building on our first two research questions, our third research question explores the linkages between media perceptions and public communication by explicitly asking "How do nano-scientists' perceptions about media coverage of science correlate with their perceptions about the public communication of scientific results?" Even though we are not aware of any existing studies focused on the relationship between scientists' perceptions about media coverage and their perceptions about public communication timing, we speculate that scientists with more negative views of science media coverage will be more supportive of delaying the public communication of research results. In the next section, we outline our data collection process for the study. Then, in the following section, we present the results for our three research questions.

Data collection

The data collection for this study was conducted by the University of Wisconsin Survey Center in 2007 under the auspices of the Center for Nanotechnology in Society at Arizona State University (CNS-ASU). The data were collected via a mail survey of 363 leading U.S. nanotechnology scientists and engineers. The survey was administered in three ways following Dillman's Tailored Design Method (Dillman et al. 2008), which yielded a final response rate of 39.5% (American Association for Public Opinion Research RR-3: 39.5%) (AAPOR 2009). To design the sample for the survey, we identified the first authors and contact authors for the most highly cited, nanotechnology publications that were indexed in the ISI Web of Knowledge database. To define the domain of scholarly publications that were actually in the multidisciplinary field of nanotechnology, we used the definition outlined by Porter et al. (2008), which draws on the results of bibliometric analysis to define the publication domain of peer-reviewed scholarship on nanotechnology.

To develop the final sample for this project, we received from Porter and colleagues a database of 91,479 peer-reviewed nanotechnology publications that were published between January 2005 and July 2006. Our team then filtered these records to remove non-U.S.-affiliated scientists, graduate students, and first or contact authors who were cited less than five times in the publication database. The purpose of the filtering process was to focus the sample design on the most highly cited, U.S.-affiliated scientists within the nanotechnology field. The final filtering process produced 1,022 names; this yielded 363 completed questionnaires (for an overview, see Scheufele et al. 2007).

As Table 1 demonstrates, about 86% of the respondents were male and the average age was 45 years old. We also asked the respondents about their economic and social values. The scientists in our sample were more economically conservative than they were socially conservative. On average, religion did not play a large role in the scientists' lives with an average of 3.42 on a scale of 10 (where 1 = no religious guidance in life and 10 = a great deal of religious guidance in life). The majority of the scientists worked in universities and 46% were tenured professors. Only about 6% of the scientists worked in industry laboratories. In the next section of the article, we present our

Table 1 Mean responses for demographic, values & career variables ($N = 363$)

	Mean	Std. Dev.
Demographic variables		
Percent male	85.59	N/A
Respondent's age	44.94	10.72
Economic conservatism[a] (1 = very liberal; 7 = very conservative)	3.77	1.48
Social conservatism[b] (1 = very liberal; 7 = very conservative)	3.10	1.57
Religious guidance[c] (1 = no guidance; 10 = great deal of guidance)	3.42	2.96
Career affiliation variables		
Percent working in universities	93.66	N/A
Percent working in industry	5.79	N/A
Percent not reporting affiliation	0.55	N/A
Career tenure variables		
Percent in non-tenure-track positions	40.22	N/A
Percent tenure-track position, untenured	11.57	N/A
Percent tenure-track position, tenured	46.28	N/A
Percent not reporting tenure status	1.93	N/A

[a] The terms "liberal" and "conservative" may mean different things to people, depending on the kind of issue one is considering. In terms of economic issues, would you say you are:__ (1 = very liberal; 7 = very conservative)

[b] Now, thinking in terms of social issues and people's behavior, would you say you are:__ (1 = very liberal; 7 = very conservative)

[c] How much guidance does religion play in your everyday life? (1 = no guidance; 10 = great deal of guidance)

data results and (when relevant) link them back to the literature in the previous section.

Data analysis and results

Perceptions about public communication of research findings

Our first research question is "What are the perceptions of the leading U.S. nano-scientists about the public communication of their research findings?" We address this question through the results presented in Tables 2, 3, and 4. Within these tables, we outline three categories of scientists' perceptions about the public communication of research results: (1) general perceptions about the timing of public communication, (2) perceptions about the types of information that should be included in public communication if citizens are asked to vote on a nanotechnology referendum, and (3) perceptions about the groups that should be responsible for the public communication.

In Table 2, we present the results of scientists' perceptions about the general public communication of scientific findings, as well as their perceptions about the timing of public communication of results. We found that the leading U.S. nano-scientists were likely to believe that there is a relationship between public communication of research findings and public attitudes about science. The scientists had a more neutral response, however, to the survey questions about the timing of the public communication of research results. When we asked the scientists if new research findings should be communicated to the public immediately, the average response was neutral with a mean of 2.99 and a standard deviation of 1.29. Thus, the scientists were split on support for research results being communicated with the public as soon as they are generated in the laboratory. On the other hand, scientists were more likely to support communicating research results with the public after they have been published in a scientific journal (mean of 3.79 and standard deviation of 1.20).

This result confirmed our first hypothesis about scientists' perceptions regarding the timing of public communication of research results. From the scientists' responses to these questions, we can conclude that in general the leading U.S. nano-scientists believe that communicating scientific results to the public is one way to influence public attitudes about science;

Table 2 Scientists' perceptions about public communication of research findings ($N = 363$)

(1 = strongly disagree; 5 = strongly agree)	Mean	Std. Dev.
Scientists communicating research results with the public		
Communicating results does not affect public attitudes[a]	1.86	1.07
Scientists should communicate findings only after they have been published[b]	3.79	1.20
New findings of public interest should be communicated to the public immediately[c]	2.99	1.29

[a] Thinking of science more generally, communicating with the public does not affect public attitudes toward science. (1 = strongly disagree; 5 = strongly agree)

[b] Thinking of science more generally, scientists should communicate research findings to the general public only after they have been published in a scientific journal. (1 = strongly disagree; 5 = strongly agree)

[c] Thinking of science more generally, new scientific findings of public interests should be communicated to the public immediately. (1 = strongly disagree; 5 = strongly agree)

Table 3 Scientists' perceptions about public communication before the public votes ($N = 363$)

Areas for informing citizens	Mean	Std. Dev.
What are the claimed benefits and what are the possible risks?	3.96	1.48
Who is funding the research and who will benefit from it?	3.38	1.25
What scientific processes and techniques are being used?	3.16	1.38
What are the current regulations and who is enforcing the regulations?	3.02	1.19
Who is responsible for setting the moral limits?	2.77	1.50

Question: If there was a national referendum on long-term funding for nanotechnology research, which would be the most important areas that citizens should be informed about before casting their vote? Please rank the following areas from 1 through 5, with 1 being the "least important" and 5 being the "most important" area

Table 4 Scientists' perceptions about groups responsible for public communication ($N = 363$)

(1 = not at all; 5 = very much)	Play formal role (Mean)	Play formal role (St. Dev.)	Has expertise (Mean)	Has expertise (St. Dev.)
Groups or agencies				
University scientists doing research in nanotechnology	4.50	0.77	4.40	0.79
Regulatory agencies (such as the FDA or EPA)	4.15	0.88	3.45	1.02
Consumer organizations testing nanotechnology products	3.84	1.05	3.21	0.99
Nano-scientists working for big companies	3.75	1.04	4.02	0.99
Environmental organizations	3.60	1.02	2.90	1.06
Business leaders	3.30	1.18	2.94	1.11
Congress	3.10	1.13	2.01	0.92
News media	2.93	1.29	2.10	1.01
International institutions (such as the United Nations)	2.91	1.23	2.32	1.08
The White House	2.70	1.21	1.74	0.91
Religious organizations	1.53	0.91	1.32	0.73

Question: "Please indicate for each of the following groups or agencies if you think they have the necessary scientific expertise and should be playing a formal role in communicating about the risks and benefit of nanotechnology" yet, the scientists are more likely to think that the results should be communicated after they have already been peer-reviewed and published in a scholarly journal, which demonstrates a more cautious approach to public communication.

In Table 3, we present the results for the scientists' perceptions regarding the types of information that should be included in public communication. Specifically, we asked the scientists to rank five different types of scientific information that should be communicated with the public before citizens are asked to vote on a national referendum on long-term funding of nanotechnology research. The five categories of scientific information that we asked the scientists to rank included (1) the benefits and risks of the nanotechnology research, (2) the funding agency for the nanotechnology research, (3) the scientific processes used in the nanotechnology research, (4) the current regulations for nanotechnology and the party responsible for enforcing them, and (5) information about the moral limits for nanotechnology research. The scientists then ranked these categories of public communication content from 1 (least important to communicate with the public) to 5 (most important to communicate with the public). The results show that the scientists thought that the risks/benefits of nanotechnology were the most important content area that should be communicated with the public. The second most important content area was the funding agency for the research. Even though we did not ask an open-ended question to learn why the scientists chose their responses, we speculate that the scientists thought the funding source was important information for the public because federal-level science funding agencies are publicly funded agencies (e.g., the National Science Foundation or National Institutes of Health).

The content areas that were less important to the scientists were scientific processes used in the research (mean = 3.16; SD = 1.38), details about current regulations of nanotechnology (mean = 3.02; SD = 1.19), and information about the moral limits of nanotechnology research (mean = 2.77; SD = 1.50). Further, the standard deviation values demonstrate that the scientists exhibited more variation in their responses to content areas focused on risks/benefits, scientific processes, and moral limits. Overall, these results confirmed our speculation that scientists think that the public should know about the risks and benefits of nanotechnology, but it did not confirm our speculation that they would also rank scientific processes as particularly important for public communication.

Given that the scientists most strongly supported public communication about the risks and benefits of nanotechnology, we further explored their perceptions about the groups that should be responsible for communicating with the public about these risks and benefits of nanotechnology. These results are presented in Table 4. We asked the nano-scientists two groups of questions: (1) which groups have the necessary scientific expertise to communicate with the public about nanotechnology risks and benefits? and (2) which groups should have a formal role in communicating with the public about the risks and benefits of nanotechnology? Within these two questions, we asked the scientists to rank a variety of groups or agencies that are involved in nanotechnology including university scientists, regulatory agencies, consumer organizations, nano-scientists working for big companies, environmental organizations, business leaders, congress, news media, international institutions, the White House, and religious organizations.

The scientists' responses to the "scientific expertise" and "formal role" questions were similar with some minor differences for a few groups. For example, the survey respondents thought that university scientists doing nanotechnology research had the highest level of expertise to communicate with the public and that they had a responsibility to engage in communication with the public. This result confirmed our speculation that the university scientists would be rated as the group with the strongest responsibility to engage the public in communication about nanotechnology. According to the respondents, the second and third most qualified groups for communicating nanotechnology risks and benefits to the public were nano-scientists working in industry settings and regulatory agencies (e.g., Environmental Protection Agency), respectively. Even though the respondents believed that industry nano-scientists had higher levels of expertise for communicating risks and benefits to the public, they believed that regulatory agencies had more responsibility for playing a formal role in that communication. According to the survey respondents, the groups with the lowest level of scientific expertise for communicating with the public about nanotechnology were the White House and religious organizations.

Since one goal of this article is to explore nano-scientists' perceptions about media coverage of nanotechnology and science, we think it is important to pay particular attention to the role that the respondents thought the news media should play in the public communication of nanotechnology risks and benefits. On a scale of 1 (not much at all) to 5 (very much), the nano-scientists in our survey rated the news media an average score of 2.10 on scientific expertise about nanotechnology risks and benefits and a score of 2.93 for the formal role that they should play in public communication about risks and benefits. From these results, we can see that even though the nano-scientists did not believe that the news media had particularly high levels of expertise (mean = 2.10; SD = 1.01), they did seem to be neutral about the media playing a role in the communication with the public about nanotechnology (although the news media ranked behind multiple other groups for this question).

Perceptions about media coverage of science and nanotechnology

As we outlined earlier, many existing studies demonstrate that the news media is one substantial outlet for the public communication of scientific research findings. Therefore, our second research question for this study is the following: "What are the perceptions of the leading U.S. nano-scientists about media coverage of scientific topics (in general) and nanotechnology topics (in particular)?" We present our results for this research question in Table 5 where we summarize the nano-scientists' perceptions regarding general science media coverage and nanotechnology news coverage.

This table demonstrates that the scientists are neutral about the accuracy and credibility of general science media coverage (with mean values near 3 on a 1–5 scale). Yet, they were likely to believe that even though general science media coverage is not hostile to science, it is also not sufficiently comprehensive. The patterns of responses about nanotechnology media coverage were quite similar to the responses for general science media coverage. For example, the scientists tended to have similar responses about the level of hostility and comprehensiveness of media coverage for both the general science coverage case and the particular case of nanotechnology coverage. To test whether the differences in positive and negative media perceptions about general science media coverage (in general) and nanotechnology media coverage (in particular) were statistically significant, we created a positive and negative media perception index for both cases. For the case of general science media coverage, we calculated this negative media perception index simply by summing the response to the statement "media coverage is inaccurate" with the response for the statement "media coverage is hostile." Similarly, the positive media perception index was computed by summing the response to the statement "media coverage uses credible scientific sources" with the response for the statement "media coverage is sufficiently comprehensive." The results in Table 5 demonstrate that the respondents did not have significantly different positive or negative perceptions about general science media coverage—in other words, they tended to think that the coverage is equally positive and negative. Therefore, this result did not confirm our second hypothesis.

After computing these two indices (positive and negative) for general science media coverage, we repeated the process for nanotechnology media coverage. The computation of the indices for nanotechnology allowed us to also test whether there were significant differences in the negative/positive indices for nanotechnology media coverage. The results in Table 5 demonstrate that we did find significant differences in the mean responses for the negative and positive media perception indices for nanotechnology. Since the respondents were more likely to have a negative view (instead of a positive view) of media coverage of nanotechnology, we were able to confirm our third hypothesis.

The goal of our fourth (and final) hypothesis was to test whether scientists were more positive about media coverage of general science or nanotechnology. As we pointed out in the literature review, previous researchers have found that scientists tend to be more positive about general science media coverage than they are about coverage in their own disciplinary fields (Ruth et al. 2005). We did confirm our fourth hypothesis with this analysis; the scientists' perceptions about the accuracy and credibility of the media coverage were significantly different for general science coverage and nanotechnology coverage. On average, the scientists thought that media coverage of general science was more accurate than the media coverage of nanotechnology. Similarly, they perceived that

Table 5 Scientists' perceptions about media coverage of science and nanotechnology ($N = 363$)

	General science media coverage (Mean)	General science media coverage (St. Dev.)	Nanotechnology media coverage (Mean)	Nanotechnology media coverage (St. Dev.)
(1 = strongly disagree; 5 = strongly agree)				
Media coverage is inaccurate[a]	2.99*	0.94	3.12*	0.98
Media coverage is hostile to science[b]	2.39	0.94	2.47	0.95
Media coverage uses credible scientific sources[c]	3.10*	0.85	2.95*	0.89
Media coverage is sufficiently comprehensive[d]	2.39	1.04	2.36	1.04
Negative and positive media perception indices				
Negative index: Inaccurate[a] + Hostile[b]	5.39	1.54	5.59**	1.54
Positive index: Credible[c] + Comprehensive[d]	5.49	1.56	5.31**	1.64

Note that the mean differences across negative/positive indices for general science media coverage were ***not*** significant at the 0.05 level

* Mean differences across general science media coverage and nanotechnology media coverage are significant at 0.05 level

** Mean differences across negative/positive indices for nanotechnology media coverage are significant at the 0.05 level

[a] Thinking of mass media such as newspapers, radio and television, media coverage of *scientific topics in general* usually is inaccurate. (1 = strongly disagree; 5 = strongly agree). "Thinking of mass media such as newspapers, radio and television, media coverage of *nanotechnology research* usually is inaccurate." (1 = strongly disagree; 5 = strongly agree)

[b] Thinking of mass media such as newspapers, radio and television, media coverage of *scientific topics in general* usually is hostile to science." (1 = strongly disagree; 5 = strongly agree). "Thinking of mass media such as newspapers, radio and television, media coverage of *nanotechnology research* usually is hostile to science." (1 = strongly disagree; 5 = strongly agree)

[c] "Thinking of mass media such as newspapers, radio and television, media coverage of *scientific topics in general* usually uses credible science sources." (1 = strongly disagree; 5 = strongly agree). "Thinking of mass media such as newspapers, radio and television, media coverage of *nanotechnology research* uses credible scientific sources." (1 = strongly disagree; 5 = strongly agree)

[d] "Thinking of mass media such as newspapers, radio and television, media coverage of *scientific topics in general* usually is sufficiently comprehensive." (1 = strongly disagree; 5 = strongly agree). "Thinking of mass media such as newspapers, radio and television, media coverage of *nanotechnology research* usually is sufficiently comprehensive." (1 = strongly disagree; 5 = strongly agree)

general science media coverage was more likely to use credible sources than nanotechnology coverage. Even though we do not have data to confirm the reasons for these results, we speculate that the scientists see nanotechnology as a more specialized and technical area for media coverage and therefore they might think that journalists are not as accurate in their coverage of it.

We would like to conclude this section by outlining that we ran the above analyses for subgroups based on gender (i.e., female versus male) and disciplinary field (i.e., doctoral degrees in Biology, Chemistry, Physics, Engineering, Materials Science and Other). Several scholars have found gender differences in risk perceptions about scientific or environmental hazards among the lay public (Finucane et al. 2000; Flynn et al. 1994; Greenberg and Schneider 1995; Gustafson 1998; Lazo et al. 2000). And in studies that are focused on scientists, scholars have also explored gender differences in risk perceptions (for example, Barke et al. 1997; Slovic et al. 1995). Even though most of these previous studies focus on gender differences across "risk" perceptions rather than "media" perceptions (which are the focus of our article), Ruth et al. (2005) did explore gender differences among U.S. scientists that communicate with the media. Ruth et al. (2005) concluded that male U.S. scientists were more confident than female U.S. scientists in their ability to communicate with the media. Given that multiple previous studies have found gender differences across risk perceptions and (in fewer cases) media perceptions, we also wanted to test whether there were significant gender differences in our media perception and public communication timing variables. Yet, after comparing the means of these variables across the male and female scientists in our sample, we did not find any significant gender differences for the media perception variables.

In addition to exploring differences across gender, we wanted to determine whether there were any significant differences in the media perception or public communication timing variables across the six general disciplines represented in our sample (Biology, Chemistry, Physics, Engineering, Materials Sciences, and Other). For our analysis, the disciplinary affiliation for a scientist was assigned by the self-reported discipline of the Ph.D. degree. As with the gender analysis, we did not find many noteworthy results for the comparison of the media perception and public communication timing variables across disciplinary fields. The one significant difference that we found across these variables was for scientists' perceptions about media hostility. We found that Biologists were more likely than scientists in other disciplines to perceive the media as being hostile toward science. Since this was the only significant difference across disciplines for the media perception variables and the public communication timing variables, we did not include a full table of results across disciplines in this article.

Linkages between media perceptions and public communication of research

Now that we have explored the scientists' perceptions about public communication of research findings as well as their perceptions about science media coverage, we turn to our third research question. This question explores the potential linkages between the scientists' perceptions about media coverage and public communication of research. To answer this question, we explored the correlation between media perceptions about science and the timing of public communication of research findings. Since the news media can serve as a relatively rapid outlet for the communication of scientific findings (if scientists are willing to share their results with journalists), we expected to see a positive correlation between support for immediate public communication of research results and positive attitudes about the media coverage. Likewise, we expected to see a positive correlation between support for delaying pubic communication of results until after publication and negative attitudes about media coverage. Our results are presented in Table 6.

Table 6 Correlations between science media coverage perceptions and public communication perceptions ($N = 363$)

	Public communication after publication	Public communication immediately
(1 = Strongly disagree; 5 = strongly agree)		
Science media coverage is inaccurate	0.115*	−0.138**
Science media coverage is hostile to science	0.084	−0.171**
Science media coverage is credible	−0.172**	0.125*
Science media coverage is comprehensive	−0.236**	0.176**

* Correlations significant at 0.05 level

** Correlations significant at 0.01 level

In all cases except one, we found the significant correlations that we expected between media perceptions and attitudes about public communication of research findings. As the scientists had more positive perceptions about science media coverage (i.e., that it was credible and comprehensive), they were more likely to support immediate public communication of scientific results and less likely to support delaying public communication until after results are published in a scholarly journal. As scientists believed that science media coverage was inaccurate, they were more likely to support delaying public communication of research results until after they had been published in a scholarly journal. These results confirmed our speculation about the relationship between media coverage perceptions and timing of public communication.

Potential study limitations

As with any social science data collection effort, there are some limitations to our study that we should highlight before delving into our conclusions. First, issues of question ordering and primacy are important considerations for the design of any questionnaire and we were particularly attentive to them when we constructed the questionnaire. First, all of the media perception questions were placed at the beginning of the survey, so they should not be impacted by prior questions. In cases other than the media questions, we were careful to avoid making concepts salient that could potentially prime responses to subsequent questions in the survey.

Second, some of our results that focused on high levels of expertise for university scientists could potentially be artifacts of our sample (since over 90% of the respondents were university scientists themselves), but this sample design is not just a limitation; it is also a strength. Since we originally designed our sample to capture the most prolific and highly cited researchers in the field of nanotechnology, we have been able to report findings for the most active and successful individuals in the field right now. Of course, given the nature of the academic enterprise, the majority of publishing scientists are located at universities. Thus, our sample design includes a large proportion of university scientists. Therefore, the limitation is in our inability to analyze subgroups of scientists based on their career affiliations (such as industry-based versus university-based analyses). And some researchers have shown that career affiliations can impact scientists' perceptions (Kraus et al. 1992; Slovic et al. 1995). For example, Kraus et al. (1992) studied the impact of career affiliations on scientists' risk perceptions to conclude that industry-based toxicologists viewed chemicals as less risky than their peers in universities or government. Even though Kraus and colleagues focused more on risk perceptions than media perceptions, we are interested in exploring this potential affiliation bias for media perceptions in future studies when we have a larger percentage of industry-based and government-based scientists. So, on the one hand, this sample has been ideal for our research questions because we targeted the group that we wanted to study. On the other hand, future studies that include more industry-based scientists, as well as regulators, would add to the richness of the data results and flesh out the landscape of perceptions about public communication and media coverage more broadly.

A third potential limitation could be the respondents' perceptions about the timing of public communication of research results based on their tenure status. One might assume (given that presenting controversial results is not always positive for the promotion and tenure process) that untenured, tenure-track faculty members might want to postpone communicating their results with the public more than their tenured peers. Even though we have a somewhat small percentage of untenured, tenure-track faculty members in our sample, we wanted to see whether this assumption was true. Therefore, we compared the mean values for untenured, tenure-track faculty with tenured faculty for the two variables focused on the timing of public communication (i.e., after publication or immediately when results are found). With respect to communicating research findings to the general public only after publication, the tenured faculty had a mean of 3.93 ($SD = 1.18$) and the untenured, tenure-track faculty had a mean of 3.90 ($SD = 1.14$). Similarly, with respect to communicating research findings to the general public immediately, the tenured faculty reported a mean of 2.71 ($SD = 1.28$) and the untenured, tenure-track faculty reported a mean of 3.00 ($SD = 1.26$). We ran a series of *t*-tests to compare the means for these two groups and found no significant differences across them for the timing of public communication variables. Therefore, this issue could have been a potential limitation for our analysis, but our comparison tests indicate that it is not a significant issue. Now that we have discussed some potential limitations of our study, we will draw some general conclusions for our results in the next section.

Conclusions

Most importantly, the results of our study demonstrate that nano-scientists do see a connection between the public communication of research findings and public attitudes about science. This result makes us optimistic about the future engagement of nano-scientists with regulators and the public about key issues of nanoregulations, as well as nanorisks and benefits. Clearly, the scientists in our study did not think that their scientific results were useless or unimportant for public consumption.

On the other hand, the scientists demonstrated mixed views on the timing for this public communication, with some scientists supporting the immediate public communication of research findings and others arguing that communication should take place only after research findings have gone through the peer-review process and been published. So what drives this difference in views? While our data did not allow us to fully answer this question with a causal model, we were able to explore some variables that allowed us to get a better picture of nano-scientists' attitudes about the timing of public communication. For example, we concluded that scientists with positive attitudes about the media were more likely to support immediate public communication of research findings and scientists with negative attitudes about the media supported delaying public communication. This leads us to the question of how to get more nano-scientists engaged in disseminating their results to the public and regulators through news media without waiting for the full peer-review process (which can often take months to years). Even though we do not have the data to answer all aspects of this question, we can report that the scientists that viewed media coverage as being largely credible and comprehensive were more likely to support circumventing the peer-review process and communicating their results to the public immediately. We also found that journalists might have a more difficult challenge in getting nano-scientists to talk with them about nanotechnology news stories than they do with general science stories because the scientists viewed nanocoverage as less credible and less accurate than general science media coverage.

These results about scientists' negative perceptions of media coverage are aligned with previous studies that have highlighted the implicit tension in the relationship between journalists and scientists (Gunter et al. 1999; Dunwoody and Scott 1982; Nelkin 1996; Ruth et al. 2005; Geller et al. 2005; Maille et al. 2010; Peters 1995). Our study results imply that (for nano-scientists at least) this tension seems to be linked more to a concern for accuracy and credibility than it is to a sense that media coverage is actively hostile toward science. Therefore, our findings could suggest that nano-scientists are less concerned that media coverage of their field is hostile or intentionally wrong; rather they seem to view journalists as being driven by the need to embellish a story to make it more sensationalistic (and, in the process, less accurate). This supposition is reinforced by previous studies that have highlighted scientists' perceptions about the sensationalistic nature of science media coverage (Hartz and Chappell 1997; Gunter et al. 1999; Petersen et al. 2009). In this study, we do not have the data to formally test this speculation but our results do seem to indicate that scientists are more concerned about the journalistic norms of writing a catchy and intriguing story than they are about individual journalists intentionally writing a hostile story about science.

So if scientists decide to communicate their nanotechnology research results with the public through news media, what issues do they think are most important for the public to know? Overwhelmingly, the scientists felt that the risks and benefits of nanotechnology were the most important content areas for public communication. Interestingly, the scientists did not consider issues of existing nanotechnology regulations or moral issues about nanotechnology to be as important for public communication. Since we concluded that scientists believe that public communication of research does have an impact on public attitudes, which groups do they believe should be responsible for this communication? Despite the hesitation of some scientists to engage the public on these issues, our respondents thought that scientists like themselves (i.e., university-based scientists doing nanotechnology research) had the most expertise and the highest level of responsibility to communicate with the public. This finding aligns with previous studies that have found that scientists have an ethical obligation to communicate their findings with the public in the name of democracy (Dibella et al. 1991; Weigold 2001; Petersen et al. 2009; Glass 1993). In sum, our results indicate that the nano-scientists in our sample do feel an obligation to communicate with the public about their research findings, but attitudes about the timing and the pathway of that communication vary across the group.

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