Stimulating Upstream Engagement: An Experimental Study of Nanotechnology Information Seeking*

Michael A. Xenos, *University of Wisconsin–Madison*
Amy B. Becker, *Towson University*
Ashley A. Anderson, *University of Wisconsin–Madison*
Dominique Brossard, *University of Wisconsin–Madison*
Dietram A. Scheufele, *University of Wisconsin–Madison*

Objectives. The current study examines upstream engagement initiatives using the issue of nanotechnology as a case study. *Methods.* A series of logistic and OLS regression analyses explore data from a laboratory experiment on information-seeking behavior, knowledge, and willingness to engage with the issue of nanotechnology in the future. *Results.* Our results fail to offer evidence of positive relationships between anticipated discussion and learning and the willingness to engage with the issue of nanotechnology in the future. In addition, our results show that anticipated discussion with opposing others actually encourages individuals to seek out an editorial or opinion piece first as opposed to a news item. *Conclusion.* Our findings point toward important variations in the kinds of information-seeking behaviors likely to emerge from different conditions under which individuals may be motivated to learn more about emerging science issues, and provide practical insights into which kinds of information-seeking behaviors are most conducive to knowledge gain and issue engagement.

Movement toward a model of public engagement with science is difficult to resist. Such an approach promises a strongly democratic paradigm that seeks to actively draw publics into policy discussions about science through what Lezaun and Soneryd (2007) aptly refer to as "technologies of elicitation"—discussion groups, consensus conferences, citizen juries, and a variety of similar fora. Reflecting contemporary interest in deliberative democracy and inclusive

*Direct correspondence to Michael A. Xenos, Department of Communication Arts, University of Wisconsin–Madison, 6152 Vilas Hall, 821 University Ave., Madison, WI 53706 ⟨xenos@wisc.edu⟩. Michael A. Xenos will provide all data and coding information to anyone wishing to replicate this study. This material is based on work supported by grants from the National Science Foundation to the Center for Nanotechnology in Society at Arizona State University (Grant SES-0531194) and the UW–Madison Nanoscale Science and Engineering Center in Templated Synthesis and Assembly at the Nanoscale (Grant SES-DMR-0832760). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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policy making, efforts at public engagement with science thus offer attractive mechanisms for facilitating discursive processes that identify and grapple with the potential implications of scientific and technological developments. In their ideal form, such efforts at engagement take place "upstream," that is, before either significant research and development decisions or major public controversy has emerged in connection with a particular scientific domain (Pidgeon and Rogers-Hayden, 2007; Rogers-Hayden and Pidgeon, 2007). By bringing nonexpert publics into the conversation at such an early stage, efforts at *upstream engagement* seek to create the best possible conditions for sound policy making and public judgments based on careful assessment of objective information. Policymakers have made explicit calls for upstream engagement by citizens for a variety of scientific issues in numerous contexts (see Scheufele, 2011:Appendix). An early example of such requests is a 2000 U.K. House of Lords report recommending that direct dialogue with citizens should be a mandatory and integral part of policy processes (U.K. House of Lords, 2000).

In this article, we attempt to shed light on the dynamic processes by which upstream engagement initiatives are believed to promote healthy patterns of citizen involvement with science and technology issues. In contrast to most previous research, which takes a more practical or observational approach (e.g., Einsiedel and Eastlick, 2000; Pidgeon et al., 2008; Powell and Kleinman, 2008), we use a laboratory experiment to test basic hypotheses derived from theoretical accounts relevant to the kinds of opinions, processes, and behaviors involved in many public engagement initiatives, with a topical focus on nanotechnology. In this way, our study seeks to provide a focused social scientific account of efforts that aim "to increase the public's level of knowledge and understanding about these technologies so that they may make informed decisions about the appropriateness of such technologies in promoting human welfare" (Kyle and Dodds, 2009:86).

In so doing, we hope to shed light on two areas of research. First, we hope to provide insights into questions about which publics are most likely to search for factual information about new technologies, form more reasoned opinions about them, and seek out further engagement with others through political discussion about science and technology policy. Though we explore these issues in a controlled experimental setting, we are fundamentally interested in practical questions concerning how these processes may be best stimulated by key design features of public engagement interventions. Our findings point to important variations in the kinds of information-seeking behaviors likely to emerge from different conditions under which individuals may be motivated to learn more about new technologies, and provide insights into which kinds of information-seeking behaviors are most conducive to knowledge gain and further engagement in discussion of related policy questions. To be sure, some of the inherent limitations of our approach prevent us from offering definitive conclusions about the viability of upstream engagement initiatives. However, we believe such an approach does offer a number of unique insights relevant to processes involved in such interventions.

Since discussions about science and technology are ineluctably political (Sturgis and Allum, 2004), our investigations also engage issues treated by classic literatures in political psychology and political communication. Indeed, in many ways the "technologies of elicitation" involved in upstream engagement initiatives are a direct application of principles derived from an increasingly mature literature on deliberative democracy (Einsiedel and Eastlick, 2000). However, science and technology issues, particularly those involving new concepts relatively unfamiliar to most people, differ markedly from the more familiar issues typically treated in studies of deliberation. Thus, we believe the findings presented here may also have important implications regarding the broader applicability of deliberative models of public engagement.

Nanotechnology: Opinion, Knowledge, and Information Seeking

Some have identified nanotechnology as the archetypical example of a fertile area of scientific and technological development in which the seeds of an upstream engagement approach could bear fruit (Lezaun and Soneryd, 2007; Pidgeon and Rogers-Hayden, 2007; Rogers-Hayden and Pidgeon, 2007). Indeed, although there has been some growth in basic public awareness over the past decade, current estimates suggest that nanotechnology is "off the radar" for most people. In fact, the proportion of the U.S. public that reports having heard "just a little" or "nothing at all" about this burgeoning scientific field remains in the neighborhood of 80 percent (Satterfield et al., 2009). At the same time, in a manner that would not surprise most public opinion scholars, when pressed for a response, many individuals will offer some form of opinion even if they have little or no concrete information on the subject in question (Neuman, 1986; Scheufele and Lewenstein, 2005). Based on these expressed preferences, one may characterize the overall tenor of public opinion regarding nanoscale technologies as somewhat positive, with an emphasis on the potential benefits of nanotechnology over potential risks (Cobb and Macoubrie, 2004; Peter D. Hart Research Associates, 2008). However, though currently mildly positive on balance, public attitudes toward nanotechnology bear all the earmarks of fluid tides that could shift dramatically as a result of new information or other events that might suddenly increase the visibility of nanoscience and related issues (Anonymous, 2009). This is due to the fact that neither major policy activity nor controversy has yet to stimulate the kind of significant attention to these issues among members of the general public that can produce stronger, more stable public attitudes (Yankelovitch, 1991). In other words, nanotechnology appears to offer an ideal context for exploring processes of upstream engagement with science and technology issues. In fact, scholars have implemented several studies of upstream engagement with nanotechnology, including consensus conferences and other educational fora (e.g., Besley et al., 2008; Cobb, 2011; Kleinman, Delborne, and Anderson, 2011; Powell and Kleinman, 2008), identifying the issue of nanotechnology

as an important one in terms of reaching members of the public early in its development.

More specifically, three clear characteristics or patterns concerning the public's knowledge and opinions toward nanotechnology help to contextualize it as an opportunity for studying upstream engagement dynamics. One of these, as suggested at the outset, is that awareness of nanotechnology and factual knowledge about related issues is relatively low. Indeed, in Cobb and Macoubrie's survey, in response to an item designed to tap familiarity with nanotechnology, just over half of respondents (51.8 percent) reported having "heard nothing" about nanotechnology, and almost a third (31.8 percent) reported having heard only "a little" about these issues (2004:397). These perceptual measures are further corroborated by data on factual knowledge, which were gathered using three "true/false" questions concerning the scale of nanotechnologies and their current and potential industrial applications. Totaling correct answers from this three-item scale, Cobb and Macoubrie (2004) reported that only a minority of respondents could answer more than one correctly. These low levels of knowledge measured using true/false questions have remained relatively stagnant since 2004 (Scheufele et al., 2009). A recent overview study of a range of similar investigations suggests that these low levels of awareness have remained stable and relatively robust (Satterfield et al., 2009; Anonymous, 2009), even though some studies have identified widening gaps in understanding across socioeconomic fault lines (e.g., Corley and Scheufele, 2010). Within the context of broader research in public opinion, such patterns suggest that, however positive, opinions about nanotechnology among the general public are not firmly rooted in the kinds of knowledge structures typically associated with more stable and predictable opinion patterns. In the face of low levels of awareness, individuals often turn to heuristics, or cognitive shortcuts, such as the way an issue is framed in the media, strength of religious beliefs, or perceptions of the risks and benefits of nanotechnology, to form opinions about nanotechnology (Brossard et al., 2009; Scheufele, 2006; Scheufele and Lewenstein, 2005). This established pattern of opinion formation based on heuristics has shown nanotechnology to be an interesting case of how people form attitudes around issues for which they have low levels of awareness.

At the same time, a second pattern is that some ideas about nanotechnology have entered popular culture (at least to the point at which opinions can be registered) and, on balance, attitudes toward nanotechnology based on the faint images reflected in these ideas are positive. For example, in one of the first large-scale studies of public attitudes toward nanotechnology, Bainbridge reported that nearly 60 percent (57.5 percent) of respondents agreed with a statement that "human beings will benefit greatly from nanotechnology" (2002:562). As a corollary, only 9 percent agreed with the oppositely valenced statement that nanotechnology is "threatening to make humans an endangered species" (Bainbridge, 2002:563). A later and more elaborate investigation of opinions toward nanotechnology conducted by Cobb and Macoubrie (2004)

explored this pattern further by documenting a plurality of respondents who perceived the potential benefits of nanotechnology as more probable than the possible risks. A recent survey shows that while 20 percent of Americans think the benefits of nanotechnology outweigh the risks, only 7 percent believe the risks outweigh the benefits and a quarter believe the benefits and risks are equal (Peter D. Hart Research Associates, 2008).

The third pattern emerges from the analytical combination of the first two. Specifically, in these early studies of awareness of, and attitudes toward, nanotechnology, as well as subsequent related studies, there is frequently an observed positive correlation between knowledge and positive opinion (Bainbridge, 2002; Cobb and Macoubrie, 2004; Lee and Scheufele, 2006; Satterfield et al., 2009). Dubbed the "familiarity hypothesis," this pattern speaks to the dominance of positive attitudes and opinions toward nanotechnology among the relatively small fraction of individuals with the most familiarity and knowledge. Taken together with the other observed characteristics of opinions and consistently low levels of knowledge toward nanotechnology, this finding presents a positive picture suggesting that as individuals acquire greater awareness and knowledge of nanotechnology, aggregate opinion may continue on a positive path.

Such a conclusion, however, requires a kind of willful ignorance concerning the limitations of cross-sectional data with respect to causal questions, and overlooks other ways in which opinions and information seeking may be related. As Kahan (2009) points out, an obvious alternative explanation for positive correlations between attitudes toward, and knowledge of, nanotechnology posits that attitudes (and perhaps deeper, cultural predispositions) drive information acquisition rather than the other way around. This explanation is also consistent with a model of motivated reasoning that, inter alia, predicts that individuals will seek information with a confirmation bias and that these patterns are most pronounced among those with the strongest attitudes (Taber and Lodge, 2006). Given the state of public opinion toward nanotechnology described earlier, there is strong overlap between those with the strongest opinions and those with positive opinions. Thus "[a] natural hypothesis is that individuals who are in general pro-technology are moved to acquire more information about nanotechnology" (Kahan, 2009:706). Indeed, experimental research by Kahan and his colleagues on "cultural cognition" has provided indirect support for this interpretation by showing that information exposure does not appear to drive opinions toward nanotechnology (Kahan et al., 2009). Similarly, work by Brossard and colleagues has shown how information processing and attitude formation about nanotechnology depends on lay audiences' preexisting value systems, including a general deference toward scientific authority (Brossard et al., 2009, Brossard and Nisbet, 2007). However, such findings are oriented toward explaining opinions rather than information acquisition itself, and do not in and of themselves confirm a central assumption of this alternative explanation. Toward that end, our first hypothesis formalizes this assumption for testing in the present study. This provides us

with an initial baseline expectation for exploring information seeking related to nanotechnology.

H_1: *Support for nanotechnology will be positively associated with seeking factual information about nanotechnology.*

A central goal of seeking information from news media, particularly for those anticipating discussion with others either in a citizen jury or a less formal setting, is, of course, the development of knowledge that can serve as a basis for refining opinions and considerations that one might share in conversation. A second assumption we begin with is that consumption of relevant information is associated with greater factual knowledge. As will be discussed below, information seeking stimulated by the anticipation of discussion has been posited as a mechanism for explaining observed relationships between discussion and knowledge in cross-sectional data. In the case of nanotechnology, relevant factual information can come in a variety of formats. In particular, we focus on general news coverage, more specialized science coverage, and editorial coverage. Further, we begin with the assumption that science coverage, given its specialized focus, offers the highest level of factual information about nanotechnology, followed by general news and then editorial coverage. On the basis of these assumptions, we offer the following hypothesis.

H_2: *Consumption of science coverage related to nanotechnology will be positively associated with factual knowledge about nanotechnology.*

Anticipated Discussion as a Catalyst for Engagement

Turning more directly to the processes by which efforts at upstream engagement may work, our remaining hypotheses deal with a central contextual factor that we believe lies at the heart of most "technologies of elicitation," the anticipation of future discussion, and its effects. Indeed, we submit that the effects of anticipated discussion with others, whether in formal or informal contexts, may hold important contributions to our understanding of how patterns of awareness, knowledge, and opinion related to nanotechnology are likely to change in the future. As implied by the upstream engagement perspective, these dynamics may either be stimulated artificially, or they may arise (albeit in a less controlled form) as a result of "significant research and development decisions or major public controversy." Whereas H1 and H2 may provide substantial leverage over questions of how individuals may respond to information exposure under ordinary circumstances, they provide less insight into questions of how information exposure itself may come about under these less ordinary circumstances, particularly among those without the kinds of predispositions associated with learning about science. Indeed, we seek to understand how individuals who are relatively unfamiliar with nanotechnology are likely to search out new information about it, as well as how various

patterns of information seeking may be related to factual knowledge gain and willingness to engage in subsequent information seeking and discussion. As noted earlier, we believe these dynamics are implicated in various kinds of "upstream" engagement interventions and outreach activities commonly pursued surrounding nanotechnology and other new areas of science and discovery, as well as conditions that may emerge naturally from a sudden increase in the profile of these kinds of issues in public discourse either through policy activity or social controversy.

Research in social psychology and political communication has long identified the expectation of an impending discussion with others as a powerful catalyst for the kinds of knowledge gain, opinion formation, and cognitive elaboration that upstream engagement initiatives are intended to stimulate. Based on the expectation of a context in which they may be called on to state or justify their opinion to others, individuals are believed to become motivated to seek information and to process it carefully. In psychology, the anticipation of discussion is typically considered within the framework of "accountability," and although a careful assessment of the research literature suggests that different forms of accountability may have divergent effects on patterns of information processing, learning, and opinion formation, at least some have been found to predict increased cognitive effort of the kind we are discussing here (Lerner and Tetlock, 1999). In particular, researchers have investigated the possibility that group composition factors, such as the presence of and/or membership in majority and minority factions, "may importantly influence subjects' motivation to acquire, process, and retain issue-relevant information" (Levine and Russo, 1995:296).

In the political communication literature, these matters are approached in a slightly more concrete format, often within the context of individuals' media consumption patterns, particularly with respect to information-rich "hard news" content. For example, in her classic work, *Processing the News*, Doris Graber (1988) reported results from a study in which she found that a strong determinant of whether citizens took an active interest in information about certain political issues was the presence of social cues identifying these topics as ones that most citizens ought to be concerned about. Referring to her study participants, she noted that "[w]hen they sensed that a topic had become the focus of attention for conversation among their friends or associates ... or when one of their contacts persisted in mentioning the topic, they were apt to search for relevant information" (Graber, 1988:99).

These ideas find further elaboration in more recent research on the impacts of political discussion on knowledge and participation. Scheufele's analyses of national survey data, for example, suggest that "political discussions with others may also prompt individuals to more closely scrutinize media reports and to process messages more carefully" (2002:51). Following this line of argument, Eveland (2004) discusses possible explanations for the well-documented empirical association between political knowledge and frequency of political

discussion, and identifies the anticipation of future discussions as a possible explanation for why some individuals pay greater attention to information about particular issues in the news media. He calls this process "anticipatory elaboration" and finds support for it in a study based on survey data collected during the 1996 presidential campaigns (2004:180). Conceptually, this idea of anticipatory elaboration overlaps significantly with Cloven and Roloff's (1995) notion of cognitive tuning effects, in which individuals try to make sense of information—especially contradictory or incomplete information that they receive from mass media—in order to be able to better describe the information to others or perhaps to defend it during future discussions. Finally, Scheufele et al. (2004) found hard news use to be an important mediating factor in explaining relationships between various kinds of recurrent political conversations and factual political knowledge. Together, these accounts suggest that one important mechanism by which individuals may become motivated to seek information and learn about particular issues is the anticipation of engaging in some form of conversation with others. We expect individuals to respond to the context of anticipated discussion by seeking out factual information from hard news sources so that they may have the most widely applicable material to use in conversation and for the purposes of forming and possibly defending related opinions.

As Lerner and Tetlock's (1999) review of the psychological research on accountability suggests, however, there are in fact a wide variety of forms that accountability cues, such as the anticipation of discussion, may take, and these variations may be consequential. In the context of communications research, the kinds of variations that have received the greatest attention from scholars concern the composition of groups in which anticipated discussions may occur. For example, a substantial body of research in political communication has examined the implications of heterogeneity and homogeneity, or the extent to which expected discussions may be expected to take place with individuals of similar or different opinions (Eveland and Hively, 2009; Huckfeldt and Sprague, 1995; Nir, 2005; Scheufele et al., 2006). Results from these studies suggest generally consistent predictions concerning information seeking, but diverge with respect to impacts on future engagement and participation. For example, positive relationships between both discussion network heterogeneity and homogeneity (or "dangerous" vs. "safe" discussion contexts) and hard news use have been documented in multiple studies (Eveland and Hively, 2009; Scheufele et al., 2006). However, the impacts of these contexts become more distinguishable with respect to other behaviors, such as future participation related to the topic of discussion. Whereas the experience of political disagreement has been found to be negatively related to subsequent participation, the opposite has been found for "safe" discussion encounters among individuals with which one largely agrees (Eveland and Hively, 2009; Mutz, 2006). Given that such experiences with "dangerous" and "safe" discussion contexts are likely the strongest point of reference for individuals faced with an upstream engagement scenario, we believe it is reasonable to expect

that similar dynamics are likely to emerge for anticipated discussions about a new scientific issue. On the basis of these slightly more refined considerations about varying anticipated discussion contexts and their effects, we offer the following additional hypotheses.

H_{3a}: *Anticipation of discussion with individuals holding opposing opinions will be positively associated with seeking factual information about nanotechnology.*

H_{3b}: *Anticipation of discussion with individuals holding opposing opinions will be negatively associated with intentions toward future conversation and engagement.*

H_{4a}: *Anticipation of discussion with individuals holding similar opinions will be positively associated with seeking factual information about nanotechnology.*

H_{4b}: *Anticipation of discussion with individuals holding similar opinions will be positively associated with intentions toward future conversation and engagement.*

Finally, though researchers have explored the relationship between general exposure to media and future participation for some time (e.g., Lemert, 1984; see also Becker et al., 2010), we find only a very limited basis for generating expectations concerning the relationship between these distinct forms of information seeking and future engagement. Nevertheless, we have strong suspicions that variations in information-seeking behaviors may play a significant role in subsequent engagement activities such as seeking further information and engaging in discussion with others. Thus we limit our consideration of these issues to a research question, rather than offering a formal hypothesis.

RQ_1: *Are particular kinds of information-seeking behaviors (such as consuming general news, science news, or editorial content) related to intentions toward future engagement with nanotechnology issues?*

Data

To test our hypotheses and explore the research questions outlined above, a four-group experiment was conducted using the MediaLab software platform. Undergraduates enrolled in upper- and lower-level communications courses at two large public U.S. universities (one in the Midwest and one in the South) participated in the experiment and received extra credit during the fall 2009 and spring 2010 semesters as compensation for their participation. Together a total of $N = 250$ subjects participated in the lab-based experiment ($n = 62$ subjects from the midwestern university campus participated in the experiment between November 9–13, 2009; $n = 188$ subjects from the university located in the South participated in the experiment between

November 18, 2009–March 26, 2010). Across both campuses, the gender composition of the participant pool was 59.6 percent female. Average age in years was 21.10 ($SD = 1.86$), and average parental education level was 5.67 ($SD = 0.90$), which corresponds to somewhere in between "some college" and "college diploma." Statistical analysis revealed no significant variation on these demographic characteristics by condition, indicating a successful process of random assignment (for gender: $p = 0.45$, for age: $p = 0.82$, and for parental education: $p = 0.86$). Additional preliminary tests also revealed no significant variation in condition assignment by data collection site (*chi-squared* = 1.10, $df = 3$, $p = 0.78$).

Experimental Design

The lab sessions began with a standard consent form that described the session as a study focused on the "Processing of Information on Nanotechnology." Participants were randomly assigned to one of four conditions by the software program. Each condition included some basic introductory information about nanotechnology and its applications, including the use of nanoparticles made of silver in commercial products. All conditions also began with the same short pretest questionnaire including items tapping media use, awareness of nanotechnology, general attitudes toward nanotechnology, political interest, and political talk. After the pretest questionnaire, participants assigned to the first three conditions were told that they would be asked to take part in "a discussion with other study participants about the pros and cons of having the government regulate the use of silver nanoparticles" after completing the computer portion of the study. Participants assigned to the first condition ($n = 72$) were simply told that they would be required to participate in a brief discussion session with others concerning possible regulation of silver nanoparticles. Those in the second and third conditions received additional statements that referred to real-time preprocessing of pretest responses from others present in the lab. In the second condition ($n = 56$), participants were told that they should expect to encounter individuals who held opinions on the regulation of silver nanoparticles that were the opposite of, or in disagreement with, their own opinions. Finally, participants in the third condition ($n = 67$) were told that they would be taking part in a discussion session on the regulation of silver nanoparticles with others who were known, based on pretest responses, to hold similar opinions on, or attitudes in agreement with, their views on the regulation of silver nanoparticles. The fourth condition was treated as the control cell ($n = 55$) and did not make mention of or actually feature a discussion session. Participants assigned to the control group were informed that they would simply leave the lab after completing the computer portion of the study.

Participants in all four conditions were then told that they would have eight minutes to review a collection of news media content that contained

additional information about the use of nanosilver particles and nanotechnology research in general. Participants were also told that after browsing the information board they would then be asked some additional questions about their opinions and thoughts regarding regulations on the use of silver nanoparticles, such as the potential benefits or risks of nanotechnology. Finally, participants who were instructed that they would be taking part in a discussion session after the computer portion of the study were also told that "a large part of the discussion you will have later will involve sharing and talking about your opinions and thoughts about this issue."

The webpage that participants encountered during the timed browsing session was integrated into the experimental platform such that a detailed history or "clickstream" could be recorded and later merged with data from the pre- and posttest instruments. Thus it operated as an "information board," similar to those used in classic studies of information seeking and decision making. Titled "Information on Nanotechnology," the information board featured 28 news articles on nanotechnology that were divided into columns under three category headings: (1) General News, (2) Science & Medicine, and (3) Editorial & Opinion. Some of the articles focused specifically on nanosilver particles while others focused on the risks and benefits of nanotechnology more broadly, the application of nanotechnology to health-care technology, or the connections between nanotechnology and consumer products. During the eight-minute browsing session, subjects were able to click on an article of interest, review it, and then hit a "back" button to return to the main information board browsing screen. All the articles were culled from major news publications, with the majority appearing in major newspapers during the 2008 calendar year. Each selection included the original article text, publication date, byline, and headline for the piece. Having been pulled from Lexis-Nexis, the articles did not include graphics or source masthead images. The web information board was designed in such a way that the sequence of the stories within each category was randomly reordered each time a subject returned to the index screen so as to remove any bias toward articles at the top of each list and force participants to review headlines more carefully when selecting what to read next. Some sample article titles included: "EPA to Regulate Nanosilver Particles" (General News), "Tiny Science, Big Advances" (Science & Medicine), and "Building a New World, Atom by Atom" (Editorial & Opinion).

The actual discussion among participants assigned to the first three conditions lasted about five minutes and was conducted in an informal fashion. Discussions were not recorded given that we were actually only concerned with the effects of anticipated discussion on information-seeking behavior. As Eveland notes, the logic of the anticipatory elaboration process "does not actually require the actual discussion to take place" (2004:180). After the brief discussion sessions, participants were thanked and excused from the lab.

Key Measures

Information Seeking. Our principal outcome measures were derived from the information board platform described above, and relate to a variety of data available from participant clickstreams. First, we extracted data on the very first article selected by each participant. Specifically, we used these data to identify whether their first destination within the information board was a General News, Science & Medicine, or Editorial & Opinion article. Additionally, we also aggregated views by category to produce measurements of the total time, in seconds, participants spent reading different kinds of articles. Since the number of articles in each section was not equal, we averaged these to produce measures of average news viewing, average science and medicine viewing, and average editorial viewing.

Knowledge. Factual knowledge about nanotechnology was measured through eight true/false questions, many of which were similar to those that have previously been used in studies of public awareness about nanotechnology. By design, correct answers to all these items were available within the articles included in the information board. These questions focused on topics such as what nanoscale means, as well as industrial and commercial applications of nanotechnology. Our summed knowledge variable ranged from 0 to 8, with a mean of 4.64 ($SD = 1.32$) across all conditions.

Intentions Toward Future Engagement. Our final outcome measure, willingness to engage, was created using seven posttest items that asked participants to agree or disagree (on a seven-point scale) with a variety of statements concerning predispositions toward having conversations about nanotechnology in the future (with family and friends, as well as with safe and hostile discussion partners) and also toward the seeking of additional information about nanotechnology. Although these items span a fairly wide conceptual gamut in terms of their reference objects, their degree of co-variation was deemed high enough to consider them as tapping a single underlying construct. Thus our measure of willingness to engage is a mean of responses to these items (Cronbach's $\alpha = 0.83$, $M = 4.00$, $SD = 1.21$).

Support for Nanotechnology. We also included a measure tapping pretest support for nanotechnology. The support for nanotechnology variable was based on agreement with two statements ("Overall, I support the use of nanotechnology" and "Overall, I support federal funding for nanotechnology") on 10-point agree/disagree scales (Pearson's $R = 0.72$, $p \leq 0.001$, $M = 6.42$, $SD = 1.72$).

Covariates and Demographics. Although our principal focus is variation in the outcome measures attributable to our experimental manipulations, we also included a number of additional variables in our analysis to account for

any variation that might exist in the subject pool, both within and across university campuses. For example, we included a measure of participants' interest in politics, which was tapped by asking participants about how often they follow politics and collecting responses using a five-point scale ranging from "never" to "all of the time" ($M = 2.99$, $SD = 0.78$). Finally, we also use a number of demographic variables in the analyses that follow, including participants' year in school ($M = 2.48$, $SD = 1.18$), gender (coded 1 for female, 60 percent of participants), and parents' educational level (seven-point scale ranging from "elementary school or less" to "graduate school or above," $M = 5.67$, $SD = 0.90$).

Results

Preliminary inspections of our data were conducted by first generating simple cell percentages and means corresponding to what kinds of articles participants clicked on first and how long, on average, they spent viewing articles from each section of the information board. Table 1 presents the percentages of "first views" by condition and also provides a set of percentages across all four of our conditions. Table 2 provides means and standard deviations of the average number of seconds spent viewing each type of article, by condition. Although none of the by-condition comparisons relevant to our hypotheses reach statistical significance, we believe these preliminary cross-tabulations reveal a number of interesting patterns. For example, though unsurprising, it is noticeable that regardless of condition, our participants displayed a clear preference for general news coverage of nanotechnology. General news articles were the first place most participants went during their browsing sessions, and the average viewing time measures indicate that news articles were lingered on the longest as well. Specifically, nearly 60 percent of all participants selected a news article as their first target in the information board, and in three of four conditions, participants seemed to spend the most time reading news articles. The only exception with respect to time spent with each type

TABLE 1

First Views in Each Section by Condition (Percentages)

Section	Discussion w/Unknown Others	Discussion w/Opposing Others	Discussion w/Similar Others	No Discussion	All Conditions
General news	63.2	52.7	52.3	71.2	59.6
Science & medicine	11.8	9.1	20.0	13.5	13.8
Editorial & opinion	25.0	38.2	27.7	15.4	26.7

$N = 240$.

TABLE 2

Means by Condition: Average Number of Seconds Spent Viewing News, Science, and Editorial Stories

Condition	General News	Science & Medicine	Editorial & Opinion
Discussion with unknown others ($n = 72$)	17.53 (12.05)	7.27 (8.14)	10.17 (11.42)
Discussion with opposing others ($n = 56$)	13.74 (11.41)	9.22 (8.14)	15.79 (13.93)
Discussion with similar others ($n = 67$)	14.44 (11.07)	10.41 (10.16)	13.15 (14.39)
No discussion ($n = 55$)	17.37 (10.26)	9.83 (9.59)	9.10 (11.29)

of article comes from the condition in which participants were told to expect a hostile discussion environment dominated by people holding opinions toward nanotechnology contrary to their own. In that condition, participants instead spent the most time reading editorials ($M = 15.79$ seconds, $SD = 13.93$). A second pattern, similar to that seen in other kinds of information board exposure variables (e.g., Xenos and Becker, 2009), is that the viewing time measures are highly variable, with most displaying a standard deviation approaching the mean itself, which explains the difficulty in identifying clear differences by condition by simple means comparison.

We turned to logistic and ordinary least squares regression models for more rigorous tests of our first hypothesis concerning the relationship between support for nanotechnology and information seeking, as well as our third and fourth hypotheses concerning the effects of anticipated discussion. This analysis enabled us to model participants' accessing of information board material on the basis of our experimental conditions (dummy coded, with the control condition serving as a reference group) and other variables of theoretical interest, while controlling for variables we considered to be likely predictors of our outcome measures, as well as our demographic variables. In addition, each of the regression models presented here was also run with a dummy variable for location—Midwest versus South. We also ran versions without any of the demographic or location-based variables. Though not reported, the results from the latter models were substantively equivalent with respect to variables of theoretical interest. Additionally, we note that results for either initial views in the science and medicine section, or average viewing time for science and medicine articles, are also not reported. The reason for this is that in the case of first views in the science and medicine section, the chi-squared statistic fails to reach significance; likewise, for our OLS models of average viewing time in science and medicine articles, the F statistic fails to reach significance. Thus, with respect to what we originally considered the

TABLE 3

Logistic Regressions Predicting First Views in Each Section

	General News	Editorial & Opinion
Demographics		
Year in school	0.11 (0.13)	−0.09 (0.14)
Female	0.49 (0.29)$^{\#}$	−0.58 (0.33)
Parents' education	0.13 (0.16)	0.04 (0.18)
Data Collection Site		
Midwest	0.14 (0.36)	0.17 (0.40)
Predispositions		
Political interest	−0.49 (0.18)**	0.66 (0.20)**
Support for nano	0.02 (0.08)	0.08 (0.09)
Anticipated Discussion Manipulations		
Unknown others	−0.35 (0.41)	0.59 (0.49)
Similar others	−0.87 (0.41)*	0.75 (0.50)
Opposing others	−0.85 (0.42)*	1.30 (0.50)**
Constant	0.99	−4.00
Nagelkerke R^2	0.10	0.15
Chi-square	18.60*	25.65**
df	8	8
N	250	250

$^{\#}p \leq 0.10$; $^{*}p \leq 0.05$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$.
NOTE: Cell entries are logistic regression coefficients. Standard errors appear in parentheses.

most information-intensive category of material in the information board, none of our variables offers an ability to predict viewing time beyond chance.

Turning to the analyses concerning news and editorial viewing, a number of noteworthy patterns emerge from the results presented in Tables 3 and 4. Table 3 presents results from logistic regressions in which viewing a general news article first (or not) and viewing an editorial/opinion article first (or not) are regressed on our demographics, relevant covariates, and manipulation variables. For example, we find limited support for H1, which predicted that support for nanotechnology should predict seeking factual information about nanotechnology. This is seen in the marginally significant positive relationship between support for nanotechnology and time spent reading news articles about nanotechnology ($b = 0.71$, $p = 0.07$). With respect to H3a and H4a, our results were somewhat surprising. Recall that we expected anticipated discussion to stimulate factual information seeking, and that we considered science and medicine coverage, news coverage, and editorials to provide information in descending order. Upon inspecting the results of these models, however, one can readily see that our results provide no support for H3a, or H4a.

In fact, with respect to viewing a news article first, we find that anticipated discussion generally depresses the likelihood that participants began their information session with a news item. Specifically, both anticipation of

TABLE 4

OLS Regression Explaining Variations in Average Viewing Time (in Seconds) for News & Editorial Content

	General News Viewing	Editorial & Opinion Viewing
Demographics		
Year in school	0.89 (0.65)	−0.067 (0.74)
Female	2.50 (1.49)#	−0.39 (1.71)
Parents' education	−0.94 (0.80)	−0.23 (0.92)
Data Collection Site		
Midwest	2.33 (1.81)	−1.48 (2.08)
Predispositions		
Political interest	−1.41 (0.91)	3.31 (1.04)**
Support for nano	0.71 (0.39)#	−0.47 (0.45)
Anticipated Discussion Manipulations		
Unknown others	−0.27 (1.99)	1.17 (2.28)
Similar others	−3.33 (2.04)	4.33 (2.33)#
Opposing others	−4.16 (2.11)#	7.06 (2.42)**
Constant	18.32	5.71
Adjusted R^2	0.04	0.05
N	249	249

#$p \leq 0.10$; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.
NOTE: Cell entries are unstandardized regression coefficients. Standard errors appear in parentheses.

discussion with similar others and the anticipation of discussion with opposing others are associated with negative and significant coefficients. Conversely, in the case of anticipated discussion with opposing others, we see a dramatic increase in the likelihood that participants will seek out an editorial or opinion piece first. Specifically, our results indicate that individuals in the opposing others condition were between three and four times more likely to select an article from the editorial and opinions section first. A similar pattern emerges from the OLS results displayed in Table 4. There again, we see a significant depression of news viewing among participants who were expecting to have a discussion with others who disagreed with them about nanotechnology, and in hydraulic fashion, a significant and concomitant increase in time spent with editorial content. Specifically, participants in the opposing others condition spent seven seconds longer, on average, reading editorials as opposed to reading the other kinds of materials available through the information board.

Tests of our predictions regarding information consumption and knowledge, and the impact of expected discussion on willingness to engage in future activity, as well as our research question concerning information consumption and intentions toward future engagement, were investigated through a series of OLS regressions. These models predicted knowledge and intentions toward future engagement and included experimental factors as well as variables

TABLE 5

OLS Regression Explaining Impacts of Information Seeking on Knowledge

	Model 1	Model 2	Model 3
Demographics			
Year in school	0.09 (0.07)	0.09 (0.07)	0.10 (0.08)
Female	0.06 (0.17)	0.06 (0.17)	0.11 (0.17)
Parents' education	−0.07 (0.09)	−0.08 (0.09)	−0.09 (0.09)
Data Collection Site			
Midwest	−0.24 (0.21)	−0.18 (0.21)	−0.21 (0.21)
Predispositions			
Political interest	0.05 (0.10)	0.01 (0.10)	0.03 (0.11)
Support for nano	0.18 (.05)***	0.17 (0.05)***	0.19 (0.05)***
Anticipated Discussion Manipulations			
Unknown others	0.12 (0.23)	0.06 (0.23)	0.12 (.23)
Similar others	−0.19 (0.23)	−0.23 (0.23)	−0.24 (0.24)
Opposing others	−0.04 (0.24)	−0.13 (0.24)	−0.09 (.25)
Information Seeking			
Average news viewing	0.02 (0.01)**		
Average science viewing		−0.26 (0.01)**	
Average editorial viewing			−0.00 (0.01)
Constant	3.26	4.04	3.64
Adjusted R^2	0.07	0.08	0.05
N	249	249	249

#$p \leq 0.10$; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.
NOTE: Cell entries are unstandardized regression coefficients. Standard errors appear in parentheses.

corresponding to patterns of information exposure. Given the nature of our information board, in which all participants spent eight minutes browsing the available articles, it is impossible to estimate the effects of viewing articles in each of the three sections simultaneously. Since every second that a participant spent viewing a science and medicine article directly reduced the number of seconds available for other kinds of articles, doing so would inevitably introduce an unacceptable level of collinearity into the models. We thus estimated three separate models for each of these dependent variables, examining the impact of time spent with each type of article in turn. The results of these regressions are reported in Tables 5 and 6.

With respect to knowledge, the results in Table 5 reveal no significant relationship between anticipated discussion and actual learning, controlling for other relevant variables such as support for nanotechnology. However, these results do provide some support for H2, which predicts that factual information consumption is associated with actual knowledge. In particular, the results provide support for our assumption that general news articles provide a modicum of information about nanotechnology, as seen in the positive and significant impact of news viewing on knowledge reported in the first column of Table 5 ($b = 0.02$, $p = 0.010$). This trans-

TABLE 6

OLS Regression Explaining Impacts of Information Seeking on Willingness to Engage (in Nano-Related Discussion and Media Use)

	Model 1	Model 2	Model 3
Demographics			
Year in school	0.12 (0.07)#	0.12 (0.07)#	0.11 (0.07)#
Female	0.25 (0.15)#	0.25 (0.15)#	0.25 (0.15)
Parents' education	0.05 (0.08)	0.06 (0.08)	0.05 (0.08)
Data Collection Site			
Midwest	0.16 (0.18)	0.16 (0.18)	0.14 (0.18)
Predispositions			
Political interest	0.25 (0.09)**	0.24 (0.09)**	0.28 (0.09)**
Support for nano	0.23 (0.04)**	0.23 (0.04)**	0.22 (0.04)**
Anticipated Discussion Manipulations			
Unknown others	−0.29 (0.20)	−0.29 (0.20)	−0.28 (0.20)
Similar others	0.07 (0.21)	0.07 (0.21)	0.12 (0.21)
Opposing others	−0.18 (0.21)	−0.18 (0.21)	−0.10 (0.22)
Information Seeking			
Average news viewing	0.00 (0.01)		
Average science viewing		0.00 (0.01)	
Average editorial viewing			−0.01 (0.01)#
Constant	1.08	1.08	1.14
Adjusted R^2	0.15	0.15	0.17
N	249	249	249

#$p \leq 0.10$; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.
NOTE: Cell entries are unstandardized regression coefficients. Standard errors appear in parentheses.

lates roughly into one more question answered correctly for every additional minute spent with news articles on average. Surprisingly, as seen in the second column of Table 5, we find a significant and negative relationship between time spent with science and medicine articles and factual knowledge scores ($b = -0.26$, $p = 0.005$). Less surprisingly, we find no relationship between exposure to editorial content and knowledge. Turning to intentions toward future engagement with nanotechnology, we again see no significant effects attributable to our anticipated discussion manipulations, and only a relatively small and marginally significant negative effect for average time spent with editorial content.

In sum, the results presented here provide some limited support for the reverse causal relationship between attitudes toward nanotechnology and nanotechnology-related information seeking posited by critics of the familiarity hypothesis. In addition, however, they suggest that a principal factor believed to motivate average individuals to learn more about particular issues—the anticipation of discussion with others—does not appear to offer a viable strategy for stimulating significant growth in seeking factual information about nanotechnology. To the contrary, our results suggest that particularly

in situations where individuals anticipate discussions tinged with opinionated interactions of any kind, such forces strongly drive attention toward content focused more on persuasion than information, and little benefit in terms of imparting factual knowledge. We now turn to a discussion of the implications of these findings for future research on the development of knowledgeable opinions about nanotechnology and other emerging science and technology issues among the general public.

Discussion

Public engagement scholars have sought to respond to scholarship stemming from the deficit model that is concerned primarily with transmitting information from scientists to the public in order to increase knowledge of and, ultimately, support for science. In the present study, we seek to contribute further to that response by examining processes through which individuals may be or become motivated to learn more about nanotechnology and engage in discussions about it with others. Our data provide empirical support for the notion that individuals who are positive toward nanotechnology are more likely to seek information about it, casting further doubt over the "familiarity hypothesis," which suggests increasing support as a result of information seeking and learning. In addition, we document a number of patterns relevant to questions about how individuals relatively unfamiliar with nanotechnology are likely to engage with related media content within the context of anticipated discussion with others. In part, we chose the context of anticipated discussion because it represents a key feature of both "upstream engagement" interventions (such as consensus conferences and other outreach activities), as well as scenarios in which nanotechnology or similar kinds of issues might be subject to a rapid increase in public attention (as seen in the case of genetically modified foods). Though by no means definitive, we believe our findings offer three important insights for future research on how public awareness, knowledge, and opinions of nanotechnology and other emerging science and technology issues are likely to develop in the future. We also discuss practical implications of these findings for those involved in public outreach activities in which participants anticipate discussion with others.

First, our findings serve to further highlight the need for research in this area to consider not only information exposure, but also the conditions under which individuals are likely to expose themselves to information about nanotechnology and other emerging science and technology issues. As highlighted in recent debates surrounding the future of communication theory (e.g., Bennett and Iyengar, 2008; Holbert, Garrett, and Gleason, 2010), our contemporary media environment is one that is increasingly self-directed, calling into question traditional approaches to "media effects" that tend to treat exposure as an exogenous factor. Likewise, we would contend that the same

factors create similar problems for the deficit model. As seen in our experimental data, individual predispositions toward nanotechnology not only predict information seeking, but these effects appear to overshadow contextual factors (i.e., anticipated discussion) long believed to provide a powerful stimulus to these same behaviors. Moreover, despite a relatively clear pattern of findings concerning anticipated discussion within the political communication literature, typically using much more familiar topics, we do not find similar patterns in the case of a relatively new issue, suggesting that basic awareness may operate as a previously unexplored background condition within those models. To be sure, however, our study only examines one of many possible stimuli that might serve to increase engagement with information about nanotechnology or other, similar issues in the future. In addition, while our study is specifically tied to nanotechnology as a case study, the implications for engagement with other emerging scientific issues (e.g., synthetic biology, new energy-transfer technologies, and applications of artificial intelligence) are of paramount and parallel importance as well. Thus it is only one part of what we contend should become a much broader effort to understand how individuals without preexisting positive predispositions toward nanotechnology and other emerging scientific issues may become motivated to learn more (and form more stable and solid opinions) about these topics in the future.

A second noteworthy set of patterns revealed in this study deals with the kinds of media content through which information about nanotechnology is transmitted or communicated to the public. Recall that our study focused on general news, science news, and editorial content, and that we began with the assumption that specialized science coverage would be the most beneficial in terms of increasing factual knowledge. Contrary to these expectations, we found that not only did exposure to science coverage not lead to increases in factual knowledge, but there was in fact a negative and significant relationship between exposure to science coverage and posttest knowledge scores. To be fair, the nature of our design pitted all three kinds of coverage directly against one another, so it is more accurate to characterize the effect of science coverage exposure as relative to the other materials. However, combined with other related findings, the implication is that general news coverage is more beneficial than science coverage in helping individuals learn about new scientific and technological issues such as those surrounding nanotechnology. Given that nonspecialized articles often include basic background information usually not found in science coverage, and the generally low levels of familiarity and knowledge in the general public, this finding may not be that surprising. Nevertheless, we believe it provides important practical insights to those interested in developing materials and interventions targeting the vast majority of citizens who still report very little exposure to even basic information about nanotechnology and its applications and other pressing scientific concerns. For those charged with designing consensus conferences, deliberative exercises, and other upstream engagement activities surrounding science and

technology issues, our research suggests that the emphasis should be placed on providing citizens with accessible information that takes a more general approach to explaining an issue's scope and applications. Even more broadly, the results of our information-seeking analyses suggest that those charged with communicating with publics about emerging science and technology issues may see greater practical benefit from promoting news stories and coverage that are less information rich and able to extend beyond the "science section" of mainstream news publications.

Finally, while our anticipated discussion manipulations failed to produce a number of the effects we had predicted, we believe that the results of our experiment still provide important insights into how individuals are likely to respond to particular social dynamics. These dynamics, specifically the anticipation of discussion, are present in many deliberative outreach activities (in which participants know that discussing a particular science or technological issue with others will occur) and likely to manifest if an issue like nanotechnology suddenly captures media and public attention. Most notable here are the findings with respect to variations in opinion climate, which suggest that both "dangerous" and "safe" discussion climates may drive information seekers away from news content, and that "dangerous" climates rather dramatically increase the attractiveness of editorial and opinion content. In some sense, this pattern may be viewed as consistent with past research documenting increased cognitive activity among individuals anticipating discussion under majority or minority conditions (Levine and Russo, 1995). The key difference, however, is that in our example increased cognitive activity appears to be directed toward opinion-laden rather than information-rich materials. Together, we believe these findings suggest caution surrounding conflict-oriented framings of science and technology issues in engagement interventions as well as ideologically tinged debate in the broader public sphere. Although we are unable to explore the deeper nature of the processes by which individuals are stimulated to seek valenced information about nanotechnology in the present study, these results speak strongly concerning the effects of these contexts on information-seeking patterns associated with the development of balanced and considered opinions about emerging science and technology issues such as those associated with nanotechnology research and its applications.

It is of course impossible to determine whether nanotechnology will, in fact, become "the next genetically modified foods" or if public opinion will move deliberatively toward an enlightened consensus about how its development should proceed. However, it is equally clear that present levels of awareness and, potentially, support for nanotechnology are bound to evolve over time through processes similar to those explored here. The present study provides a number of insights into these processes, but also underscores the need for further research into upstream processes of public engagement and the conditions and circumstances most conducive to the development of balanced and well-reasoned opinions concerning the future development of new and emerging technologies.

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