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# Using Public Engagements to Provide Input and Insights into Policy, Legal, Ethical, and Other Impacts of Science

Lisa M. PytlikZillig, Alan J. Tomkins, Peter Muhlberger, Rosevelt L. Pardy, Thomas Jack Morris, Yuris A. Dzenis, Joseph A. Turner and Timothy P. Collins

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# Using Public Engagements to Provide Input and Insights into Policy, Legal, Ethical, and Other Impacts of Science

Lisa M. PytlikZillig, University of Nebraska, Nebraska, USA
Alan J. Tomkins, University of Nebraska, Nebraska, USA
Peter Muhlberger, Texas Tech University, Texas, USA
Rosevelt L. Pardy, University of Nebraska-Lincoln, Nebraska, USA
Thomas Jack Morris, University of Nebraska-Lincoln, Nebraska, USA
Yuris A. Dzenis, University of Nebraska-Lincoln, Nebraska, USA
Joseph A. Turner, University of Nebraska-Lincoln, Nebraska, USA
Timothy P. Collins, University of Nebraska, Nebraska, USA

*Abstract: Fueled in part by governmental regulatory requirements and in part because of science's own interest, public engagements are used to provide input about the policy, ethical, legal, social, and other impacts of science and technology. While public engagements show promise for ensuring that public values are incorporated into science and technology policy, current models of public engagement are disconnected from empirical evidence, are too general to guide decisions about public engagement in specific contexts or for specific purposes, and fail to adequately explain why public engagement outcomes differ across studies. In this paper we briefly review prior models, as well as an approach to building new models that we are currently employing in our research. We describe preliminary results from an experimental study conducted using our approach, which varies the cognitive goals emphasized by an engagement concerning nanotechnology, and the social context for giving input. Results suggest that variations in these factors do matter: Compared to individual input, group discussion of input questions resulted in less-focused, less argumentative, and more active and self-regulated forms of engagement; and emphasis on cognitive learning goals did appear to support learning to a greater extent than emphasis on critical thinking goals. We conclude that future experimental research is warranted and necessary to populate a social science of public engagement with models that answer questions of which public engagements work under what conditions, for what purposes, and why.*

Keywords: Ethics, Public Participation, Citizen Engagement, Technology and Science

**NO ONE QUESTIONS** the personal and societal interests in removing human tissue for purposes of medical diagnosis or treatment. Questions do arise, however, about what happens to such tissue samples, both from a patient's and society's perspectives. For example, is it acceptable for a physician-researcher, after removing a patient's cancerous spleen, to use that tissue to develop a line of cells? Does it make a difference if the cell line is patented, with a potential value in the billions of dollars? Is it pertinent that the physician-researcher never explicitly obtained the consent of the patient? The patient who found himself in this situation sued the researcher and the university that employed him, arguing it was unethical and illegal not to be informed of the research and development and not to share in the resulting profits. The California Supreme Court disagreed that the

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patient was entitled, as a matter of civil law, to benefit from the doctor's patent and share in the financial rewards (Moore v. Regents of the University of California, 1990).

Who has what interests in science and technology has often been left as questions for the legislature and/or the courts to decide, often with benefit of extensive ethical analyses. For example, returning to the tissue controversy, President Clinton created an advisory committee to provide him, the research community, and the nation with ideas of how to address the complicated issues surrounding tissue samples (National Bioethics Advisory Commission, 1999, 2000). In fact, over the past forty years, detailed ethical and legal assessments have become increasingly commonplace to assure that science and technology do not veer off in directions inconsistent with societal interests (e.g., Katz, 1972; Moreno, 2001; Rothman, 1991).

From the 1950s through the 1970s, there were a handful of scholars, journalists, and policymakers who argued there needed to be effective regulation of science rather than leave science to its own devices to regulate itself (e.g., Katz, 1972). Many argued for the integration of legal, ethical, and societal interests into a cohesive policy of science oversight. In the early 1970s, Congress convened an advisory group, established an extensive advisory process, and enacted legislation to provide formal oversight of science through a variety of processes (e.g., National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979) (see also, Annas, 1979; Edgar & Rothman, 1995; Lipsett, Fletcher, & Secundy, 1979; Veatch, 1979). Included as a central part of these oversight processes was the involvement of the public as a small part of much broader, formal institutional review boards primarily populated by scientists who would examine the risks and benefits, as well as ethical and societal interests, before research was conducted.

By the end of the 20th century, scientists and policymakers were finding that specifically considering ethical, legal, and social implications (ELSI), as well as some degree of public involvement, was proving itself helpful both for scientific and public purposes. The prime example of the success of this approach was the ground-breaking Genome Project that resulted in substantial scientific and technological advancements (see e.g., National Institutes of Health, 2010b) while simultaneously attending to complicated ELSI concerns (see e.g., National Institutes of Health, 2010a).

The involvement of the public was not especially well developed in the Genome Project. This is understandable: Although including the public's perspectives provides another assurance that community values are taken into consideration as a part of science policy and practices, it is also difficult and time-consuming. Nevertheless, the promise of meaningfully and extensively involving the public in science policy is great in a democracy (Farrelly, 2007; PytlikZillig & Tomkins, 2011). In a democracy, the public should be the ultimate arbiter of values, and experts have no claim to being better able to choose values than the public, once the public is aware of key facts surrounding an issue. Moreover, public consultation on science policy is crucial for the legitimacy of such policy. Not surprisingly, then, Congress specifically called for extensive public involvement in developing nanotechnology research and development, an area that promises to lead to significant and far-reaching advances ("21st Century Nanotechnology Research and Development Act," 2003; Lewenstein, 2005; Roco, 2003; Sargent, 2010).

The Nanotechnology Act requires public participation to inform nanotechnology policy and provides for the "the convening of regular and ongoing public discussions, through mechanisms such as citizens' panels, consensus conferences, and educational events, as appropriate" (Sec. 2(b)(10)). Congress explicitly recognized that public engagement is part of what will make the ELSI ideal, "vital in the nanotechnology R&D enterprise" (National Nanotechnology Research Initiative, 2010b), a reality (National Nanotechnology Research Initiative, 2010a).

While Congress's mandate is laudatory, in order to ensure the public will make *meaningful* contributions to nanotechnology policy, it would be beneficial to know more about the social science of public engagement. It is clear that the public is often so unfamiliar with the substance of policy issues that it cannot provide meaningful input, without, at minimum, engagement techniques that can remedy these knowledge deficits. Currently, however, it is not clear which engagement techniques to use and why. This is an important question: Which public engagement techniques work best for critically examining nanotechnology issues and will result in valuable policy input? Ideally (and practically), we would want to know what evidence supports the preference for some techniques or activities over others.

In this article, we provide a brief description of various theoretical models that have been used to guide approaches to public engagement and point to a number of unanswered questions about informing science and technology policy using public input (for more detail, see PytlikZillig & Tomkins, 2011). We then give an overview of our own approach to the study of public engagement and present the methods and some preliminary data from research we have conducted to uncover heretofore unreported impacts of experimentally varied characteristics of public engagements to inform science and technology policy.

## Prior Models: A Brief Overview

A number of prior models have been suggested and applied to guide and understand public engagement with science, science communication, and the impacts of such engagements and communications. Perhaps the most well-known model, the *deficit model*, refers to the idea that public engagement activities that increase or correct public knowledge deficits will be effective engagements. In its extreme form, this model assumes that filling the public's lack of knowledge will change people's attitudes toward science in positive ways, allow them to make better decisions, enhance their trust in science and scientists, and so on (Ziman, 1991). Consistent with the deficit model, it has been found that differences in the amount of and distribution of knowledge about a topic can change the results obtained from public opinion surveys (e.g., Althaus, 2004) and, with regard to science in particular, more highly educated people tend to hold more positive attitudes toward science (Bak, 2001). Indeed, as some have noted,

> the simple logic of the deficit model is supported by a good deal of cross-national empirical evidence for a robust but not especially strong positive correlation between "textbook" scientific knowledge and favorability of attitude toward science. (Sturgis & Allum, 2004, p. 57)

However, the deficit model has been challenged both theoretically and empirically (Lewenstein & Brossard, 2006; Ziman, 1991). For example, Bak (2001) finds that the relationship between education and science attitudes is not entirely accounted for by level of science education; and when the scientific issue is controversial, gender is actually more predictive of attitudes than science education. Ziman (1991) lists a number of problems with the deficit model, including that the public does not have a "deficit" of knowledge so much as an actively constructed (though sometimes incorrect) knowledge of science that includes a little formal knowledge mixed in with additional knowledge and assumptions that they glean from the social contexts in which they live (e.g., from the media, and their social networks). Ziman also notes that, within specific situations and contexts, even when people do have accurate scientific knowledge, knowledge is only one of many elements that people rely upon to determine their responses (see also Wynne, 1991). Furthermore, within different contexts, the impact of increasing knowledge varies. For example, while greater science knowledge tends to predict more positive attitudes toward science in general, it sometimes predicts more skepticism toward controversial science (Ziman, 1991).

Consideration of contextual impacts on use of science knowledge led to the formation of contextual and lay expertise models of science communication and engagement. *Contextual models* recognize that, in different contexts, different social and cultural forces will come into play and influence the way people learn and respond to science information (Sturgis & Allum, 2004; Wynne, 1991, 2007). Contextual models have been shown to be beneficial for considering how to create persuasive messages that will appeal to different audiences, and have incorporated consideration of psychological theories into the understanding of contexts. However, contextual models have been criticized for still being deficit-oriented (Lewenstein & Brossard, 2006). In addition, to date, no comprehensive model has been formulated to account for the contextual conditions under which different public engagement techniques will work for different purposes, and why. For example, in which contexts and for what purposes would it be best to use survey methods, public forums, or online public education to engage the public?

In contrast to the deficit or contextual models, *lay expertise models* give greater weight to participants' own understanding of their contexts, recognizing that,

> [r]arely, if at all, does a practical situation not need supplementary knowledge in order to make scientific understanding valid and useful in that context. This supplementary knowledge may be highly specialist and 'expert,' even if it is not recognized widely as such. (Wynne, 1991, p. 114)

Like contextual models, lay expertise models pay close attention to differences in contexts and the participants in those contexts. In addition, lay expertise models are committed to incorporating local knowledge into understanding the gaps that occur between scientists and the public. Practitioners who embrace lay expertise models aim to empower the public to use their local knowledge and expertise when engaging with scientific issues (Lewenstein & Brossard, 2006).

Once again, while the goals of lay expertise models are commendable, they have not yet been sufficiently developed into formalized models that would predict which features of public engagements would produce effective engagements that reach those goals. For example, we do not know what features of public engagement best ensure that local expertise is incorporated into solutions and outcomes, nor do we know how much scientific knowledge the public needs, in addition to their lay expertise, to make important value judgments regarding science policy. Indeed, the field is still struggling to define what is meant by "effective" public engagement (e.g., Neresini & Bucchi, 2011).

Lewenstein and Brossard (2006) review the deficit, contextual, and lay expertise models and describe a number of activities that seem especially related to each model. For example, they mention surveys of scientific literacy associated with the deficit model, efforts to design effective science communication associated with the contextual model, and activities designed to enhance trust among groups especially relevant to lay expertise models. They also identify a fourth major category of *public engagement models*, which emphasize direct engagement between stakeholders and science information and experts. These engagement methods include deliberative polling, consensus conferences, citizen juries, and other activities aimed at increasing public participation in science policy. Lewenstein and Brossard note that the goal associated with these public participation models is the "democratization of science," a goal that they note might be viewed as more closely related to promoting the public's active engagement (with or without understanding) than to promoting public understanding *per se*. However, others point out the possibility of conceptualizing a model of "scientific citizenship" that includes dimensions of both understanding and active participation (Mejlgaard & Stares, 2010).

All of these models grapple with questions about how to best approach and involve the public. However, they do not specify how to engage the public for different specific purposes and under specific conditions, and are mostly disconnected from empirical evidence that would support recommendations about specific uses. Most importantly, current models fail to adequately explain why public engagement outcomes differ across studies, or to provide clear guidance for questions such as "how should we engage the public to effectively gain public input regarding policy, legal, ethical, and other issues in science?"

## Using a Multi-level Social-Cognitive Framework for the Study of Public Engagement

In our research we are attempting to meet the need for developing more specific, empirically-based, and practically useful models of public participation by employing four strategies: (1) broad consideration of current variations in public engagements; (2) broad consideration of theoretical perspectives from multiple disciplines; (3) narrow experimentation that varies public engagement features to determine their effects; and, (4) generalization of findings to real-world contexts (PytlikZillig & Tomkins, 2011). We next describe our use of these strategies and provide a description of the methods and results of a preliminary study.

Use of Strategy 1 (considering current variations in public engagements) led us first to differentiate among various facets of engagements such as features, processes, and outcomes (see PytlikZillig & Tomkins, 2011). In line with observations by Lewenstein and Brossard (2006), we further identified two features—the social situation and engagement goals—as dominant variations in common public engagement techniques. For example, a commonly varied *social* feature of public engagements is whether a public engagement emphasizes *group versus individual* input. Group discussion techniques include deliberative discussions, focus groups, and online forums; and individual approaches include responding to surveys, testifying at legislative hearings, or writing letters to policymakers. Regarding the *goals* of engagement, an especially common variation is the relative extent to which *knowledge dissemination* (where information flows from sponsor to participant) *versus public consultation* (where information flows from participant to sponsor) goals are emphasized.

Use of Strategy 2 (broad consideration of relevant theories) resulted in the identification of numerous potentially and theoretically important mediating, moderating, and outcome variables that might relate to or impact the effects of variations in social situation and engagement goals we had identified. Such variables, which came especially from consideration of social-cognitive theories (e.g., Bandura, 1997, 1999; Mischel, 2004), include group-level (e.g., gender composition, size, and demographics of social groups) and individual-level (e.g., need for cognition, goal orientations, self-efficacy, satisfaction, and confidence in governmental institutions) variables. Given the different goals associated with public engagement, differentiating cognitive, affective, and behavioral engagement indicators (Fredricks, Blumenfeld, & Paris, 2004), and engagement types associated with pre- and post-decision mindsets (e.g., creative and open engagement, vs. focused, critical, goal-oriented engagement) (Kruglanski & Webster, 1996; PytlikZillig, Horn, & Glider, 2006) seemed especially relevant.

Our use of Strategy 3 (experimentation) to vary the two features we had identified (i.e., the individual vs. group social context and the engagement goals) in order to examine their impacts on theoretically relevant variables, including their impact on participants' levels of cognitive, affective, and behavioral engagement, resulted in the study discussed next.

## Methods

### *Participants*

Participants were 219 (52% female) students enrolled in a freshman-level introductory biology course at the University of Nebraska-Lincoln. Participants included primarily first (25%) and second (53%) year students, and fewer students in their third (16%) and fourth years (or beyond) (5%). Most (78%) of the students reported being enrolled in a science-related major.

### *Participant Recruitment*

All of the activities described here were part of course requirements. Approximately mid-semester and immediately prior to engaging in the activities evaluated as part of this research, students were informed that the researchers wished to examine different methods of discussing ELSI topics in science, and therefore would like to analyze their data from the course activities. Students were assured of their confidentiality but told that there would be no immediate benefit to them for participating. Approximately 90% of the students present at the beginning of the activities (219 out of 242) gave their consent for their data to be used in study analyses.

### *Overview and Design*

After indicating their consent, students completed a pre-survey that contained questions assessing prior knowledge and attitudes about nanotechnology, as well as demographics, political attitudes, and personality traits. Next, students were given a background document pertaining to nanomedicine to read and were randomly assigned to complete one of three assignments, each of which was designed to support a different cognitive goal (*information organization*, *critical thinking* , or *feedback*, as detailed later). Students completed these assignments as homework during the week prior to the class in which they were asked to give written input on questions related to nanomedicine and ELSI issues. Upon arriving at class, students turned in one copy of their assignment, and kept a second copy to use as they answered the input questions. Although all students individually wrote their input during class, students were randomly assigned to give their input in one of two social contexts: a group discussion input context or an individual input context. Thus, the combination of randomly assigning students to one cognitive goal assignment and one social context for input resulted in a 3 (cognitive goal) x 2 (social context) between-groups design. Immediately after giving their input, all students completed a post survey.[1]

## Materials and Measures

**Background document.** The background document provided students with information about the ELSI topics under discussion and included peer-reviewed information suggested by the nanoscientists on the project as well as information from other resources. The information included descriptions of the both current and potential future uses of nanotechnology for drug delivery, as well as numerous links to sources of additional information. All students received identical background documents, regardless of experimental condition. Students were told that they needed to read the background document as part of the course requirements, but were free to explore the links to additional information as much or as little as they wished.

**Manipulation checks.** In the post-engagement survey, students in all three cognitive goal conditions were asked to make numerous ratings of their assignment, including the extent to which their assignment helped them to think “critically about evidence,” and helped them to get their “thoughts organized.” We hypothesized that statements corresponding to the goal of the assignments would be rated more highly by students in the appropriate cognitive goal condition.

**Engagement**. On the post-survey, students were also asked to evaluate the extent to which different adjectives described their engagement during the input activities. These adjectives included items intended to assess affective engagement (e.g., engaged, focused, creative, argumentative) and disengagement (e.g., frustrated, annoyed, bored), as well as states of open, creative engagement, and conscientious focused engagement, two types of engagement theorized to have different effects (Kruglanski & Webster, 1996; PytlikZillig et al., 2006).[2] Student cognitive and behavioral engagement was also assessed by asking students to indicate the extent to which they, for example, took notes, thought about how the nanotechnology topics related to other things they knew, tried to think creatively about the impacts of nanotechnology on society, and other items adapted from self-regulated learning measures (e.g., Shell & Husman, 2008). Because our research was preliminary, our goal was to explore a large number of engagement items that might be sensitive to our experimental manipulations. Thus, each student was administered a different random subset of the total items (data was obtained for all items, but no student completed all items) and we focus on item-level results in our analyses.

**Knowledge.** In order to more objectively assess participant engagement, we assessed pre- and post-*knowledge* of the topics that were discussed as part of the engagements, using

[1] Later in the semester, students repeated this procedure (pre-survey, assignment, input, post-survey) with a new ELSI topic (nanogenomics, results not complete and not reported here). For this second engagement, all students stayed in the same assignment condition; however individual students who had been assigned to the individual input and group discussion conditions now switched conditions.

[2] Prior factor analyses of these items in a separate study supported their categorization as relevant to positive engagement or negative disengagement, or creative and open or focused and conscientious engagement (PytlikZillig et al., 2006).

approximately 17 identical multiple-choice knowledge questions (e.g., "How many nanometers are in a meter?" and "What is the most efficacious way of administering liposomal nanoparticles?") administered during the week prior to and then again immediately after students gave their written input in class. Student answers were scored for correctness and the proportion correct was calculated at pre- and post- engagement.

## Experimental Manipulations

**Cognitive goals.** As previously noted, the *feedback* assignment was a control condition assignment designed to encourage active evaluative engagement without necessarily emphasizing learning or quality of input. The feedback assignment asked students to explore and comment on the quality of the background documents in terms of how interesting, enjoyable, clear, confusing, and biased the materials were. The *critical thinking* assignment was designed to prime and scaffold critical evaluation of the arguments in the background document in a manner hypothesized to encourage higher quality, well-reasoned, and well-justified input. For this assignment, students were introduced to an approach to evaluating arguments that focuses on judging the relevance, accuracy, typicality, and sufficiency of the evidence for those arguments (Fulkerson, 1996). They were asked to identify statements or claims in the background document and to evaluate them using this approach. The *information organization* assignment was designed to scaffold understanding of the relationships between claims provided in the background documents in a manner hypothesized to enhance learning and recall. For these assignments, students were given examples of and asked to create and use note taking matrices. For example, some students created lists of benefits and risks associated with nanotechnology and some organized their lists in terms of ethical versus legal versus social risks and benefits.

**Social contexts.** Students were randomly assigned to either individual input or group discussion social contexts. Students knew they would be working either alone or with a group, but they did not know which condition they would be in until they arrived to the engagement. Thus, all students in both conditions came to the engagement (conducted during class) and were instructed to answer the same set of ELSI questions related to the background document (e.g., "What regulations and guidelines do you think should be in place to maximize the future benefits of nanomedicine and minimize the risks? *Why* do you think the regulations/guidelines should be in place?"). However, students in the *individual* input condition worked in a different room than those in the group discussion condition, and answered the input questions on their own. In the *group discussion* input condition, students were in groups of 3-6 students who had completed the same cognitive goal assignment. These students shared and discussed their answers to the input questions during the same time period that students in the individual input condition worked on their answers (in a separate room). The discussions were not guided or moderated, but were supervised and students in either social context condition could ask present researchers or their instructor questions if they wished.

## Results

Data were first examined for outliers and extreme data points (no data needed to be dropped for the current analyses), and then analyzed using analysis of variance and covariance procedures. We first tested for interactions between the assignment and input condition factors, and if no significant interaction was present, we examined the main effects of the two factors, conducting Bonferroni-corrected pairwise follow-up analyses if a significant main effect of cognitive goal was found.

## Manipulation Check

Table 1 shows the results of 2 x 3 analyses of variance (and relevant follow-up comparisons) applied to exemplar manipulation check items. Overall, there were very few significant effects of social context or cognitive goal on student perceptions of the assignment (only two of 10 questions detected differences). Notably, hypothesized differences on items such as “the assignment helped me to… think critically about evidence” and “get my thoughts organized” did not significantly differ between cognitive goal conditions. On the questions where differences were revealed, the information organization and group discussion conditions appeared to be perceived as more helpful and beneficial.

**Table 1: Manipulation Checks: Perceptions of Cognitive Goal Assignments by Experimental Condition**

| Item | Feedback (F) | | | | Critical Thinking (CT) | | | | Information Organization (IO) | | | | Significant | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| The assignment | Individual (I) | | Group (G) | | Individual (I) | | Group (G) | | Individual (I) | | Group (G) | | Differences | |
| helped me to... | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | Social Context | Cognitive Goal |
| Think critically about evidence | 3.24 | .831 | 2.95 | 1.079 | 3.07 | 1.174 | 3.52 | 1.184 | 3.12 | 1.395 | 2.73 | 1.033 | | |
| Get my thoughts organized | 3.21 | .787 | 3.00 | .756 | 3.26 | 1.327 | 3.05 | 1.133 | 3.44 | 1.155 | 3.00 | 1.317 | | |
| Compare the benefits and risks related to nanotechnology | 2.90 | .995 | 3.25 | 1.020 | 2.83 | 1.193 | 3.25 | 1.225 | 3.57 | 1.260 | 3.75 | .716 | G > I + | IO > F**<br>IO > CT* |
| Understand perspectives opposite of my own | 2.45 | 1.055 | 2.79 | 1.215 | 2.36 | 1.224 | 2.29 | 1.189 | 3.00 | 1.200 | 3.00 | 1.138 | | IO > CT** |
| Overall, to what extent was the public participation module a beneficial part of your learning in the course? | 2.48 | .933 | 3.03 | 1.043 | 2.82 | .716 | 3.06 | .906 | 2.65 | 1.111 | 2.83 | .889 | G > I* | |
| +p < .10,*p < .05, **p < .01 | | | | | | | | | | | | | | |

## Engagement

The 2 x 3 between-group analyses of variance revealed a number of main effects of social context, significant at the $p < .05$ level (see Table 2). Compared to those in the group discussion condition, those in the individual input condition reported feeling more “engaged” and “focused.” However, participants in the individual condition also indicated their minds were more made up, and they felt more argumentative than those in the group discussion condition.

Table 2 also shows some marginally significant (at Bonferroni-corrected $p < .033$ levels) pairwise comparisons that were the result of follow-up analyses to significant ($p < .05$) main effects of cognitive goal variations. These analyses provide some evidence that those in the feedback condition felt more frustrated (than those in the critical thinking condition) and like their minds were made up (than students in either of the other conditions), while giving input.

**Table 2: Affective Engagement while giving Input by Experimental Condition**

| Affective term | Feedback (F) | | | | Critical Thinking (CT) | | | | Information Organization (IO) | | | | Significant | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| During the | Individual (I) | | Group (G) | | Individual (I) | | Group (G) | | Individual (I) | | Group (G) | | Differences | |
| engagement I felt… | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | Social Context | Cognitive Goal |
| Positive Engagement | | | | | | | | | | | | | | |
| Engaged | 3.41 | .95 | 2.88 | .96 | 3.44 | 1.20 | 3.44 | .78 | 3.76 | .93 | 3.08 | .67 | I > G* | |
| Interested | 3.24 | .83 | 3.29 | .91 | 3.39 | .78 | 3.50 | .91 | 3.56 | 1.23 | 3.59 | .87 | | |
| Distracted | 1.95 | .89 | 2.00 | .95 | 1.94 | 1.11 | 2.09 | 1.11 | 2.00 | 1.00 | 1.87 | 1.09 | | |
| Bored | 2.67 | 1.24 | 2.31 | .88 | 2.00 | .69 | 2.18 | 1.29 | 2.47 | 1.12 | 2.26 | 1.14 | | |
| Negative Engagement | | | | | | | | | | | | | | |
| Argumentat-ive | 2.67 | 1.07 | 1.44 | .73 | 3.00 | 1.10 | 1.67 | .84 | 2.78 | 1.04 | 2.20 | 1.15 | I > G** | |
| Frustrated | 2.28 | 1.06 | 1.91 | 1.27 | 1.48 | .79 | 1.70 | .98 | 1.87 | 1.04 | 1.56 | .73 | | F > CT+ |
| Annoyed | 2.26 | 1.10 | 2.13 | 1.18 | 1.67 | .90 | 1.92 | 1.21 | 2.25 | 1.11 | 1.54 | .88 | | |
| Open-Creative Engagement | | | | | | | | | | | | | | |
| Open-minded | 3.61 | .83 | 3.79 | .86 | 3.57 | 1.04 | 3.71 | .86 | 3.71 | 1.05 | 4.07 | .59 | | |
| Closed | 2.25 | .91 | 1.80 | 1.04 | 1.62 | .81 | 1.95 | .85 | 1.71 | .92 | 1.70 | .98 | | |
| Like my mind was made up | 3.22 | .90 | 3.00 | 1.17 | 2.48 | 1.08 | 2.64 | .99 | 2.57 | .90 | 2.59 | 1.18 | I > G** | F > CT+<br>F > IO+ |
| Creative | 2.68 | 1.03 | 2.42 | 1.02 | 2.92 | .80 | 3.06 | .97 | 3.08 | 1.22 | 2.82 | 1.02 | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conscientious-Critical Engagement | | | | | | | | | | | | | |
| Focused | 3.96 | .77 | 3.29 | .91 | 3.71 | .85 | 3.59 | 1.12 | 3.62 | 1.02 | 3.44 | .71 | I > G* | |
| Responsible | 3.56 | .96 | 2.93 | .96 | 3.21 | .98 | 3.19 | 1.12 | 3.24 | 1.35 | 3.16 | .69 | | |
| Conscientious | 3.37 | 1.12 | 3.22 | 1.06 | 3.00 | .79 | 3.00 | .80 | 3.16 | 1.43 | 3.06 | 1.09 | | |
| Careful | 2.92 | 1.14 | 2.96 | .91 | 3.15 | 1.18 | 3.08 | .97 | 3.22 | 1.05 | 2.94 | 1.06 | | |
| Competitive | 2.00 | 1.04 | 1.44 | .71 | 1.64 | .95 | 1.60 | 1.19 | 1.72 | .96 | 1.88 | 1.03 | | |
| +p < .10,*p < .05, **p < .01 | | | | | | | | | | | | | |

Table 3 shows results from comparisons examining student reports of their cognitive and behavioral engagement. Not surprisingly, students in the group discussion condition reported higher engagement on items referring to interaction with “others” (social engagement items in Table 3). However, there was also evidence that those in the group social context actively engaged using cognitive and behavioral strategies that did not necessarily require social interaction (e.g., checking their understanding of the issues and taking notes). Differences between cognitive goal conditions were, again, less salient and less numerous: Those in the critical thinking condition only indicated that they tried to compare the benefits and drawbacks in terms of their importance to a significantly greater extent than those in the feedback condition.

**Table 3: Cognitive and Behavioral Engagement While giving Input, by Experimental Condition**

| Item | Feedback (F) | | | | Critical Thinking (CT) | | | | Information Organization (IO) | | | | Significant | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| During the engagement | Individual (I) | | Group (G) | | Individual (I) | | Group (G) | | Individual (I) | | Group (G) | | Differences | |
| today I… | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | Social Context | Cognitive Goal |
| Social Engagement | | | | | | | | | | | | | | |
| Discussed my ideas with others. | 1.24 | .436 | 2.43 | .507 | 1.25 | .550 | 2.42 | .692 | 1.59 | .734 | 2.27 | .458 | G > I** | |
| Actively shared my ideas about nanotechnology with others. | 1.28 | .542 | 2.26 | .594 | 1.50 | .707 | 2.26 | .752 | 1.43 | .662 | 2.47 | .514 | G > I* | |
| Discussed ethical, social and legal issues related to nanotechnology with others. | 1.34 | .484 | 2.32 | .671 | 1.47 | .612 | 2.64 | .569 | 1.52 | .653 | 2.41 | .618 | G > I* | |
| Listened to ideas suggested by others. | 1.56 | .616 | 2.50 | .513 | 1.47 | .516 | 2.72 | .461 | 1.68 | .839 | 2.47 | .513 | G > I** | |
| Tried to identify what others thought about the impacts of nanomedicine on society. | 1.73 | .604 | 2.05 | .575 | 1.71 | .784 | 2.48 | .680 | 1.53 | .612 | 2.28 | .575 | G > I** | |
| Asked others what they thought about the issues. | 1.32 | .557 | 2.38 | .498 | 1.40 | .707 | 2.50 | .607 | 1.38 | .590 | 2.58 | .515 | G > I** | |
| Active Engagement | | | | | | | | | | | | | | |
| Tried to think about how the topics of nanotechnology and drug delivery related to other things I know. | 2.04 | .562 | 2.11 | .583 | 2.06 | .725 | 2.32 | .627 | 2.15 | .671 | 2.37 | .496 | | |
| Checked myself to see how well I understood the issues related to nanotechnology and drug delivery. | 1.67 | .565 | 2.20 | .696 | 2.00 | .632 | 2.05 | .669 | 1.86 | .774 | 2.21 | .579 | G > I* | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Took notes about the issues related to nanotechnology and drug delivery. | 1.35 | .562 | 1.74 | .806 | 1.26 | .541 | 1.67 | .620 | 1.36 | .581 | 1.74 | .562 | G > I** | |
| Identified questions that I still had about nanotechnology and drug delivery. | 1.67 | .734 | 1.83 | .717 | 1.87 | .619 | 1.94 | .639 | 2.09 | .733 | 1.83 | .618 | | |
| Tried to find answers to my questions about nanotechnology and drug delivery. | 1.62 | .590 | 1.83 | .650 | 1.65 | .745 | 2.12 | .697 | 1.91 | .733 | 1.70 | .733 | | |
| Explored topics related to nanotechnology in order to satisfy my own curiosity. | 1.45 | .605 | 1.52 | .730 | 1.42 | .504 | 1.68 | .748 | 1.26 | .562 | 1.62 | .650 | G > I+ | |
| Did some of my own research on nanotechnology and drug delivery. | 1.35 | .573 | 1.50 | .722 | 1.41 | .590 | 1.53 | .772 | 1.50 | .673 | 1.35 | .702 | | |
| Visited the links and other additional resources listed in the background document for the module. | 1.32 | .476 | 1.35 | .489 | 1.26 | .452 | 1.43 | .676 | 1.52 | .643 | 1.53 | .697 | | |
| Critical Thinking | | | | | | | | | | | | | | |
| Tried to compare the benefits and drawbacks in terms of their importance. | 2.10 | .700 | 2.20 | .768 | 2.33 | .485 | 2.75 | .444 | 2.33 | .730 | 2.14 | .663 | | CT > F*<br>CT > IO+ |
| Carefully evaluated the accuracy of the evidence for various benefits and drawbacks. | 1.96 | .662 | 1.88 | .781 | 2.09 | .610 | 2.18 | .588 | 1.86 | .727 | 2.14 | .573 | | |
| Carefully evaluated the relevance of various arguments about nanomedicine . | 1.82 | .548 | 2.06 | .539 | 1.90 | .553 | 2.21 | .631 | 2.04 | .706 | 2.24 | .664 | G > I* | |
| Carefully evaluated the "typicality" of evidence for various benefits and drawbacks of nano -drug-delivery. | 1.84 | .624 | 2.17 | .565 | 1.92 | .584 | 2.14 | .573 | 2.09 | .750 | 2.00 | .866 | | |
| Creative Thinking | | | | | | | | | | | | | | |
| Tried to think creatively about the impacts of nanomedicine on society. | 2.29 | .561 | 2.37 | .496 | 2.35 | .489 | 2.57 | .507 | 2.37 | .576 | 2.35 | .487 | | |
| Tried to identify new second-order effects of nanomedicine that others may not have thought of yet. | 1.52 | .593 | 1.82 | .664 | 1.70 | .635 | 2.22 | .647 | 1.68 | .749 | 2.05 | .780 | G > I** | |
| +p < .10,*p < .05, **p < .01 | | | | | | | | | | | | | | |

## Knowledge

Analyses of participant pre and post answers to the knowledge questions indicated that knowledge increased over time. Specifically, a repeated measures mixed analysis of variance (2 x 3 x 2) using knowledge as the dependent variable and time (pre and post) as a within subjects factor and cognitive goal and social context as between subjects factors, revealed a strong significant effect of time ($F(1, 204) = 145.53$, $p < .001$, $\eta_p^2 = .416$, $M_{pre} = .60$, $SD_{pre} = .10$ ; $M_{post} = .75$, $SD_{post} = .18$). There was also evidence that participants in different cognitive goal conditions did not all gain the same amount of knowledge, as indicated by a significant time by assignment interaction ($F(2,204) = 3.19$, $p = .043$, $\eta_p^2 = .030$; see Figure 1 for pattern of increases). Follow-up comparisons (pairwise, 2 cognitive goal x 2 time) revealed that the increase in knowledge scores was significantly greater for students in the information organization condition (*M* increase = .19, SD = .16) compared to those in the critical thinking condition (*M* increase = .11, SD = .19; $F(1,133) = 6.32$, $p = .013$, $\eta_p^2 = .045$).[3]

[3] While examination of the change in knowledge scores by individual conditions in Figure 1 suggests additional interactions, when we explored for hidden interactions, we only found one additional marginal time x social context interaction, which was when examining only the feedback and critical thinking conditions (those working alone showed marginally greater improvements than those working in groups). There were no statistically significant 3-way interactions to support the idea that improvements in knowledge scores over time depended both on the cognitive goal assignment and the social context conditions.

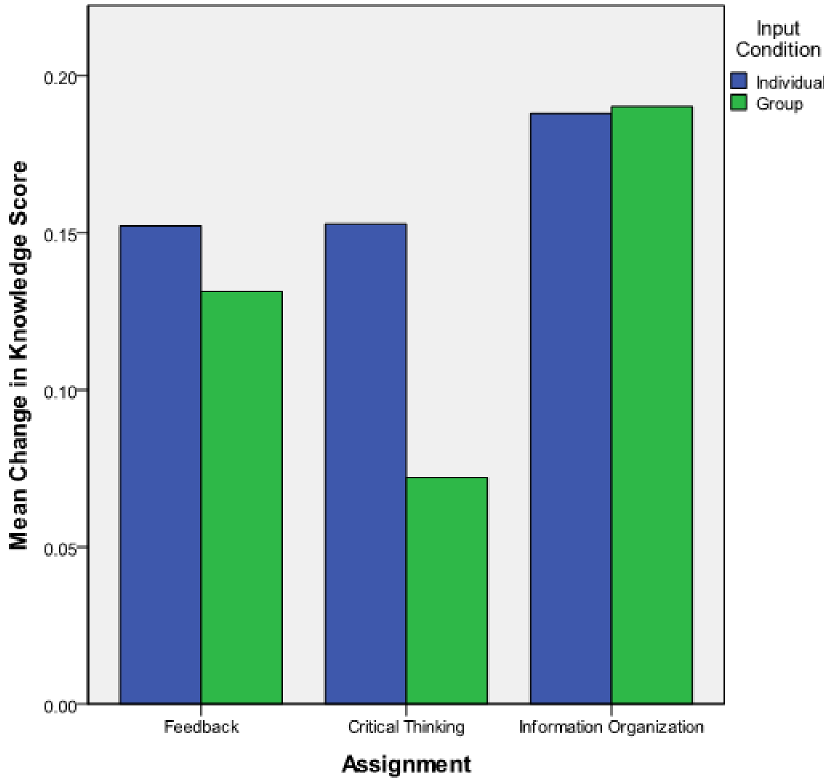


Figure 1: Comparison of Pre-post Change in Knowledge Scores by Experimental Condition

## Discussion

Clearly, a major weakness of this Strategy 3 experiment is that it was conducted with students enrolled in college-level introductory biology courses, who were engaged in the discussion of ELSI issues as part of the course requirements. Thus, the generalizability of our preliminary findings is uncertain until we employ our previously mentioned Strategy 4 (testing the generalizability of findings in real-world contexts). In addition, the study we report is quite preliminary, employing manipulations of questionable efficacy (given the evidence from manipulation checks), and under-developed measures. Nonetheless, the preliminary results presented here have the advantage of coming from a highly controlled experiment where we were able to hold constant or use random assignment to reduce the impact of all extraneous variables other than the independent variables.

Our preliminary results provide evidence that individual versus group social contexts—a feature that commonly varies between different public engagement types—may impact the perceived benefits of public engagement to participant learning, as well as the nature of their affective, cognitive, and behavioral engagement. Participants who give their input while interacting with groups may feel less focused and engaged than individuals giving input alone, but may also feel more open—that is, that their minds are less made up and less argumentative; and may be more likely to engage in a number of cognitive and overt behaviors that are associated with self-regulated learning, creativity, and critical thinking.

Our preliminary analyses also reveal that a focus on knowledge dissemination by providing learning support (through information organization) may promote learning to a greater extent than a focus on quality input by providing support to think critically. Participants in the information organization conditions not only tended to rate their assignment as more beneficial (e.g., for understanding opposing perspectives and for learning) than participants in other cognitive goal conditions, they also appeared to learn the most (and significantly more than those in the critical thinking condition), as measured by the knowledge questions.

On the other hand, our analyses also suggest several directions for future research. For example, there was less evidence for the impacts of our cognitive goal manipulations than the manipulations of social context. Refinements of the manipulations also may require changes in both the content of the exercises and, perhaps, in increased numbers of exposures to the exercises, given that whole semester courses are sometimes devoted to teaching students study strategies to enhance learning and critical thinking skills. It then remains to be seen if more effective manipulations will result in finding stronger and more consistent impacts on different types of engagement. In addition, continued testing and refinement of the scales designed to assess engagement in public engagement contexts is necessary, and future research should include assessments of knowledge over longer periods of time. In the present study, the post-knowledge questions were completed shortly after the learning activities—immediately after students gave their written input in class, and anywhere from an hour to seven days after the students had finished reading the background document and completed the associated assignment. Thus, is still uncertain the extent to which the knowledge questions assessed longer-lasting learning versus a more short-term recall.

The federal government's National Nanotechnology Research Initiative (2010a, 2010b) continues to focus on ELSI considerations and also identifies public engagements as one way to address ELSI and other societal interests. Our preliminary results suggest that it does matter *how* you engage the public if an objective of the engagement is to increase public understanding and/or provide scientists and policymakers with high quality input. Participants will not necessarily find the same value in any engagement activity. While the structure of ELSI and public engagements may, *per se*, be sufficient to decrease the likelihood of scientific abuses, the more ambitious objectives of involving the public in meaningful ways to inform science and technology policy requires care in selecting the features of public engagements to maximize the likelihood that positive outcomes occur.

In conclusion, although our work is admittedly preliminary, it points in directions that would help to populate a social science of public engagement. Thus, our research shows the value of systematically varying aspects of public engagements in order to determine what aspects of public engagements might make desired outcomes more or less likely. Clearly more research is needed, and warranted.

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## About the Authors

*Lisa M. PytlikZillig*
Authors PytlikZillig, Tomkins, and Collins are correctly identified as from the University of Nebraska.

*Alan J. Tomkins*
University of Nebraska, USA

*Peter Muhlberger*
Texas Tech University, USA

*Rosevelt L. Pardy*
University of Nebraska-Lincoln, USA

*Thomas Jack Morris*
University of Nebraska-Lincoln, USA

*Yuris A. Dzenis*
University of Nebraska-Lincoln, USA

*Joseph A. Turner*
University of Nebraska-Lincoln, USA

*Timothy P. Collins*
University of Nebraska, USA

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