SCIENCE IN THE SERVICE OF CITIZENS & CONSUMERS:

THE NSF WORKSHOP ON PUBLIC KNOWLEDGE OF SCIENCE, OCTOBER 2010

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Margaret Glass, Thomas M. Guterbock,
A. Eamonn Kelly, & Bruce Lewenstein

Chris Toumey
USC NanoCenter
1212 Greene Street
University of South Carolina
Columbia, SC 29208 USA

Toumey@mailbox.sc.edu

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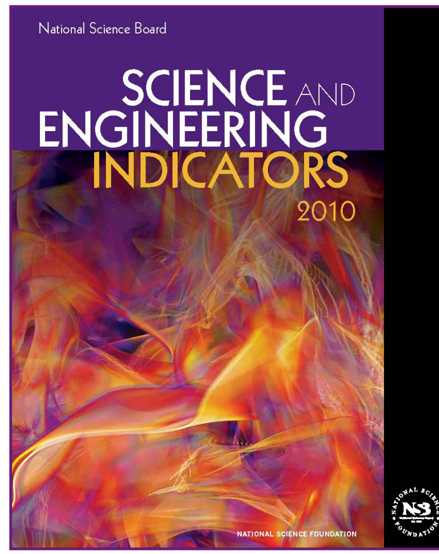
EXECUTIVE SUMMARY

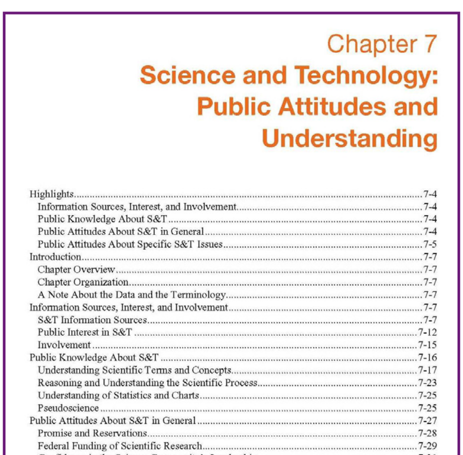
During the preparation of the 2010 *Science & Engineering Indicators*, there arose a concern about measures of public knowledge of science, and how well they capture public knowledge for Chapter Seven of the *Indicators*. A workshop at NSF in October 2010 concluded that the process of measuring and reporting public knowledge of science should start with the question of what knowledge a person in the public needs, whether for civic engagement with science and science policy, or for making individual decisions about one's life or health, or for feeding one's curiosity about science. This starting point is different from that which informed the previous conceptual framework, when the principal purpose was to measure "civic scientific literacy" as a reflection of scientific knowledge in general. The revised conceptual framework entails a series of consequences for how we think about relations between the public and scientific knowledge, as well as a package of recommendations for measuring that knowledge.

CONCEPTUAL FRAMEWORK

The National Science Foundation (NSF) collects data on “Public Attitudes and Understanding”, and reports that data in Chapter Seven of the *Science & Engineering Indicators*. For the 2010 edition, a disagreement arose regarding the value of some of the data. One response to this problem was a call from NSF to convene a workshop to reevaluate the purpose and assumptions behind the process of measuring and reporting public knowledge of science. That workshop took place at NSF in Arlington VA in October 2010.

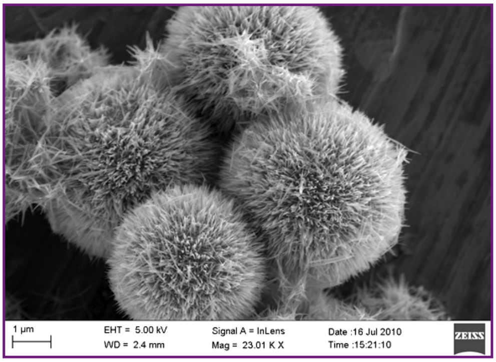
Regarding the purpose for measuring the data reported in Chapter Seven, the workshop participants agreed that NSF and other government science agencies have an interest in fostering people’s capacity to adopt a scientific orientation toward the empirical world. Thus these agencies need to have data about whether and how the public examines evidence, reasons about evidence, and uses evidence to make judgments, either as individuals or as communities.





Chapter 7
Science and Technology: Public Attitudes and Understanding

For purposes of conceptual clarity, the workshop participants used the term “public knowledge of science”, for three reasons. First, the expression “public *understanding* of



Manganese oxide spheres. Image from a Scanning Electron Microscope, by the University of South Carolina NanoCenter.

science" has acquired a highly charged negative connotation in both the research and the policy communities as a result of criticism of certain projects conducted earlier under that title. Second, the existing framework is often identified with the term "civic scientific literacy"; if hypothetically the workshop was to recommend a different conceptual framework, then a new framework would need a new identity. Third, "understanding" can include both the scientific knowledge that the public possesses *and* the attitudes, values, concerns, perceptions and other factors that shape public interpretations of that knowledge.

It was understood that the responsibility of this workshop was to reevaluate the conceptual framework for public knowledge of science, and not the influences that shape interpretations of knowledge. A reevaluation should think toward the future: how can a conceptual framework improve the process of measuring and reporting information for the 2014 *Indicators* and beyond? Those other influences are both interesting and important, but the problem at hand was to examine the conceptual framework that has guided the process of measuring and reporting public knowledge of science for the past twenty-five years, and then to consider whether and how to revise this framework. The influences that shape interpretations of scientific knowledge deserve to be examined in a separate process.

The first order of business of the workshop was to examine the history of measuring and reporting public knowledge of science. Dr. Robert Bell of Science Resources Statistics at NSF presented this history from an administrative perspective, after which the workshop participants discussed the contributions and conceptual framework of Dr. Jon D. Miller, who established a framework in 1985, and who made various revisions since then.

Miller's framework was anchored in certain features of John Dewey's theory of liberal democracy, particularly Dewey's 1934 essay on "The Supreme Intellectual Obligation" (Dewey 1981; Miller 1983; 1987). Here Dewey argued that if citizens know how to think scientifically, then democracy will benefit from good knowledge combined with good decision-making processes. According to Miller's account,

> In a democratic society, the level of scientific literacy in the population

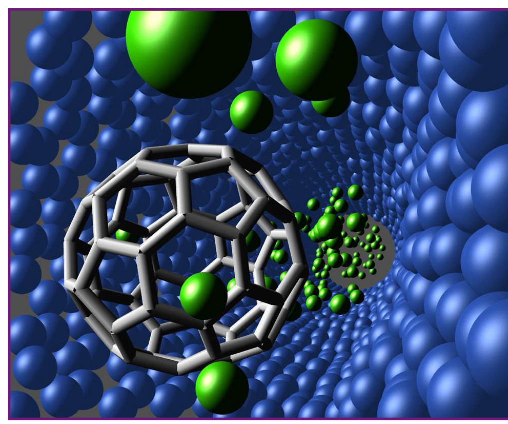
has important implications for science policy decisions… any measures we can take to raise this level… will improve the quality of both our science and technology and our political life (Miller 1983).

While no one at the workshop opposed scientific literacy *per se*, there are two reasons to develop an updated, more robust conceptual framework. One is that this vision has failed to improve our political life. While higher levels of scientific thinking might or might not affect democracy for the better, there is no optimism that the American public will achieve the levels of scientific literacy that Dewey and Miller hoped for. The civic virtue that Dewey envisioned would include individual voting, presumably, and making personal decisions, but it had no sense of larger-scale political grassroots organizing to support or resist a particular science policy.

The second reason for reevaluating the current conceptual framework is that this vision treats the person in the public as a micro-scientist. It presumes that one can identify a very large quantity of scientific knowledge that a working scientist possesses, and then measure how much of that knowledge the non-scientist possesses. Consistently the answer is that most of the public possesses miniscule quantities of scientific knowledge, leading to stories with titles like "America's Scientific illiterates" or "The Dismal State of Scientific Literacy".

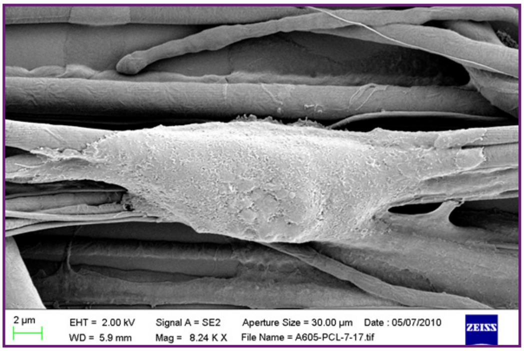
Indeed these reports are empirically valid, but the reporting of public knowledge of science in Chapter Seven of the *Indicators* needs a different conceptual framework to provide useful information to government agencies and others who use the *Indicators*.

What should be the standard of acceptable scientific literacy? Sometimes it is said to be the ability to read the "Science" section in the Tuesday edition of the *New York Times*. Why? What is the citizen supposed to do with this information? If the citizen accepts scientific information passively or uncritically, is that an acceptable form of scientific literacy?



Helium atoms and a C60 molecule pass inside a carbon nanotube. Image by Oak Ridge National Lab.

It was easy for the workshop participants to agree upon one particular purpose for measuring and reporting public knowledge of science. Decades of data collection have



A breast cancer stem cell. Image from a Scanning Electron Microscope, by the USC NanoCenter.

enabled high-quality longitudinal research. Long-term trends can be identified and analyzed. Likewise, comparative research is made possible. Public knowledge of science in the US can be weighed against the same in other nations, and perhaps insights can be derived from that kind of comparison. This kind of analysis is already made possible for K12 science education, e.g., in the *Science Framework of the 2009 National Assessment of Education Progress* (NAGB 2009). The workshop participants agreed that it would be regrettable if the longitudinal and comparative value of that information was diminished, either because Miller's conceptual framework was found unsatisfactory, or because a different conceptual framework failed to appreciate the importance of longitudinal and comparative analysis.

Following that conclusion, and with the benefit of the participants' expertise in science communication, science policy, science education, informal science education, survey design, and other related backgrounds, the workshop explored ways to improve the conceptual framework by incorporating recent thought about relations between the science and the public. One insight that was especially salient is that persons in the public have different reasons for acquiring scientific knowledge and using it (e.g., Shen 1975; Toumey 2006; Wickson et al. 2010).

Sometimes a person is in the role of an information consumer, and so wants the kind of practical knowledge that enables one to comprehend the ingredients in a food label, or to know how to take antibiotics without developing antibiotic-resistant bacteria. Other times a person is in a civic role, and needs scientific knowledge in order to have an active and constructive role in a science policy decision-making process. If a nuclear reactor is planned near one's home, what knowledge will a person need to weigh the benefits and the risks, and then to participate in supporting or opposing the construction of the reactor? In a third situation, a person might have an aesthetic reason for acquiring scientific knowledge. For many people, science is interesting, and learning about science is enjoyable. Unlike the reasons of the consumer or the citizen, this motive has no instrumental goal beyond the pleasure of learning about science. We can call this public knowledge of science for its own sake, and we can note that by acquiring it, people are connected to a shared worldview which enables them to transcend limited identities like socioeconomic status or gender.

In addition to considering the reasons *why* people acquire scientific knowledge, it is worth realizing that there are *different kinds* of knowledge, and that some kinds will serve one purpose while other kinds serve another. The consensus of the workshop was that there are three principal categories of scientific knowledge that can serve persons in the roles of information consumers, citizens, and the curious:

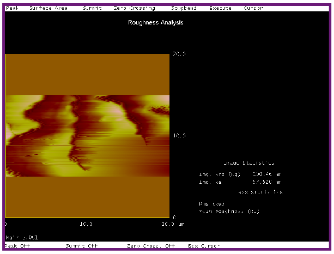
First, ***factual scientific knowledge*** gives one a vocabulary of scientific information and scientific conclusions about the empirical world. For example: What is an atom? What is a species? What is a vitamin? What are genetically modified organisms? What are stem cells? In addition to knowledge that might be conveyed as definitions, it also includes natural and technical processes: What is adaptation, and how does it work? How does a solar cell work? How does a nuclear power plant work?

Secondly, ***knowledge of scientific processes and standards*** enables one to comprehend intellectual practices and standards like experimental design, naturalistic explanation, sampling and probability, and so on.

Third, ***institutional scientific knowledge*** enables one to know how scientific institutions operate. This includes peer review; the adjudication of scientific claims; the funding of scientific research; how science identifies and prioritizes emerging issues; how scientific advice is used; processes of making science policy; and so on.

From those considerations comes the core of a conceptual framework for measuring and reporting public knowledge of science in the *Indicators*:

> In order to place science in the service of citizens and information consumers, the concept of public knowledge of science refers to: (a) factual scientific knowledge; (b) knowledge of scientific processes and standards; and (c) knowledge of how scientific institutions operate. It equips persons in the public for: (1) active civic engagement in scientific issues, including organized efforts to support or oppose specific science policies; and for (2) using scientific knowledge for practical decision-making by individuals; and for (3) a better scientific understanding of the world.
>
> In addition, the process of measuring and reporting public knowledge of science continues the long-term responsibility of collecting data which



The topography of a human hair. Image from an Atomic Force Microscope, by the USC NanoCenter.

enables high-quality longitudinal and comparative analysis.

This conceptual framework can be envisioned as a three-by-three matrix. The horizontal dimension is “Purposes”, with columns for: the purpose of serving people in their roles in civic engagement; the practical purpose of serving people in their decisions as individuals; and the cultural purpose of serving people in their curiosity about science and how it enables us to better understand the world.

The vertical dimension is “Content”, with rows for: factual scientific knowledge; knowledge of scientific processes and standards; and, institutional scientific knowledge. One can then categorize items to be measured by putting them in cells according to which purpose they serve and what kind of content they represent.

For example, the principle of naturalistic explanation would belong in the row for scientific processes and standards and the column for scientific understanding of the world. It would also go in the column for the civic purpose of public knowledge of science in the case of a policy controversy about evolution and creationism. But it is not necessarily urgent for it to be in the column for the practical purpose of serving consumers. One can imagine how a person who wants to understand the label of ingredients on a food package does not particularly need to invoke the standard of naturalistic explanation. It is noted that some items to be measured can go in more than one column and more than one row.

		Purposes of public knowledge of science		
		Civic engagement with science	**Practical/ Individual Decision-Making**	**Cultural curiosity about the scientific worldview**
Content	**Factual Knowledge**		How should antibiotic meds be used?	What is an electron?
	Processes & Standards	How is probability relevant to a particular issue?		Principle of naturalistic explanation
	Institutional Knowledge	Why does nanotechnology receive gov’t funding?	Which experts and institutions can I trust?	

A 3 by 3 Matrix of Purposes and Content, showing how certain kinds of knowledge fit into cells.

CONSEQUENCES OF THE CONCEPTUAL FRAMEWORK

This revised conceptual framework for measuring and reporting public knowledge of science can be abbreviated as ***SSCC***, for "science in the service of citizens and consumers". A series of insights regarding relations between the public and scientific knowledge follows as a consequence of this framework.

The starting point for this conceptual framework is not what the public ought to know about science in general (and how little science the public knows), but rather what persons in the public need to know in certain roles and circumstances.

A related point is that the public is not a homogeneous entity. There are various levels of formal education and multiple levels of encountering science through informal science education. Topics of interest will differ. Some people will be interested in nuclear power; others will concentrate on one disease or another; still others will be curious about the ethics of embryonic stem cell research; or what they need to know for a career in environmental management; and so on. Furthermore, some people will care about a given issue more than others. The first responsibility of those who disseminate public knowledge of science is to serve the segments of the public that want this knowledge. This takes precedence over an aspiration to deliver public knowledge of science to everyone equally, including those persons who do not particularly care about that knowledge.

Thus public knowledge of science is largely topical. This can be contrasted with universal or long-term scientific principles. Topical knowledge does not arise from the same needs as the content in a science course or a science textbook. On the contrary, it arises when a citizen or a consumer is curious, concerned, alarmed, or excited about a particular topic. A resident of the Louisiana coast may want to know how the residue of the recent oil spill can be made to disperse. The molecular structure of hydrocarbons is relevant at one level, but the resident probably does not want a tutorial on that. Instead, the resident wants to know which products will work, and how quickly they will work, and whether they will harm the coast.

Related to the topical character of public knowledge of science is the point that nonscientists can often acquire, comprehend and employ the relevant scientific knowledge when they have to. Self-motivated learning

Workshop participants discuss the conceptual framework.

by adults has an impact almost as strong as formal undergraduate science courses. It is not expected that, during a controversy or a crisis, persons in the public will aspire to acquire knowledge that is equivalent to a degree in a scientific discipline. But these citizens do not need to become scientists with formal degrees in order to know what they need to know to have active and constructive roles in a scientific issue. This reinforces the insight that the starting point for public knowledge of science is the need of the citizen or the information consumer, rather than a microcosm of what a scientist knows.

Next, it is no secret that persons in the public, like persons in scientific communities, seek scientific knowledge from multiple sources. It is known from the *Indicators* and other surveys that television is the leading source of scientific information for the American public, and that internet sources constitute the next leading source. Access to knowledge is not limited to a small number of authorities. When persons in the public acquire scientific knowledge from institutions and persons that are considered authoritative by the standards of scientific communities, those institutions and individuals are communicating in a very competitive marketplace where other sources claim to be equally authoritative.

This conceptual framework need not be seen as a radical departure from the previous framework, let alone a repudiation of Jon D. Miller's contributions. The workshop participants understood the new conceptual framework to be congruent with "civic scientific literacy", but more encompassing than that earlier framework. By updating the framework to account for research and critiques generated in the last twenty-five years, the participants sought to retain the value of data collected under the framework developed by Jon D. Miller, while providing a more robust structure with new perspectives on public interactions with science. The new framework makes explicit some assumptions that were earlier implicit, and it changes some of the emphases. By re-reading Miller's work on civic scientific literacy over the past thirty years, one could find parts of the new conceptual framework prefigured there.
The fundamental goal of collecting data on public knowledge of science, in the service of government policy making, remains the same.

RECOMMENDATIONS

In the workshop on public knowledge of science, the participants realized that their deliberations suggested certain recommendations to the National Science Foundation and the National Science Board. The participants' recommendations are as follows:

First, the public which uses knowledge of science is heterogeneous, and the audience which uses measures of public knowledge of science in the *Indicators* is also heterogeneous. Science means different things to different communities. So, who uses the *Indicators*, and why? Who are the current users, and who might be the potential users of a revised conceptual framework? The workshop participants recommend that the National Science Board and the National Science Foundation explore the question of who uses the *Indicators* and why; and whether the base of users should be expanded to serve additional populations; and that this question be explored through grant-funded proposals.

Second, regarding the early 2010 disagreement about the value of an item about evolution: the workshop participants strongly feel that the NSB, the NSF, and the *Indicators* cannot retreat from controversies about important scientific concepts. Evolution is a cornerstone of Biology. Measures and reports of public knowledge of science in the *Indicators* and elsewhere need to explore knowledge of evolution.

To explore knowledge of evolution, the following steps are recommended: First, there cannot be only one binary item on evolution. Instead, there should be a scale of knowledge of evolution. This means a module with multiple items. A module on evolution can survey knowledge of individual elements (genotypic variation; phenotypic variation; adaptation; natural selection; speciation; and so on). Second, the topic of evolution ought not to be reduced to human evolution. Plant evolution, for example, is critical to public policy in the area of genetically modified organisms, and microbial evolution is relevant to questions about antibiotics and vaccines.

Third, these items need to be knowledge questions, not religion or attitude questions. It is noted that the General Social Survey (GSS), which collects data for Chapter Seven of the *Indicators*, also collects high quality data about religion and other phenomena. Correlations can be used to explore the interesting relations between religion and knowledge of evolution, but knowledge of evolution has to be defined and measured in its own terms.

If it is not practical to pursue knowledge of evolution within the *Indicators*, then this topic deserves to be explored otherwise, e.g., with a grant-funded program.

The same can be said of other controversial topics, including climate change, embryonic stem cell research, and nuclear power. Because they are controversial, the public is especially interested in them, and the public needs scientific knowledge about them. These too deserve modules with multiple items, and they need to define scientific knowledge apart from religion or attitudes before the measures of knowledge are correlated with those latter phenomena. Topics need to be rotated over time and sometimes repeated. While the topic of evolution deserves priority, all these topics deserved to be explored, especially when they are pertinent to policy decisions. The NSF may need to find ways to gather information on a more frequent basis (every few months), with particular topical modules rotated over a brief period (one to three years).

The third recommendation is to support a program of grants to investigate the values, beliefs, concerns, and other factors that affect public knowledge of science. These phenomena are as important as the measures of public knowledge of science.

Let us say that there are three related phenomena: (a) public knowledge of science; (b) the values, beliefs, and concerns – or in the title of Chapter Seven of the *Indicators*, "Attitudes" – which affect that knowledge, and that can affect which scientific knowledge a person acquires; and (c) a body of public *interpretations* of science that emerge from the interaction of (a) and (b). When public knowledge of science is transmuted into public interpretations of science, then the processes which cause those changes deserve to be explored with a grant-funded program.

The participants' fourth recommendation is to ensure the interoperability of survey data on public knowledge of science. NSF-funded surveys of this phenomenon, whether reported in the *Indicators* or elsewhere, should be encouraged to include a core template of standard items so that data can be compared from one survey to another. NSF-funded data on this phenomenon should be required to be deposited in an archive where the data would be accessible to other researchers. One good model for this recommendation is Susan Losh's archive of data on Chapter Seven topics for the years 1979 to 2006 (Losh 2006).

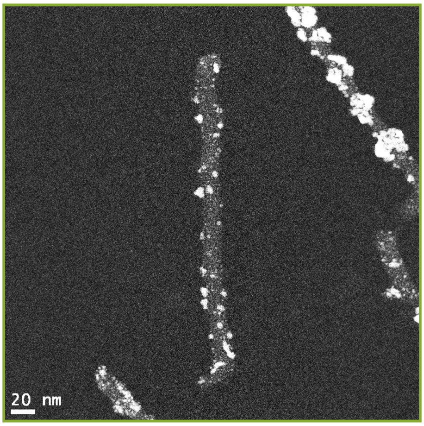
Lastly, the phenomenon of public knowledge of science deserves more than a modest research agenda. Just as controversial topics deserve their own multiple item modules, so too do individual scientific disciplines (e.g., Biology, Chemistry, Geology and Physics). If this data cannot be accommodated within Chapter Seven of the *Indicators*, then the National Science Foundation and the National Science Board should report it in parallel publications.

CONCLUSION

For the process of measuring and reporting public knowledge of science, the revised conceptual framework reported here has a clear and distinct starting point: what kinds of scientific knowledge do people in the public need for purposes of civic engagement with science and science policy, and for purposes of making individual decisions about one's life and one's health, and for purposes of feeding a person's curiosity about science? Furthermore, the revised framework reveals a series of insights about relations between the public and scientific knowledge: the public is far from homogeneous in its relation to scientific knowledge; public knowledge of science tends to be topical rather than nomothetic; and, many persons in the public have a considerable ability to acquire, understand and employ scientific knowledge when they need to (even if this ability is often underestimated).

In clarifying the purposes underlying the measuring and reporting of public knowledge of science, this report points to items that can be extrapolated for future editions of the *Science & Engineering Indicators*. It enables those who design the surveys to weigh competing issues and topics, and it puts science in the service of citizens and information consumers.

A second workshop, to be convened by Dr. Tom Guterbock of the University of Virginia, has a responsibility to develop items for the General Social Survey, within this new conceptual framework, for the benefit of the 2014 *Indicators*. Among the resources available to that workshop are the *Science Framework for the 2009 National Assessment of Educational Progress* (NAGB 2009), the 2009 NRC report on informal science education (Bell et al. 2009), and related reference materials.



Palladium particles on the shell of a Tobacco Mosaic Virus. Image from a Scanning Transmission Electron Microscope, by the USC NanoCenter.

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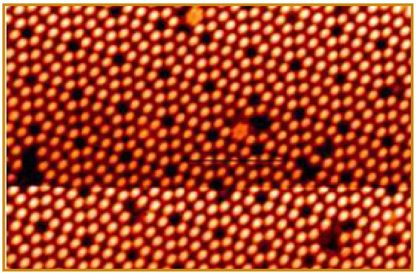
A Silicon surface, showing the hexagonal arrangement of silicon atoms. Image from a Scanning Tunneling Microscope, by the USC NanoCenter.



PARTICIPANTS IN THE WORKSHOP ON PUBLIC KNOWLEDGE OF SCIENCE

John Besley, University of South Carolina (science communication).

Meg Blanchard, N.C. State University (science education).

Mark Brown, California State University – Sacramento (science policy).

Michael Cobb, N.C. State University (science policy & survey research).

Elaine Howard Ecklund, Rice University (science & culture; religion & science).

Margaret Glass, Assoc. of Science & Technology Centers (informal science ed.).

Tom Guterbock, University of Virginia (survey research methods).

A. Eamonn Kelly, George Mason University (learning & cognition).

Bruce Lewenstein, Cornell University (science communication).

Chris Toumey (organizer & chair of the workshop), University of South Carolina (anthropology of science, especially public scientific controversies).

In addition, the workshop benefitted greatly from the services of graduate research assistants **Debbie Rexrode** (University of Virginia) and **Colin Townsend** (University of South Carolina). The participants sincerely appreciate their contributions.

Fall 2006: participants in the Citizens' School of Nanotechnology discuss scientific instruments with Dr. Donggao Zhao of the University of South Carolina Electron Microscopy Center.

Cover: Gold nanorods in cardiac fibroblast.
Image from Dark Field Microscopy, by the USC NanoCenter.

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