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Rev. 3

Guidelines—A Primer for Communicating Effectively with NABIR Stakeholders

J. R. Weber

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March 2002

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
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Preface

In this primer, we attempt to synthesize what is known about communicating about fundamental scientific research with nonscientists and to help scientists in their communication efforts. We have drawn information from diverse sources, primarily literatures in science, social science, and communication, from direct observations we continue to make during a variety of communication events on NABIR-related science (e.g., interviews, focus groups, designed engagements), and from the analysis and interpretation of taped interactions involving scientists and other stakeholders. Perhaps the most important observation that we have made is that the communication of science with nonscientists is highly contextual – what happens during the communication of fundamental scientific research and the resulting effectiveness of that communication is dependent on multiple factors that are extrinsic to the science itself. For this reason, there is no "silver bullet" for communicating about science with nonscientists. Different types of scientific inquiry, different participants, differing relationships among those participants, and differences in the outcomes that the participants expect from a communication "event" all influence how effective and satisfying the event will be to the participants. Thus, while it is tempting to rely solely on the terminology and communication practices that can most accurately communicate scientific content, this approach is very risky. It is important that thought be given to the context within which the communication will occur, and to think about communication opportunities with the relevant contextual variables in mind. For this reason, much of this primer (Sections 1.0-3.0) is devoted to understanding the context for communication. Section 4.0 provides guidance on preparing, meeting, and following up on meetings with other stakeholders.

Summary

The purpose of this report is to help scientists communicate with stakeholders and the public (primarily nonscientists) about fundamental science research. The primary audience for this report is scientists involved in the Natural and Accelerated Bioremediation Research (NABIR) program of the U.S. Department of Energy. However, the information and insights in the report that are not program-specific should be helpful to scientists in other fundamental science research programs. The report first discusses why scientists should talk to stakeholders and the public, and the challenges associated with discussing the NABIR program. It is observed that communication initiatives can be characterized by three factors: relationships in the social environment, views of what constitutes communication, and accepted forms of communication practices and products. With a focus on informal science communication, recent efforts to gauge public understanding of science and the factors that affect public trust of science institutions are discussed. The social bases for scientist-nonscientist interactions are then examined, including possible sources of distrust and difficulties in transferring discussions of fundamental science from classrooms (where most of the public first learns about science) to public forums. Finally, the report contains specific suggestions for preparing, meeting, and following up on public interactions with stakeholders and the public, including themes common to public discussions of NABIR science and features of scientist-nonscientist interactions observed in interpersonal, small group, and large group interactions between NABIR scientists and stakeholders. A Quick Preparation Guide for Meeting NABIR Stakeholders is provided immediately following the Summary. It condenses some of the information and advice found in the text of the report.

Quick Preparation Guide for Meeting NABIR Stakeholders

This short guide is intended to help prepare scientists to discuss NABIR science with nonscientists. It condenses lessons learned from NABIR-specific communication research and provides some background essential for preparation. Please add and revise this guide to reflect your own experience. Note that this quick preparation guide is not meant to be a substitute for the full primer, but as a cryptic reminder and preparation tool. To use it successfully, it is best to read and evaluate the material in the primer itself.

NABIR Program Description

Purpose: Provide fundamental science as the basis developing cost-effective bioremediation of radionuclides and metals in the subsurface at DOE sites.

Goal: Develop strategies leading to immobilization of contaminants so that they do not move through the subsurface environment in groundwater or soil, thus reducing risk to humans and the environment.

Parts of Program: Biogeochemistry, Biotransformation, Community Dynamics/Microbial Ecology, Biomolecular Science and Engineering.

General Advice

- You do not need to try to answer *every* question on the spot. You can acknowledge some questions/concerns without trying to provide answers.

- Be able to state the purpose, goals, and some current work from the primary research areas of the NABIR program. Be able to state the purpose and progress of your own project.

- Suit the language to the audience: generally, the more educated the audience, the more variety in scientific terms that can be used. Limit use of scientific terms to essential terms and define them. Note that you may define a scientific term by using it and following its use immediately by context, allowing nonscientists to use the term themselves.

A Public Glossary

Bioaccumulation	Using plants or microbes to accumulate pollutants. Not the same as *biotransformation* because pollutants are still present.
Biogeochemistry	Chemistry that studies living things in geological (subsurface) environments.
Bioremediation	The use of living things, such as microbes or plants, to break down substances into simpler, usually safer, forms.

Biostimulation	Adding chemicals or other nutrients to increase the number of micro-organisms and thus speed up bioremediation.
Biotransformation	Changing a chemical form of a compound by using a micro-organism or enzyme.
Complexity	A condition of an environment in which multiple factors interact in multiple processes with their own outcomes, but which may or may not affect each other. Example: a busy freeway interchange.
Genome	All the genes in a cell.
Microbe	A microscopic form of life (micro-organisms), such as bacteria.
Radionuclide	A radioactive form (isotope) of an element.
Subsurface	Areas below the earth's surface.

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Common Questions and Concerns	Possible Answers
What happens when there are unwanted or unexpected results?	Be able to talk about how you have exceeded the minimum requirements and expectations. Cite monitoring and contingency plans.
Has there been any transfer from lab to applications in your NABIR project or others? Why isn't this being applied? Why keep it in the lab?	a) Acknowledge that bioremediation has been used in other venues. Then, point out that this work is different: targets inorganic materials. b) Note importance of prudence in research: "Scaling-up" transfers from well-known into unknown territory. Need to demonstrate effectiveness before applications can be attempted on a wide scale.
Are any of these microbes dangerous? Is it possible for them to resistant to antibiotics?	Do these concerns affect the microbes in your study? Be able to cite previous studies and primary regulations to answer questions about pathogenicity and resistance. (Define "pathogen" if you use the term.)
How soon will we be able to apply this science?	Concede the limitations of your knowledge: "I wish I could answer that question. I wish we had all the information we need to be that far along." Follow up with a focus on how far the knowledge has taken us. If possible, talk about promising directions.

Expressions of distrust in DOE or in science	Demonstrate good preparation and a balanced perspective: a) Acknowledge concerns. b)Tell what has been done to monitor and control outcomes in your project. c) Cite strengths and weaknesses of microbes as remediators. d) Be able to cite program and project information. Offer to follow up later when you do not know. e) Concentrate on interesting science and findings (scientists have more of the public's trust than does DOE).
Does NABIR research involve adding organisms that are not native to the soil?	NABIR does not fund work on non-native micro-organisms.
Does NABIR sponsor research on genetically engineering native organisms to perform remediation functions?	No. NABIR does sponsor genomic research in order to understand more about traits of microbes that are native to contaminated soil.
Why not use technologies that already exist?	In fact, DOE does use existing technologies (such as pump-and-treat) where they are effective. NABIR is meant to target situations where existing technologies are the least efficient or effective (e.g., groundwater contamination).
What does NABIR stand for?	Natural and Accelerated Bioremediation Research
What is the impact of bioremediation on the use of natural resources around contaminated sites?	The long-term impacts will probably depend on the type of microbes and technique used. We are trying to learn what those impacts might be before large-scale applications. Note: Native Americans are particularly interested in bioremediation's potential to enhance or detract from the ability to use natural resources on ceded lands that are currently contaminated. Permanent immobilization in situ may be less acceptable than decontamination.

You will probably hear requests for the following information:

Facts, such as,

- What are you trying to do?
- What has been done before?
- What are your methods?
- Which microbes are you studying?
- How did you pick those?
- What have you found?
- Where have you done field work?
- Have you tried applications yet?
- What happened?
- Have there been failures?

- What are the basic biology and soil/water dynamics of bioorganisms interacting with metals and rads in soil?
- What have been previous uses of bioremediation, e.g., petroleum industry, and how does that relate to this program?
- How can bioremediation contain or remediate groundwater contamination?
- Can’t current technologies, specifically pump and treat solve the all the cleanup problems?

Definitions and clarifications, such as,

- What is biogeochemistry?
- What are the scientific issues to be addressed in this research? How can they affect the general public?
- What is the meaning (in common English) of that term you just used?

Place in the decision-making or development process, such as,

- Why don’t you move this work into field-testing sooner, rather than later?
- Could this work be commercialized? When?
- How will this work advance clean-up?

Weighing of values, such as,

- Is bioremediation cost-effective versus other technologies?
- How can these findings be used in possible applications outside the DOE complex?

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1.0 Introduction

The purpose of this primer[a] is to help scientists communicate with nonscientists about the fundamental scientific research they are undertaking. Our specific objective is to help scientists involved in the Natural and Accelerated Bioremediation Program (NABIR), sponsored by the Office of Science within the U.S. Department of Energy. However, our broader objective is to help scientists in all fields of endeavor address the following questions in public settings:

- What is the nature of the scientific research are you conducting?
- Why are you conducting it?
- What do you hope to discover?
- How might your discoveries help people and the environment?

Although these appear to be simple questions, they are extremely difficult to answer, for two reasons. First, fundamental scientific research is typically highly technical, built on a history of prior research within the relevant field of inquiry, and laden with highly technical terms understood only by scientists working in the same field. In such situations, it may be very difficult to find ways of communicating with nonscientists that promote real understanding of the subject matter. Second, although scientific inquiry is a structured process, three mutually exclusive outcomes are possible: you might not discover anything (thus ensuring obscurity), you might discover what you were looking for, or you might discover something you did not expect to find (e.g., the transistor). Further, if you do discover something, there is no guarantee it will contribute to improving human welfare or the environment, either directly or indirectly. The major communication challenges for the scientist are, therefore, promoting understanding, demonstrating relevance, and characterizing uncertainty – none of which is trivial.

The frames of reference that people bring to discussions and their abilities to understand scientific concepts and facts will vary greatly among, for example, regulators, public interest groups, the general public, students, and scientists working in other fields. Likewise, the expectations for what constitutes effective communication and the desired outcomes for that communication will also vary greatly. Thus, it is important to have some understanding of the context within which the communication will be occurring, and to consider that context when planning both the content and process that will be used in an engagement event. Both will be important determinants of success.

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[a] Research for this report was conducted by staff of the Pacific Northwest National Laboratory and Portland State University and was funded by the Natural and Accelerated Bioremediation Research (NABIR) program, Biological and Environmental Research (BER), U.S. Department of Energy (grant # D8132). Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RL0 1830.

That said, we have tried to avoid too much prescription for successful communication because of the many variables that are inherent when scientists talk with nonscientists about their work. Instead, our approach (Section 4.0) is to introduce scientists, managers, regulators, and policy-makers to what they can expect from scientist-nonscientist interactions and to recommend fruitful ways to prepare for such interactions. It is certainly neither the last nor the only word on the subject. You should feel free to add to, amend, and critique the information and approaches contained here. Like a scientific hypothesis, if it doesn't work, change it and test again.

Our goal is neither the management of information to the public or manipulation of public sentiment. Rather, we want to break down the "us versus them" barriers that it are so easy to raise when an expert meets a nonexpert group. Our vision is to combine presentation and mutual exchange in a facilitated setting. The expert's role in this type of setting is unlike teaching in a classroom, presenting at a professional conference, or interacting with peers. Our vision includes an expert who is willing to listen, respond, and explain, to learn as well as to instruct. However, this requires some preparation and flexibility. Some people will find this sort of situation an easier fit than will others. We are convinced, however, that many scientists with much to share and a real passion for their work could, with some observation and practice, have much to contribute to meetings with the public.

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This primer exists to help you prepare. However, we hope that it can also help you look back at meetings you have already experienced, providing you with a vocabulary to reflect usefully on what happened and what (possibly) could work better in the future.

Section 2.0 begins with the "big picture," i.e., the factors in the societal context of government science programs that affect how scientist-nonscientist interactions may occur. Section 3.0 discusses relevant findings and perspectives on research in science communication. Section 4.0 focuses on concerns and techniques, some specific to discussions about NABIR science, for improving scientist-nonscientist interactions.

Science Communication and NABIR Stakeholders

More than any previous generations, children born after World War II have been taught that they must be active citizens, and that they have an obligation to participate in their government. They have learned this lesson well. As a result, the nature of public dialogue about local, regional, national, and global affairs has been broadening to encompass more elements of society, and deepening in content as interest in government activities increases and the education level of the citizens continues to rise. This is certainly true in the sciences, where scientists are increasingly communicating with nonscientists about their work. Communication between scientists and nonscientists fills a variety of needs, such as raising national awareness about the implications of global warming, testifying about scientific data in criminal trials, and defending government funding for scientific programs.

Unfortunately, consistently successful communication between scientists and nonscientists remains elusive. Some efforts, such communicating about the benefits and risks of medical radioisotopes, are relatively successful. Others, such as communicating about the benefits and risks of food irradiation, are more troublesome.

Although public support and politics are outside of the everyday concerns of most scientists, scientific work often depends on public support. If the project is expensive (e.g., remediating a contaminated aquifer) or controversial (e.g., the use of genetically engineered, herbicide-resistant crops), public emotions can be easily stirred. "Vagueness, anxiety, fear or abhorrence often prevail over rational judgment, and incorrect or even hostile (it is absurd, extravagant, useless or diabolical) commentary about certain kinds of research spread quickly" (*Science*, 7 August, 1998, p. 776). It is at this point that informal communication about science is both important and difficult to achieve.

Frequently, there are calls for more informed input or more understandable output in discussions of publicly funded science. Often, such calls come from scientists who feel that the public's opposition arises from a lack of understanding or misperceptions. Highly contentious issues, such as biomedical research using animals, give rise to calls not only for more scientific information but also for the use of formats such as advertising that match those used by the opponents of research (Matfield 2002).

Calls for more public relations initiatives, however, are troubling to many scientists. The whole story of a fundamental science program cannot be told in a sound byte, a magazine advertisement, or a press release. Such approaches may raise awareness but are insufficient to create an educated public that would follow and support programs over time. Moreover, playing the public relations card, though often necessary for public support and visibility, is seen by many scientists as lessening the public's respect and increasing the public's expectations for quick solutions to problems. Historically, scientists have preferred to allow their methods and achievements to speak for themselves.

However, public support for fundamental science appears to wax and wane with demonstration of useful outcomes. Business-minded public decision-makers and their constituents like outcomes. Our experience has shown a public unwillingness, even among educated people, to indulge scientists in "science for science's sake."

Although the forms of communication in which fundamental scientists engage comfortably are those involving other scientists, public funding for fundamental science may require that "progress" in understanding natural processes be conveyed, along with a program's goals and hopes. Between scientific work intended for other scientists and scientific work as conveyed in the general media, there is a gap, where scientists and their nonscientist fellow citizens can communicate *directly*. Some communication opportunities, such as National Public Radio's "Science Friday," have recently been devised to fill this gap by providing contact between scientists and the public on issues of the day. However, because they may be products of news organizations, the topics discussed meet those organizations' requirements for news currency and controversy. What about science that would benefit from public awareness and support but is neither currently controversial nor stigmatized?

Among the first problem that scientists encounter in informal communication is that nonscientists are not "blank slates," i.e., completely unfamiliar with scientific processes, terms, or issues. The public's understanding of science parallels its exposure to science in the news media and on the job and is, thus, mixed in sophistication. Thus, the goal of informal communication of science cannot be a professional's, or even a student's, level of understanding. Often, a satisfactory goal may be to clear up misunder-standings or replace incorrect stories with correct ones. One of the goals of this primer is to discuss what level of understanding may be reasonable to expect of nonscientists as a result of informal explanations and dialogue about science. In general, however, we can say now that *the goal of science communication is to interpret matters of science appropriately in diverse contexts*. Science communication should enable everyone, scientists and nonscientists, to interpret information and place it appropriately into contexts that include health, the environment, and society's well-being.

Who are the NABIR Stakeholders?

In the broadest sense, NABIR stakeholders are any persons or groups who are interested in or potentially affected by the conduct of NABIR research. By this definition, they include citizens, regulators, technology developers, science and technology users, Congress, Native American tribes, local officials, environmental groups, public interest groups—and also scientists. This list of stakeholders may be broader than those commonly considered because stakeholders include more groups from a communication perspective than from a legal perspective. Stakeholders are created through networks of interest and concern. The "stake" can be context-specific—"I'm concerned about jobs in my community"—or more general—"My concern is with protecting the environment." The stake in any given scientific or policy issue may be politically driven or be stimulated by a particular crisis or flurry of stories in the news media. Moreover, the stake that someone holds may not be apparent, that is, someone may not take a position or express a concern at all. Nevertheless, that person may be a stakeholder simply by living in an environment that will be affected. Stakeholders are thus not limited to advocacy groups or those with special legal standing; they also include citizens who have not taken a position on scientific or environmental policy issues potentially relevant to a science program.

As more voices are added to the stakeholder mix, the challenge for science communicators includes recognizing the multiple interests and viewpoints that enter our conversations about science and public policy.

Why Should We Talk with NABIR Stakeholders?

Experience to date indicates that stakeholders generally regard bioremediation as a promising way to address environmental contamination (e.g., see Weber et al. 2001). They want scientists to succeed in developing breakthrough methods to solve intractable problems, and they look to the talents of scientists to generate the knowledge-base to enable these breakthroughs. Scientists and science programs can take advantage of this public support and benefit from stakeholders' insights:

- Early involvement will help identify performance criteria, some of which, if not addressed, could be research or program show-stoppers. It may also identify opportunities that the scientists have not considered.

- Stakeholders possess valuable information about political, regulatory, and community concerns regarding site remediation and the application of research. It is far better to understand and account for these concerns at the outset of a project than to be hindered or blocked by them later.

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- Community leaders are looking for solutions to community environmental problems. The NABIR program will gain community support through constituent involvement and collaboration on related problems.

- In a democratic society, citizens will ultimately decide the nature and direction of publicly funded scientific research. Because science-infused decisions are generally considered superior to decisions made without the benefit of scientific knowledge, scientists have a responsibility to other citizens to help them understand the science that is involved in the decision they are making.

Public engagement with scientists creates opportunities for scientists and the public to gain practical knowledge about the limits and possibilities generated by scientific research programs and initiatives. According to William Paisley, "Scientific literacy is challenged to be light-footed, because science will continue to produce many surprises each year. The scientific literacy context for interpreting these surprises should be available as soon as the stories themselves are available, because the public's first impression of a scientific development is formative - whatever is misunderstood then may remain misunderstood for a long time" (1998, p. 79).

2.0 Systems of Communication—Why Information May Not Be Enough

Typically, when we think about communication, we think of providing information or persuading. Because scientists play the role of experts in public discussions of science and because they often avoid advocacy (persuasion), preparing to talk about science usually means preparing information.

However, not all stakeholder issues are informational. The technical information that the scientist wants to provide may actually lie outside the other participants' realms of concern. They may be there to discuss something else. They may be interested in the economics of bioremediation, in how DOE or another agency handles contracting issues, or in whether DOE will commit to and follow through on cleanup. They may want answers to technical questions not related directly to site cleanup: Will bioremediation help clean up nitrates in their well water? Will the cleanup operations be put up for bid and cleanup slowed after a couple years?

In our observations, we have found a paradox when we expected to communicate only by providing information. Certainly, no one who comes to a public meeting wants their time wasted with a lot of peripheral material or overt "public relations" stuff. On the other hand, providing only scientific information to the public also does not lead to satisfactory communication.

Certainly, access to good, objective scientific information is essential to a successful scientific engagement. However, scientists' intentions are affected by a set of other forces once others arrive to discuss issues involving science. We have identified at least three communication factors in public discussions of science (see Figure 2.1):

- the nature of the relationships among participants and the role of interested people who are not present, e.g., policy-makers or legislators

- participants' views of acceptable communication, i.e., what satisfactory communication looks like or results in

- the form of meetings between scientists and nonscientists, e.g., interpersonal, small group interactions, question-and-answer, lecture, etc.

These factors are discussed in Figure 2.1.

Relationships—Making Connections

The process of communication can be pivotal in developing rapport among scientists, the sponsoring agency, and members of the community. Relationships can be characterized by extrinsic considerations, such as education or political affiliations, and by intrinsic considerations, such as values, social norms, and the perceptions of others.

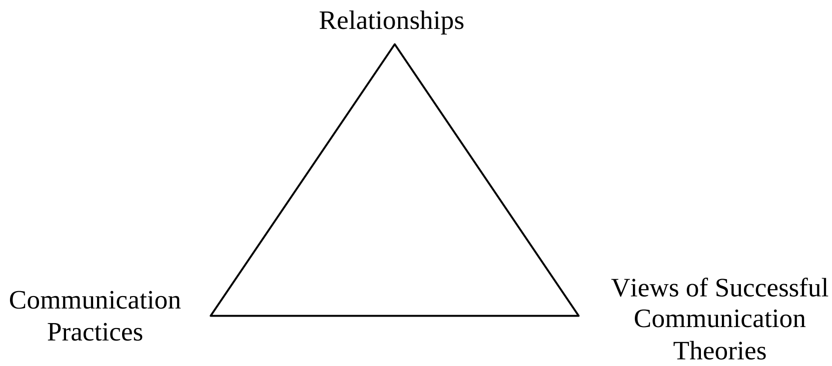

Figure 2.1. Public Context for Discussions of Science

2.1.1 Extrinsic Relationships

An overview of stakeholder groups shows them to be diverse in education, loyalties, and interests. They often include agency policy-makers; program managers; Congresspersons, legislators, and aides; educators; groups with interests in particular science or technology initiatives; the press; and science-interested people. The field includes groups who rarely engage in public discussion of science issues and those who do so regularly, including professional communicators, technical experts, expert stakeholder groups, community interest groups, oversight groups, and federal, state, and local regulators. One group often left out of these discussions has been the scientists themselves.

As a practical consideration, most scientists and project managers who interact with their colleagues and the public adopt an apparently simple audience analysis for their messages. In approaching audiences, they may be led primarily by time constraints and by the guidance of technical writing textbooks, which regularly deal with audience analysis in a simple four- or five-part division: professionals, managers, decision-makers, technicians, and the general public. However, such an audience analysis is usually inadequate. The public is rarely, if ever, "general." It comprises all of the other audience types and, for any given topic, a wide range of expertise. Simplistic audience analysis also often assumes that factual information is the only content in messages, that the audience will not challenge or ask questions, and that audiences are exclusively or mostly of one type rather than being mixed in background and interest. Most tables of audience types actually compare oranges and apples, distinguishing one type of audience (general public) by its capacity to understand and another type by what it does (e.g., decision-makers or managers). Moreover, some audience types cross numerous boundaries. For instance, a regulator, who is charged with applying and recommending standards could be technically astute, interested in policy matters, agree with scientists' concerns about unnecessary suspicions of their work, and share a public interest group's skepticism about the safety of a particular field experiment.

Thus, relationships are complicated by expectations. Not only are scientists making audience-assessments, but nonscientists are, as well. Many nonscientists who are invited to interact with scientists will be aware of the scientists' association with funding institutions such as government agencies. In the case of government agencies, in particular, these institutions appear to be large and bureaucratic with complicated histories of dealing with the public. They may also be aware that decisions about program directions will probably not be in the hands of scientists. "Science-based," programmatic decision-making is a *social* decision-making process, i.e., decisions will be made for society, often by persons who are not visible to the public (cf. Margolis 1997).

Each group, whether "stakeholders," "interest groups," "program people," or others, contributes somewhat differently to the discourse surrounding a science and technology program. The clearest differences may be those most evident in language and interactions: questions, vocabularies, interests, and criteria for acceptable evidence, to name a few. However, other differences run deeper and may be harder to detect: differences in problem-definition, for instance, or in tolerances of acceptable risk.

2.1.2 Intrinsic Considerations in Relationships

Relationship development is also affected by participants' sense of well-being and control (or lack of either one), their understanding of and interest in science, and their awareness of differences and similarities of the people involved. Although focus may be on sharing knowledge, expert-nonexpert interactions are often driven by unspoken interest and concerns that emerge during the discussions as more information is available (see Weber and Schell Word 2001b on tacit and emergent dimensions in science communication).

Many of the participants in our meetings may live and work in communities affected by cleanup activities and, therefore, have a stake in scientific discussions. However, they may have limited or minimal formal exposure to science and scientific ideas. For them, bioremediation is complicated new material. It may take time for them to understand the scientific discussions. Although we may use the same body of *facts* that we use with more sophisticated listeners, their concerns, rational or not, must also be addressed. For scientists, it is a matter of "fact," but for many community members, emotional or nonrational responses indicate deep personal concerns. One of the participants in a focus group said it well: "People give you back a scientific answer when you're talking about a question that involves you and your sense of well-being. You want to be responded to on an appropriate level."

But how do we know what an appropriate level is? Particularly when it comes to discussions of potential or actual risks, information may be less compelling than other factors, such as a sense of control or prudence.

It would be wrong to assume that the opposite of scientific rationality is simply irrational fear or ignorance. In fact, it may be one of many alternative rationales, such as actions based on prudence or on economic viability. Parents may prevent their children from going to school because of the fear of old and "sick" buildings, despite the results of certified tests showing that the buildings are safe. Although we may say that people are driven by irrational fears, the rationale for their actions is often prudence, and their "data" are concern for their family's well-being. History can be important in these situations. Parents may recall when certified tests showed a school to be safe, only to have suspicions raised later, justifying their prudence.

Our NABIR research shows that the public often wants to know the answers to several *why* and *what* questions:

- Why are you providing this information?
- Why are you doing this?
- Why are you seeking approval?
- What is your mission?
- What do you want to get out of this?
- What do you want from us? (And, in the case of a public meeting, Why are we here?)

Note that the desired information in science communication is *functional*. Science communication does its work beyond what is intended in the near term because the providers of information may not be in control of how others use it. When providing information, then, we need to provide adequate context, as well. The absence or presence of context plays an important role in our views of what is satisfactory communication, as well.

Views of Satisfactory Communication

When people discuss the context of communication, you may not be surprised to hear discussions about relationships among participants and the communication structure itself. However, it is less common to hear discussions about another factor that is very important: the standards that participants set for "successful" communication. We often communicate according to sets of unspoken rules about what is appropriate or rude, beneficial or tiresome. We also may have rules of thumb about what is adequate or understandable information.

Because there is such a wide range of possible rules of thumb—they may differ from one individual, group, or organization to another—we find a primary distinction helpful, between strategic and participatory communication. What is defined as successful outcomes differ for each mode.

Strategic communication functions to inform, direct, and coordinate activities. Strategic communication tends to be presentational, in outcome if not in method, being message-driven and involving strategies for gaining a group's understanding and adherence. The motives are primarily to inform or to persuade. The dominant theory of communication is the transmission model, which envisions communication as a linear conveyance of information with three parts: a sender, a message, and a receiver. Important issues in the transmission model are "how to facilitate attitude change and how to promote consistency between attitudes and behavior in the intended receiver" (Bradbury 1994, p. 360).

Of course, this model describes a common and useful arrangement that we could probably not do without. Our business and educational processes require one person presenting data, results, or ideas, with an opportunity to present supporting evidence and interesting sidelights. However, it is also clear that this model captures a speaker-centered situation. It seems to encourage speakers to envision audiences as single entities or as combinations of types. Evidence suggests that the speaker-listener model may encourage speakers to make awkward—and probably untrue—assumptions about an audience's degree of sympathy or aversion to their message, the listeners' preparation for understanding the message, and their ability to follow leaps in logic or to visualize what the speaker is saying.

Participatory communication emphasizes the adaptive and generative features of communication, which involve entering into a dialogue. Participatory communication is more spontaneous and interactive than typical strategic communication, allowing viewpoints to emerge (and even to merge) in various degrees of agreement. Advocacy in participatory frameworks is often from multiple perspectives, rather than from a a point-counterpoint perspective. Information in this context rarely remains static or neutral; it is integrated into sense-making activities and interpreted through multiple frameworks—drawing from listeners' experiences, questioning, countering with other views or data. This approach uses a convergent, rather than a transmission, model of communication, in which "participants share and create information, either diverging or converging on a common meaning or understanding….It is important to note that convergence on meaning does not necessarily mean agreement and the elimination of conflict" (Bradbury 1994, p. 361).

2.1.2 Science Communication as an Ecological System

Participatory communication points us toward an underlying model that embraces all the circumstances surrounding the communication events themselves. The concept of communication as an ecological system begins to capture the complexity and inter-relationships that exist in a public dialogue about science.

Communicating in a public setting possesses analogs of all three key attributes of ecological systems: structure, energy, and nutrient flow. Together, they allow the system to evolve over time. When scientists engage in public dialogue about science and basic research, they are attempting to help non-scientists understand how the basic or applied research that they are conducting has the potential to affect how their world evolves.

In this system, the groups to which people belong provide *the structure*. People may belong to these groups intentionally, unintentionally, through their employment, or simply because of where they live and work. Singly or as groups, they possess different frames of reference with respect to science as a whole and sometimes to specific scientific topics (e.g., the dangers of off-gassing of office materials, geological activity, or radioactive contamination of soil).

The energy that drives this "ecological system" is the desire or need to communicate. The desires or needs may originate in personal health concerns, concerns for environmental quality, or the need to keep an activist organization funded by a citizen constituency. Communication occurs among individuals and groups because these desires and needs exist.

The nutrients that feed the system are both the information that is communicated and the way in which that information is communicated among various individuals and organizations. The information and the process of communication itself have the potential for each party in the dialogue to benefit from any other, albeit not always equally.

The behavior of any particular part of an ecological system depends not only on its own traits but on the subsystem that it forms with other organisms, that is, on its relationships. Thus, the immediate subsystem of which any single member is a piece may be more immediately important to that organism than the system as a whole. However, the whole system sustains its subsystems in complicated and varied ways, by providing structure, energy, or nutrients, either directly or indirectly.

A small group of participants in a public meeting on relicensing a nuclear plant, for instance, who share a common political stand on the issue, gain from their similarities, their common energy, and their adaptation to available information. As a subsystem within a public meeting, they also draw from the frame of reference provided by the structure of the meeting, by the various viewpoints expressed there, and by the range of information and interpretations placed on that information by various individuals and other subsystems. Subsystems may overlap, as well. A member of a group opposed to a power plant's relicensing, for instance, may nevertheless be a neighbor of someone who supports it, so that both are part of a subsystem with roots in the community.

Indeed, in your own experience, you can probably identify four domains of communication ecology:

- microsystems - you and others and in your immediate work or home environments, such as your family

- mesosystems - the relationships among various microsystems, such as you may encounter as families gather for religious observances or get together during Little League games

- macrosystems - the relationships among mesosystems, involving the crossing of immediate boundaries to include subsystems that may not usually be gathered together, such as with ecumenical religious observances or school-district sports banquets

- exosystems - gathering the subsystems into cultural belief patterns, and social, technological, or political groups that may form the content of other subsystems.

All of us are members of such systems and all the systems exhibit topics, terminology, shared beliefs, and communication behaviors that reflect their component subsystems.

Of course, this analogy between physical and communication ecology is not perfect. Notably, energy can be received and harnessed by anyone in the communication system. This is not true of ecological systems, where plants harness the sun's energy, and all higher trophic levels are dependent on plants.

More important, though, the broader harnessing of energy and the nature of communication itself result in a system that is even more complex than an ecological system:

- Communication can occur anywhere in the system, and among any of the individuals or organizations. Hence, there are more potential interactions in a communication system than an ecological system.

- In addition, communication has the potential to change both the sender and receiver and in the process to change, what is conveyed. Such changes drive the evolution of the social system within which science operates.

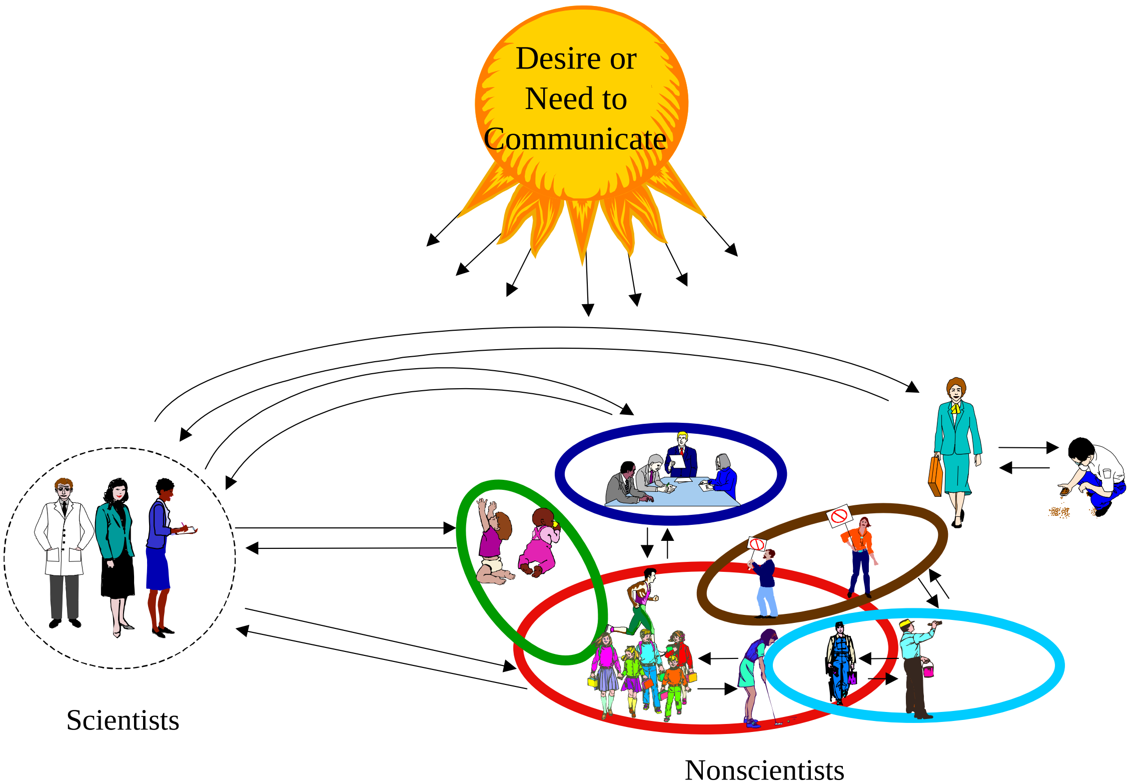

Figure 2.2. Communication as a Social Ecosystem

2.1.3 Science Communication - Meetings of Information and Contexts

This model of the grounds of communication suggests why it may seem so complex when scientists try to communicate to members of the public not familiar with their work. We need communication competencies that can adequately respond to the demands of the social/communication ecology of the public-engagement process.

The ecological model also reflects the sort of divisions that exist in public interactions. No group of people, including scientists, can be adequately characterized in only one way. Groups can be subdivided by education, personal preferences, affiliations, moral predispositions, or many other determinants. Different groups may share essential qualities but still be distinct, based on language or social loyalties. The ecological view of science communication suggests that science is conducted by communities of individuals, who through their specialized (expert) language, come to understand their area of expertise in ways that align them with some, while making them distinctly different from others, in the same field of study. Our most evident communication subsystems may prevent our seeing commonalities with others in adjoining or overlapping subsystems. Whereas our point of view allows us to frame the world in a way that makes it understandable and predictable, it can also narrow our vision by blocking out competing visions (see Appendix A).

The ecological nature of science communication can also force us to factor in the possibility that differing assumptions, beliefs, expectations, and language usage are not insurmountable. Instead of being a liability, this variety of backgrounds and experience potentially puts the scientist in the powerful position of being a *boundary-spanner* among groups, systems, and disciplines. The process of communicating is a process of looking for overlapping subsystems and commonalities.

Communication Practices

Table 2.1 lists various types of communication formats that are common in DOE science communication by some of their essential features: in what situations they are most appropriate, which communication models they may draw from, the opportunities and constraints on responses, the conflicts that each brings out, and the communication products that often accompany them. Although the types of communication formats listed may not be exhaustive, the list does contain the most commonly used formats: presentations (perhaps the most commonly used), interpersonal forms of communication, small and large group interactions, panel or roundtable discussions, networks (either open or closed), and facilitated or unfacilitated groups. No format listed is entirely exclusive of other formats: interpersonal communication may include a presentation of a viewpoint; networks may include small group interactions as participants seek out like-minded colleagues; panels may involve interpersonal and facilitated communication behaviors. However, Table 2.1 suggests that a communication format may very well create the character or tone of a communication activity as well as simply structuring the agenda.

Table 2.1. Types of Common Communication Strategies and Their Features

	When Most Appropriate to Use	**Applicable Communication Model**	**Opportunities for Responses**	**Constraints on Responses**	**Common Conflicts**	**Associated Communication Products**
Presentations	When information is critical to decision-making and problem-solving. Full views can be aired and supported. Mini-presentations can also take place in small and large group discussions, panel discussions, poster sessions, etc. Success depends on credibility, currency, relevance, representativeness, appropriateness of speaker and content.	Transmission - primarily one-way delivery, with emphasis on conveying information and/or influencing	Determined by format. Audience response pivots on gaining the attentive ear of the audience (gaining and maintaining attention). Interpersonal response limited. Individuals responses to presenter can vary widely.	Often, limited chance for feedback, e.g., constraints on time for questions, comments, counterviews. Questions and counterviews may remain unsupported. Often, lack of immediate feedback for both speaker and listener. Appropriateness of response depends on relevance of topic to listener. Speaker may be unaware of listener predispositions. Adverse affects on listeners of excessive or insufficient information.	Lack of access to listeners' viewpoints may create conflicts via differing frames of reference or orientations. Can result in listeners' sense of isolation or polarization, resistance, or covert noncompliance. Also, a confirmation bias is common: listening only for information that supports our perspective.	Speeches, texts of presentations, visual aids such as viewgraphs or computer slides

Table 2.1. (contd)

	When Most Appropriate to Use	Applicable Communication Model	Opportunities for Responses	Constraints on Responses	Common Conflicts	Associated Communication Products
Interpersonal	When two or more individuals are engaged in direct communication.	Interpersonal - Information delivery (to be useful) is a connected with critical thinking models in inter-personal communi-cation. Critical thinking requires the ability to analyze and evaluate ideas and information.	Occur in listening, interpreting and responding. Speaking and interpreting occur simultaneously. Responses include explanation of viewpoints and attempts at common under-standing. Support for partici-pants' viewpoints available.	Limited range of viewpoints. Also, words have different meanings for different people. Hidden agendas may be at work.	Differences in values, beliefs, uses of language, or goals for communicating. Defensive communication patterns. Conflicts of interest, power imbalances, or differences in interpretation of information may stand in way of understanding or agreement.	Includes the means of interaction and the outcomes of interactions. May be emails, letters or memos, plans (spoken or written), telephone calls, as well as the wide variety of possible outcomes.

Table 2.1. (contd)

	When Most Appropriate to Use	Applicable Communication Model	Opportunities for Responses	Constraints on Responses	Common Conflicts	Associated Communication Products
Small Groups	Groups outperform individuals • in broad-range tasks; • when no members of group have needed expertise (as in currently unresolvable problems); • when experts face a complex task; • when group is composed of an individual expert and an informed group.	Interpersonal + dialogue + facilitated interaction	Questioning allowed. Speakers accessible. Common work and understanding possible. Collaboration possible. Allows collective recall of information and pooling of knowledge.	Letting others speak. Some may dominate group. Limited range of views (i.e., the system is too closed, resulting in analysis paralysis). Danger of negative synergy (group members working together produce worse result). Possibility of competing goals, sharing ignorance, or establishing negative norms (e.g., mediocrity, groupthink).	Competitive group environment. A pressure to conform. Differing goals among group members, whether expressed or not (hidden agendas).	Notes, flip chart notes, trans- cripts, video or audio tapes, storyboards, hand-outs

Table 2.1. (contd)

	When Most Appropriate to Use	**Applicable Communication Model**	**Opportunities for Responses**	**Constraints on Responses**	**Common Conflicts**	**Associated Communication Products**
Large Groups	Useful in accomplishing cooperative goals through interdependent division of labor and resources with the group. Success not defined individually but in terms of group. Large groups become more effective when managed through small groups activity or networking. Then the group advantages are increased while allowing for greater participation and diversity.	Interpersonal + dialogue + facilitated interaction	Can form subgroups - individuals' viewpoints may be supported by others. Range of views may be available. Ability to divide labor.	Illusions of agreement. Complexity increases with size. Information distortion may be a larger problem. Factionalism may arise. Difficulty in achieving agreement or consensus. Very large groups decrease possibility for participation and increase pressures to conform. Coalitions may form in opposition to group norms. Group size may decrease access to information. Group size decreases speed of decision-making. Problems of coordination and efficiency increase.	Social loafing (Latane et al. 1979). i.e., the tendency of individual group members to reduce their work efforts as groups increase in size. Conflicts increase as coalitions form, increasing likelihood of interest-identification and insulation from other groups.	Hand-outs, flip charts, transcripts, video and audio tapes, storyboards, notes, collaborative reports, web sites.

Table 2.1. (contd)

	When Most Appropriate to Use	Applicable Communication Model	Opportunities for Responses	Constraints on Responses	Common Conflicts	Associated Communication Products
Panel/roundtable discussion	Small group of participants engage in information exchange on a specific issue or problem in front of listeners or viewers. Working on solving a difficult problem; informing listeners about a problem or topic of interest; stimulating an audience to think about the pros and cons of an issue.	Small group + transmission.	Moderate range of viewpoints available. Balanced perspective possible.	Views limited to choice of speakers. Posing and positioning possible. Facilitation (moderator) likely to be needed. Process limited by physical environment and time allowed.	Pre-existing agendas. May be considered as opportunity for gaining public visibility, positioning, soliciting or support.	Transcripts, video and audio tapes, topic notes.

Table 2.1. (contd)

	When Most Appropriate to Use	Applicable Communication Model	Opportunities for Responses	Constraints on Responses	Common Conflicts	Associated Communication Products
Networks	Structured opportunities for information exchange and personal contact. May be in person or via interactive television, internet or other interactive media. Systems may be open (broadly available) or closed (limited participation, e.g., by invitation).	Transmission + interpersonal + small group + large group +	Open network information accessible to broad range of individuals. Encourages examination of assumptions and change. Closed network range is bounded, encouraging stability of group and goals and accomplishment of agreed-upon tasks.	Set roles create boundaries in group functioning. May regulate degree of openness and exposure to change. Physical or technological barriers may limit possibilities. May be psychological or group barriers to connecting outsiders into closed system or closing an open system (e.g., creating interest or task-specific groups).	Control or appropriate interpretation boundaries on information. Physical isolation of individuals (e.g., in cyber networking). Use of specialized vocabulary. In-group/out-group dynamics (us vs. them). In open network, difficulty of establishing and pursuing goals.	– –

Table 2.1. (contd)

	When Most Appropriate to Use	Applicable Communication Model	Opportunities for Responses	Constraints on Responses	Common Conflicts	Associated Communication Products
Facilitated groups	When participants come from more than one domain of expertise or social group or when domains or social groups are unknown. When there is a history of conflicts among participants. Facilitator should have time to prepare with participants the strategy, process, sequence of events, and desired outcomes.	Interpersonal + small group + large group, with emphasis on crossing domains of knowledge and experience.	Overall control over process is given to a facilitator. However, often input is encouraged on strategy selection, process, goals, sequence. Facilitation can encourage viewpoints to be heard and considered, without a single viewpoint dominating.	Meeting objective and/or design may constrain facilitator from pursuing "off-task" or divergent input. Also, group composition may exclude discussion of some ideas. Some participants may resist facilitator.	Participants' goals and/or expectations for outcomes may not be harmonious. Skepticism of process or of facilitator. Inappropriate facilitation - in process, listening ability, assumptions, etc. Differences in domain-specific expertise or in communication skills among participants.	Flip charts, audio or video recordings, output designated as goal of facilitated meeting (e.g., report).

Table 2.1. (contd)

	When Most Appropriate to Use	Applicable Communication Model	Opportunities for Responses	Constraints on Responses	Common Conflicts	Associated Communication Products
Unfacilitated groups	When domain-specific expertise is shared. When tasks are clearly defined. When group members are known to be compatible.	Interpersonal + small group + large group, with emphasis on sharing domains of knowledge.	Can achieve goal quickly, given clear common goals and processes. Easily formed. Tendency to call together groups of like-minded participants.	Group depends heavily on individuals' communication skills (e.g., listening, cooperation, rephrasing, etc.). Unequal participation (e.g., dominance of one or a few group members). Uncertainty over process. Possibility of one or a few participants setting agendas and/or processes. Tendency to call together groups of like-minded participants - few divergent assumptions and/or pressure for conformity.	Uncertainty in determining goals. Coercion of group by one or a few participants. Disagreement about who decides rules and/or assigned actions. Struggles over status. Clash of unexamined assumptions and/or unstated agendas. Confusion and/or suspicion over motives.	Flip charts, audio or video recordings, output designated as goal of facilitated meeting (e.g., report).

3.0 What Do We Know About Informal Science Communication?

Science communication has been much studied since C.P. Snow pronounced the differences between scientists and nonscientists as probably irreconcilable (Snow 1954).[a] In recent years, however, public mandates have brought scientists and nonscientists face to face. The encounters have generated overlapping bodies of work that help in understanding the misunderstandings and suggest ways of remedying them. Attention has been paid to the public understanding of science, the role of trust, and the communication features common among scientist-nonscientist interactions. These topics are considered in the following sections.

What Can We Expect the Public to Understand About Science?

The literature on science literacy provides us with three major approaches for presenting scientific information to nonscientists: explaining science content (Hazen and Trefil 1991; Hirsch 1987); explaining how science works (Shamos 1995); and discussing the impact of science on society (Bauer 1994). The British science communication researcher John Durant (1993) also distinguishes three ways of discussing science: a) understanding as knowing a lot of scientific facts; b) understanding as knowing how science works; c) understanding as knowing how science really works.

Perhaps the common point of view about public understanding of science, however, is that the public does not and probably will not understand much about science in the near future. Although the U.S. public appears to be interested in new scientific discoveries or engineering innovations (90 percent reporting being very or moderately interested), people also report not feeling particularly well informed about science. A National Science Foundation poll (NSF; NSB 2000) found only 17 percent of those surveyed felt well informed and 30 percent thought of themselves as ill-informed. Moreover, about 75 percent of those surveyed revealed a flawed understanding of how science is conducted. The public appears to be particularly ill-informed about specific scientific terms and concepts, with only 13 percent in the 1999 survey able to define a molecule, 29 percent to define DNA, and 16 percent to define the internet. A poll conducted by the First Amendment Center and reported by the National Science Foundation (Hartz and Chappell 1997), found that scientists and journalists, who agreed on very little about science communication, overwhelmingly agreed that the public "is gullible about much science news, easily believing in miracle cures or solutions to difficult problems" (more than two-thirds of journalists and three-quarters of scientists polled) and that "most members of the public do not understand the importance of government funding for research" (60 percent of journalists and 80 percent of scientists).

Although these figures are widely quoted, they may tell us less than it appears. One NSF survey asked for a self-assessment of one's knowledge of science. The answers indicate, as the NSF report notes, that "the level of self-assessed knowledge appears considerably lower than the level of expressed interest" (NSB 2000). Such a response might reasonably come from many scientists themselves, who

[a] For a more recent expression of the same idea, see Garvin 2001.

lack the time to keep up, even with their own fields. Although 75 percent of the public were deemed not to be able to explain how science is conducted, questions directed to specific areas suggest a slightly more positive picture: 21 percent could explain what it means to study something scientifically, about 33 percent could explain the basics of experimental procedures correctly (including the use of control groups), and – improbably enough – 55 percent answered the questions on probability correctly (see Table 8-11, NSB 2000). Those who took science courses in high school or college were markedly more interested, better informed, and more able to think scientifically.

It appears, then, that the public understanding of science in the United States is mixed, with particular gaps in formal definitions, experience with experiments, and familiarity with current scientific findings or issues. On the other hand, there is considerable evidence of interest in scientific inquiry involving phenomena that are easily observable or that may affect people's lives directly. For instance, the Pew Research Center for the People and Press (PRCPP 1999) annually ranks news stories that have been most closely followed. Over the past 15 years, the most closely followed science news stories involve the weather (hurricanes, floods, droughts, etc.), natural disasters, and man-made disasters (e.g., the Challenger space shuttle accident). Nearly two-thirds of respondents in the NSF poll said they were very interested in new medical discoveries. The more abstract and farther removed from material evidence, then, the less likely the public will be to follow a story, i.e., to read about it or watch a report on it more than once. Such findings are consistent with other research that has shown that the public retains only that scientific information that they find useful (Levy-Leblond 1992), a finding that holds true even for scientifically knowledgeable people, who trust in their colleagues' specialist knowledge (cf. Wynne 1995).

In some respects, the public understanding of science suffers from the same systemic blindness that affects all stakeholders in science, including scientists and engineers. All must cope with the provisionality of scientific information – that is, science is always in the making and has built-in review and correction mechanisms. However, its provisionality is not always transmitted through media stories or interviews with scientists. In particular, the use in scientific discussions of evidence, assertion, and other persuasive techniques, though obvious to scientists and science-literate people, is often not appreciated in the reporting of science. The public, then, is provided with few critical tools useful in evaluating scientific reports and claims. Moreover, the public becomes aware of scientific findings without the benefit of understanding their histories.

Susan Cozzens (1997) notes that "the practical value of the knowledge pool is demonstrated concretely only when someone trying to solve a practical problem dips into it for the needed resources… . The dipping, like the appearance of discoveries, also happens at uneven and unpredictable intervals, and each dip pulls up a mixed product of the many contributing streams" (p. 86).

Several fundamental implications follow from the largely hidden sources of information in the science system: (1) Knowledge producers and knowledge users often are not in direct or immediate communication with one another. Ideas and people interact through currently unpredictable paths and at uneven intervals (Cozzens 1997). (2) There is often a lengthy gap between discovery and application. It is estimated to take at least 15 years for commercial products to appear from fundamental advances (NRC 1995). As a result, the technical capabilities developed through fundamental science are difficult to track to its consequences. (3) Direct response to the question of accountability is difficult for all stakeholders, including scientists and engineers. In advancing the interests of fundamental science, linkages need to be developed at all levels of information generation and usage. The genealogy of information functions as one means of addressing the issue of accountability, but stakeholders are overloaded with information in their lives and have little time for background information. The default approach becomes, "Tell us when you have something to report." Science communication is often difficult, then, because its raw materials are limited to radically abbreviated statements of context and findings.

In this context, discussion of the actual public levels of understanding of science can be encapsulated in two models: the deficit model and the contextualist model. The deficit model of public understanding holds that people need the information that only science can provide in order to understand science rightly. That is, ignorance of the conduct of science and of the properties of the physical world is what is standing between the public and scientists. Fill that gap in knowledge and the social gap between the two worlds will disappear. The public, then, is the recipient of scientific information.

The contextual model relies on the evidence that the public prefers to visualize or experience a setting for scientific information: placing science in or retrieving it from an observable material context. Scientific information is best provided to the public in ways relating to their special interests and needs. Emphasis is on contextualized, rather than generalized, information, preferably grounded in a real-world problem. The public and the scientist engage in negotiated meanings, i.e., in working out an understanding of the problem and the science through questioning, defining, and, where possible, mutual information-gathering.

These are differences in views about the best approach to science communication, but they are also differences in views of the nature of the public itself. In the deficit view, the public, as recipients of information, are like vessels to be filled. The concerns include what the public's capacity is, i.e., whether they can "hold" all the relevant scientific information. The contextualist view is that the public is an organism that learns by adapting information to experience. It is possible, of course, for both views to be right in different circumstances. As passive recipients of news, for instance, we can all remember instances of feeling "filled" and overwhelmed by media attention to a scandal or spectacular event. Nonscientists may also, on occasion, be overwhelmed by scientific or medical information, particularly if the information is too much to use readily. When scientific information can be applied to recognizable experience, nonscientists are no longer empty vessels but organisms selecting, questioning, and applying information. To a void that feeling of being overfilled, nonexperts prefer visual definitions to abstractions, applications to theories, and details in a setting to details listed or detached from a context.

What Do We Know About Public Trust?

The vital importance of trust in communication has been known for many centuries. Aristotle taught that trust is the response to a speaker's knowledge (expertise), openness (apparent honesty), and concern for others (goodwill). Since Aristotle's time, rhetoricians, commentators, and social psychologists have refined or expanded this list, and thus enhanced our understanding of the creation of trust, but none has succeeded in completely replacing it. Recent commenters, working from survey and interview data, have expanded the list beyond our sense of trust in a speaker to general views of how and why people trust others at all. In 1992, Kasperson et al. identified four primary factors in creating trust: our sense of a speaker's commitment to a goal (which may include fiduciary responsibility), competence, caring, and predictability. Other researchers have generated similar lists: e.g., competence, objectivity, fairness, consistency, goodwill (Renn and Levine 1991); or caring, commitment, competence, and openness (Covello 1992). Summarizing these factors: Our trust (in an individual, a group, or an institution) combines our sense of their knowledge-claims, their goodwill, and the congruence of their outer and inner persons, i.e., that they are who they appear to be. Moreover, they are principled people, committed not only to specific goals (ends) but to upright methods of attaining them (means).

Perhaps because trust depends so much more heavily upon perception than upon demonstrable evidence, it is more easily destroyed than built up. Paul Slovic has called this long-known tendency (see, for instance, Pruitt 1964) "the asymmetry principle": "When it comes to winning trust, the playing field is not level. It is tilted toward distrust…." (Slovic 1999, p. 698) Not only are trust-effacing events more noticeable and carry greater weight, but bad news tends to be more credible and reinforces existing distrust. These tendencies are true not only of individuals' assessments of the reliability of people and institutions but of the news media's approaches, as well. As a tendency of public behavior, once a person, group, or institution actually or apparently violates a trust-factor, the effects linger and create expectations of similar negative news.

In truth, nonexperts often have little choice but to trust experts – a situation that can contribute to resentment and suspicion (cf. Johnson 1999). Because we are all nonexperts in nearly all specialties, we are all familiar with being dependent on specialists, and we probably intuitively understand what may increase distance, distrust, or resentment. As nonexperts, we lack a specialized education and vocabulary, current knowledge of the field, experience in practicing the trade or profession, acceptance into the guild of professionals, and the confidence that each of these factors brings.

In speaking to the nonexpert public about science, it may be helpful to rely on an analogy to our own experiences in other arenas in which our own trust is enforced because we are not specialists. For example, a visit to the doctor results in frustration if we do not understand the medical language used, the grounds for the diagnosis, the prescription given, or what we should expect in recovery (e.g., hearing that we should call back if we get worse, what does "getting worse" really mean?). We may be likely to work around some or all of such factors if we expect the "system" to work like that (i.e., everyone is treated similarly) or if we see some responsibility falling on us. However, when institutions or individuals appear to lack concern for our well-being (e.g., if the doctor seemed not to be listening), we may well withdraw our trust.

From this analogy, note that educated patients, even if not educated in medical terminology, may be bewildered but will rarely withdraw trust because of language that they do not understand. However, trust will probably not survive the violation of a trust-factor (e.g., if we suspect that the doctor is intentionally bewildering us or refuses to translate difficult terms for our benefit). Similarly, a nonexpert is not surprised by a scientist's use of specialist terminology; indeed, nonscientists expect some technical terms to slip out. However, they may be put off by a scientist's unwillingness to translate such terms or to answer questions about the corresponding underlying physical realities. Such reluctance may well be interpreted as showing a limited goodwill or indifference.

If we are associated with a distrusted group or institution, are there ways to break the cycle of negative expectations? One answer may lie in institutions' tendency to break public trust in predictable ways. Recent research identified public levels of trust in government, private industry, and citizen activist groups and found that the public tends to perceive each group as weak in one or another trust-factor. Industry, for instance, is often seen as uncaring about the effects of their actions; citizen groups tend to be seen as potentially unreliable in their knowledge and claims to knowledge; and government agencies tend to be seen as uncommitted. Increasing trust in these areas of weakness will do the most to increase public trust overall. Increasing trust means violating public expectations: "defying a negative stereotype is key to improving perceptions of trust and credibility" (Peters et al. 1997, p. 53).

What would a violation of the public's expectations of government-agency scientists look like in practice? If Peters et al. (1997) are correct in their division of public distrust among institutions, scientists from government agencies should at least be careful not to make promises about future commitments over which they have no control. Whereas public expectations of trustworthy institutional behavior may be low, we have observed that members of the public are quite willing to believe in individual scientists' personal commitment to sound science, concern for others, and personal openness. Methodical qualitative observations have shown us that, in small group sessions, nonscientists respond positively when scientists appear to be open about both successes and failures, refer to their concerns for their own families and communities, and are ready to translate technical and programmatic language into more jargon-free English. This is consistent with a long-standing research finding that reciprocal self-exposure and reinforcement of mutual values increase the climate of trustworthiness and decreases mistrust (cf. Webb and Worchel 1986).

What Do We Know About Scientist–Nonscientist Interactions?

The central factor in the relationship between scientists and nonscientists is often assumed to be the disparity in knowledge (see Garvin 2001). As we have noted above, for the nonscientist public, this disparity means both lack of specialized education and lack of access (and, thus, understanding) to relevant scientific and technical information. But there are differences of methodology that are important in structuring how experts form judgments. Experts have systematic, often quantitative, means of testing their hunches about causes whereas nonexperts tend to rely on personal observations, what they've read on the topic, and intuitive judgments.

So, nonscientists who hear from scientists about their work may be said to be in a deficit relationship, in the sense of being uncertain about the grounds for scientists' conclusions. Although a considerable body of research has been done on decision-making in conditions of uncertainty, nonscientist members of the public may have few or no decisions to make. Instead, they may be struggling to get the facts and form a plausible picture of the future of the science and the science's impact on issues of concern. They are like students in a course for which they did not sign up, in an undefined (or, worse, a multiply-defined) subject area, for which they have little formal preparation, in languages that require translation or paraphrase, but nonetheless for which the stakes are high.

Risk-perception researcher Howard Margolis characterized the public's perceptions of science as a trade-off between danger and opportunity. Commonly, the public knows nothing about either the dangers or the opportunities in a scientific program or development. Rarely does the public know about both dangers and opportunities. Although public conflicts can erupt in either of these cases, they are most likely when the public knows something about either the putative dangers or the opportunities, but not both. The public perception of science's dangers and opportunities differs from the experts' on this point: The experts see a gap in the public understanding whereas the public sees the experts as clouding the issue by withholding information about either dangers or opportunities, either from indifference or by intent. "In the usual story, what is accounting for the stubborn conflicts is less what experts see that other people miss, but what ordinary people feel about risk that experts neglect" (Margolis 1997; emphasis in original). This dynamic may account for one peculiarity of scientist/nonscientist conflicts in the perceptions of science-risk: that the most heated controversies are "almost always associated with risks so statistically remote that ordinarily they would not prompt any sense of visceral risk at all" (Margolis 1997, p. 126).

Margolis's analysis suggests why the public's knowledge deficit may give rise to behaviors and thinking that may compensate for the lack of technical knowledge. Faced with a trade-off between danger and opportunity and a knowledge gap (therefore, a power gap), nonscientists reach for solid ground in what they do know and can plausibly infer. They draw on the authority of their experience and their position as citizens in a democracy who have the right to question and receive answers from experts funded with public money. Unfortunately, "common sense" frequently diverges from scientific sense. Often, common sense seems to rely on current information and controversies in the press and on a tendency to defer to what is immediately at hand, e.g., such visible effects as automobile emissions or the cutting of trees. The body of common knowledge that seems plausible even to educated people can lead to plausible ideas that are essential mistakes.

The differences in how experts and nonexperts view issues seems to focus on differences a) in distinguishing causes from effects and b) on perceptions of the frequency of events. In a series of studies of nonexperts' understanding of global climate change, even highly educated nonexperts displayed a spotty mastery of the facts. In two misconceptions, in particular, subjects elevated chlorofluorocarbons (CFCs) to a larger role than energy use in inducing climate change and missed the key role of carbon dioxide, emphasizing ozone depletion instead (Bostrom et al. 1994; Read et al. 1994).

However, it is one thing to acknowledge a gap in access to current knowledge and another to claim that nonscientists are prone to irrationality. By observing interactions between scientists and nonscientists and reviewing the transcripts of those interactions, we note that the public's questions of scientists are neither unstructured nor irrational (Schell-Word et al. 1999). These observations suggest that nonscientists concerns can surely be anticipated. Table 3.1 compares scientists' and nonscientists' common questions for a number of the most common topics that have arisen in transcribed meetings, e.g., definitions of technical terms, significance of technical developments, degrees of risk, potential applications, and costs. The table presents a heuristic for anticipating areas of concern in scientist/nonscientist interactions. Both scientists and nonscientists may ask or address any type of question in the table, seeking facts, values, policies, or predictions. However, we note a tendency for scientists to initiate and prefer to respond to statements of fact and, to a lesser extent, to predictions, and for nonscientists to ask for facts and predictions and to make statements about values and policies.

Table 3.1. Common Questions by Question Type and Frequently Raised Topics

Topics of Interest	Fact Questions	Value Questions	Policy Questions (includes implementative, procedural, and positional questions)	Prediction Questions
Definitions/ categories	What is it (definition)? What are the data, methods, instrumentation?	How significant is it? Are evidence/methods appropriate? Are they credible?	Should it be studied (by us)? Which data, methods should guide policy?	Will outcomes be significant (for us)?
Basis of significance	How do we interpret the data? What is most significant at present?	How trustworthy are our interpretations?	Should we prefer one interpretation over others? Are multiple valid interpretations possible (equifinality)?	How likely is it that interpretation of the data will change?
Risk	Are there dangers? Is there past evidence of danger?	How serious are the risks? Are benefits greater than risks?	Should we pursue further research/ development activities? Who determines that?	Will dangers prove to be too great? Who will be at risk?
Possible future developments	Are you looking toward the future of this program?	Is it more or less useful over time? Are the changes fearful?	How should we respond to or anticipate changes over time?	What sort of developments might we expect?
Current level of knowledge	How much do we know? What don't we know?	Will more knowledge lead to useful developments? Will it lead to bad/harmful developments?	Should we pursue future research in this area?	Which future benefits could come out of more knowledge in this area?
Knowledge acquisition	What areas of future research are needed?	What are the most important (most promising) areas?	Where should we focus our efforts (goals)?	Could the goals be achieved?
Comparison with current knowledge	Is it like anything that we are familiar with?	Is it an improvement on (better than or worse than) familiar things?	Should the new replace the old? How could the replacement be implemented?	Will this make past knowledge wrong?
Costs	How much does it cost?	Are the costs reasonable and acceptable? Is it taking resources away from a higher priority?	Should we fund it? If so, at what levels?	Will future benefits outweigh future costs? Could costs escalate?

Nonscientists and the Science Classroom Paradigm

For most people, the first and most prominent examples of interactions about science come from science classrooms. It is useful to remember that expectations derived from teacher-student classroom interactions may lie at the basis of scientist-nonscientist interactions about public issues. Such interactions most often have followed a pattern that has been called the "triadic dialogue": teacher question – student answer – teacher evaluation (cf. Mehan 1979). Of course, there are multiple variations on this pattern (e.g., student question – teacher answer – student evaluation), and also transitions that allow for a chain of questions and blocks of monologue that prepare for a question or elaborate on an answer. The features of the triadic dialogue tend to exclude many of the features of dialogue in other kinds of relationships, such as is common in conversations among friends, family, or co-workers. Although a wide range of behaviors has been called "dialogues," the triadic dialogue model is restrained in what is allowed to both experts (the teacher) and nonexperts (the students). In particular, the classroom model of scientist-nonscientist interactions is marked by constraints on acceptable interactions, the nature of acceptable evidence, and the choice of terminology considered credible and appropriate. All these features can play a role in scientists' interactions with the public.

3.1.1 Framing of Acceptable Interactions

The first word and the last are both taken by the expert, which allows the expert to frame the discussion. The nonexpert can occasionally initiate questions that drive the dialogue, but the nature of a proper question is still controlled by the expert. For instance, the teacher can choose among student questions or modify a question to most closely conform to the answer that he or she wants. The approved questions might match the lesson's aims or encourage particular types of questions rather than other types (cf. Lemke 1990, p. 102). Teachers, like many experts, have larger purposes (e.g., lesson objectives) that drive which answers are more acceptable and encouraged than others. Good students tend to cooperate with the objectives and learn to tailor questions to match those that teachers ask or might ask.

3.1.2 Nature of Evidence

There are other features of traditional interaction patterns in science classrooms that help form expectations for later interactions. The triadic dialogue pattern tends to create the expectation of one right answer to a question, indeed, for both the right question and the right answer. In its simplest version, the triadic dialogue omits an essential portion of the scientific method: evidence. In some classrooms, it could be easy even for good students to miss the fact that science is a reasoned activity, involving more or less plausible explanations. The nature of evidence in science, however, is no less complicated than in law or history. It has been observed that the role of instrumentation in data-gathering is often cloudy in classroom interactions, with teachers deferring to general "observation" as the primary form of evidence-gathering. Thus, scientific knowledge may be drawn from unknown data or methods but would not violate sensory observation. However, scientists are often confronted with supra-sensory information, with explanations abstracted from the data involving methods that do not involve direct observation, or with data obtained by highly complex instruments. So, sensory observations may not be sufficient for understanding scientific observations.

When nonscientists evaluate scientific explanations, they may lack the more arcane information about methods of inference and methods of data-gathering; however, the information that is accessible to them is that of personal observation and experience. To nonscientists, the inability to reduce scientific explanations to observable, experiential data (common sense) may be troubling. In contentious public issues, observable (sensory) data seem to become even more important to the nonscientist public. People tend to weigh abstract probabilities, for instance, against experiential evidence to determine a degree of credibility to scientists' claims.

From science classrooms, nonscientist adults might also gain an uneasy balance between common sense and science's often uncommon sense. "Science teaching," the science educator J. Lemke wrote several years ago, "creates a radical disjunction between science and common sense, routinely sets aside students' own associations, arguments, and even observations. It routinely alienates students from science, undermines their self-confidence, and proclaims a special and superior truth to be taken on trust, or on authority." (Lemke 1990, p. 148) Because the "special truth" of science may appear to contradict common sense, experiential evidence, and prudence, it should not be surprising that nonscientists exhibit skepticism about conclusions that seem to contradict observed data. Asking for public trust in such circumstances may seem somewhat irrational to nonscientists.

3.1.3 Choice of Credible Language

The triadic dialogue pattern tends to discourage language that diverges from the expected. Certainly, every profession or field has a specialized vocabulary, and education is expected to socialize aspiring practitioners to that language. For adults today, the language used in science classrooms exhibited features that removed science-talk from common speech. There was little use of metaphor or humor, both teachers and students avoided personification or human attributes for nonhuman processes, and there were few narrative accounts used for description or explanation (Lemke 1990). In recent years scientific language appears to have been assimilated somewhat more into colloquial speech: for instance, there is the use of animations on instructional videos, television shows such as "Bill Nye the Science Guy," the spread of medical information on the internet, and the increasing use of almost-recognizable technology in science fiction and thrillers. However, serious science students are still expected not just to understand but to use more "accurate" and scientifically sophisticated language. Indeed, students have been observed correcting teachers in the classroom when they stray too far into colloquial territory (Lemke 1990, p. 132).

Thus, the language of "real" science still is separated from colloquial speech. Because "real" science is difficult to understand the underlying view seems to be that its language should be, too. By a process known to linguists as relational reference to underlying states of existence (cf. M. Halliday 1985), scientific language is taken to be difficult because the truths of science are arcane and difficult to approach; only specialized language can refer adequately to the arcane truths; and only those who know the language know the truths. Thus, the language itself comes to be taken as "objective," i.e., more closely coupled than common language to objects. The language divisions can contribute to a sense of the public's alienation from science – particularly to nonscientists' feelings of inadequacy because of their inability to understand "real" science and to the sense that science is someone else's job (Michael 1996, pp. 115-119). “The norms of science language veto most of the techniques that all good communicators know are necessary for engaging the interest of an audience, helping them to identify with a point of view, and getting a point across to them effectively” (Lemke 1990, p. 134).

4.0 Focusing

This section provides guidance about preparing for interactions (Section 4.1), meeting (Section 4.2), and following up on (Section 4.3) meetings with community members. Often, the task of scientists who talk science with nonscientists is to remove the barriers placed there by long-held expectations. Those barriers include the legacy of the triadic pattern, such as the frustration of having experts frame the questions to be considered, the fact that relevant evidence is largely the possession of the experts, and the problem of an enfranchised language about which scientists may seem proprietary. The barriers also include the fruits of these expectations, such as distrust. The selective use of techniques that violate such expectations may be the most powerful communication tool for scientists (Peters et al. 1997).

"Selective" violation of expectations is key. Confronted with a Bill Nye clone when they want to discuss the dangers of fumes in school buildings, nonscientists may well react negatively. The public, like many students, want professionals to look and act the role. Listeners have long been known to give credibility to an individual speaker if the speaker demonstrates mastery of the subject. Mastery is demonstrated not just in the use of facts but also in exhibiting confidence in explaining underlying concepts and in anticipating misconceptions and objections (cf. Aristotle 1991, p. 120). In dialogue, demonstration of mastery includes being able to answer questions, adapt highly technical information to questioners, and connect the issue at hand with other issues that would be familiar to others. Credibility demands not only that scientists be able to talk like scientists but that they show confidence in their knowledge by anticipating others' likely misconceptions.

So, when should scientists be willing to violate expectations in meeting the public and when is acting-the-scientist appropriate? The target seems to be that scientists must establish credibility and remain open to a give-and-take conversation. The following sections provide some guidance that may help prepare for meeting the public without erecting unnecessary barriers.

Preparation

Preparation for meeting the public should focus on establishing a climate of trust and providing ready answers to frequent questions. This section discusses strategies drawn from experiences of NABIR scientists. Section 4.1.1 presents long-term strategies for creating trust prior to and during NABIR's involvement in a community. In the medium term, the tools for preparation include a list of topics about NABIR frequently brought up by nonscientists (Section 4.1.2). For scientists about to meet the public, Section 4.1.3 presents a short list of "talking points."

4.1.1 Contexts of Trust

NABIR scientists have had valuable experience in interacting successfully with nonscientists, in communities where DOE sites are contaminated and sites where fieldwork is taking place. Scientists who have had these opportunities return to two constant themes in describing how credibility was established and maintained: the importance of regular communication and of voluntarily exceeding minimum requirements and expectations.

Regular communication allows the project staff to get to know community members and to regularly sample their interests and concerns, which will probably exhibit more variety than is apparent at first glance. This means identifying a handful of communication needs that every project staff member should be able to handle, such as a concise description of the project's goals and progress. Everyone should have the same brief description of the project and its goals and methods. Regular communication also means *scheduling* opportunities to communicate, when scientists can describe the project and its progress and the community can bring questions and comments. The public appreciates science programs reaching beyond the "public meeting syndrome," where divisions between *us* and *them* are so easily emphasized. Regular, informal opportunities to communicate are often best for answering community members' questions or providing information for those who are simply curious. Informal or small group interactions often have the advantage of allowing scientists to see whether an explanation has been effective or convincing. A barbeque or question-and-answer booth may be as useful for spreading accurate information as a town meeting or media coverage. It has also proven useful to invite community members to see the work in progress, whether a field site or a laboratory.

For regular communication, it has proven useful to have a scientist designated as a "communicator." Normally, the designated communicator should not be a technician or public relations specialist. The credibility of the project in the public perception is at stake. The communicator should have information about the NABIR program, including parts of the program that do not directly relate to the local project such as program scope, funding, and internal policies and practices. It is important that the communicator have mastery of considerable factual information about the project and relevant background (e.g., be familiar with past research on the microbes and/or the environment being studied).

However, even a low-key, steady communication effort is successful only when participants anticipate the public's concerns. Voluntarily exceeding the public's minimum expectations whenever possible is a prudent way to prepare for questions that might otherwise be uncomfortable. The list of themes in Section 4.1 provides some areas of concern that community members have raised. Although it is certainly not possible to anticipate *every* concern or comment, it is wise to formulate answers in advance a) for those concerns that are frequently expressed and b) for those that represent real potential problems. At one field-work site, NABIR scientists made sure that they exceeded regulatory requirements for monitoring; they also developed and wrote out contingency plans. Being able to document and show community members the monitoring and contingency planning allowed curiosity rather than suspicion to prevail.

4.1.2 Regular Themes in NABIR-Talk

Certainly, a scientist who is about to meet members of the public would like to prepare adequately, but in nearly all instances there is no time to conduct a survey of the attitudes and predispositions of specific groups. Thus, a scientist must fall back on groups' probable dispositions and opinions, which can be approached by anticipating patterns of inquiry and likely concerns. Over the course of several years' interviews, small group sessions, and large group events, we have collected a body of talk about NABIR science. Because our emphasis has been on conversational science communication, our transcribed and notated data of interest have been the questions, answers, monologues, and discussions about the science and the technical and social issues accompanying the science. These sessions have yielded themes of concern to NABIR stakeholders. They are areas of concern that NABIR scientists can anticipate in future conversations with the public and the press.

However, we expect that not only the themes but a method of organization (outlined below) might be helpful when preparing for future discussions. The themes are grouped below by a pattern common to many (if not most) discussions with people largely unfamiliar with a science or technology program (Weber and Word 2001). Researchers in scientific discourse have derived similar lists from scientists' written and (to a lesser extent) spoken exchanges (Prelli 1989; Gross 1989). Our work, however, has provided evidence of patterns of concern among nonexperts who interact with NABIR scientists. As L.J. Prelli has noted in examining written interactions among scientists that "points at issue in science always concern one or more problems about existence, meaning, value, and action" (Prelli 1989, p. 147). We have found a similar division among nonscientists who have opportunities to talk to NABIR scientists. The following general areas of concern have emerged in these discussions:

***Fact-finding* –** Includes questions and statements about what-is and what-isn't, such as,

- What are you trying to do?
- What has been done before?
- What are your methods?
- Which microbes are you studying?
- How did you pick those?
- What have you found?
- Where have you done field work?
- Have you tried applications yet?
- What happened?
- Have there been failures?
- What are the basic biology and soil/water dynamics of bioorganisms interacting with metals and rads in soil?

- What have been previous uses of bioremediation, e.g., petroleum industry, and how does that relate to this program?

- How can bioremediation contain or remediate groundwater contamination? Studies show that groundwater contamination is the primary concern of stakeholders about contaminants from DOE sites. Groundwater is a cultural resource identified specifically by Native Americans.

- Proposed bioremediation work is "moving the laboratory into the ground." The question is, How do you know what's going to happen?

- Does NABIR research involve adding organisms that are not native to the soil? Does it does involve genetically engineering native organisms to perform remediation functions?

- Why not use technologies that already exist? The contamination problems at DOE sites are unique. Where else would you get americium contamination? Thus, the need for bioremediation.

- Can’t current technologies, specifically pump and treat solve the all the cleanup problems?

Defining and clarifying – Includes requests for distinctions, such as comparisons to other forms of remediation and definitions of terms, such as,

- What does NABIR stand for?

- What is biogeochemistry?

- What is the goal of the NABIR program?

- What are the scientific issues to be addressed in this research? How can they affect the general public?

- What is the meaning (in common English) of that term you just used?

Determining the place in the decision-making or development process – Includes requests for information and statements about future outcomes (predictions) and next steps in the movement toward applications, such as,

- Why don’t you move this work into field-testing sooner, rather than later?

- Commercialization of DOE technologies/applications hampered by climate of secrecy. Do not conduct research for research’s sake. Research needs to be applied. What will this buy in terms of measurable progress in cleanup?

- DOE has not been dependable in the past on following up on projects begun. DOE must commit to the project and stick with it—not start it and then stop it half-way through. NABIR research may not last long enough to generate useful results; DOE may remove financial support as it has in the past from other worthwhile programs.

Assaying – Includes requests and judgments about expediency, usefulness, cost-benefits, and acceptable outcomes, such as,

- Is bioremediation cost-effective compared to other technologies?

- How can these findings be used in possible applications outside the DOE complex?

- How are the results of bioremediation processes being monitored? Are there contingencies developed?

- What is the impact on the use of natural resources around contaminated sites? —Native Americans are particularly interested in bioremediation's potential to enhance or detract from the ability to use natural resources on ceded lands that are currently contaminated. Permanently immobilizing contaminants in place is not remediation and may not be acceptable.

- How will this science advance the cleanup of DOE sites? - The public wants accountability measures (Are you spending government dollars wisely?).

4.1.3 Talking Points

Talking points are the "generic" information that speakers have at their command, regardless of the audience. There are two primary sources of talking points for NABIR scientists: the NABIR website description of NABIR and its goals and the scientist-created descriptions of particular projects. We have noted five areas of concern about which scientists should think through their responses and strategies in advance:

- Be able to talk about how you have exceeded the minimum requirements and expectations – A corollary to this question is the question of what happens when there are unwanted or unexpected results. According to one NABIR scientist, establishing trust involves "following through on the process of saying, 'we will meet these requirements,' meetings them, and then staying in communication with the community." The process involves exceeding the minimum requirements voluntarily. Nonscientists may find plans, reports, and documentation reassuring in general, but monitoring and contingency plans appear to be more important.

- When possible, make connections between the project work and benefits to the community (either present or future) – Has there been any transfer from lab to applications in your NABIR project or others? Community members often ask, "Why isn't this being applied? Why keep it in the lab?" If this talking point cannot be addressed directly, cite the value of prudence in proceeding, note that unexpected results are often useful in learning, and concentrate on reported NABIR findings as "progress" in the study of microbial interactions in environments contaminated by metals and radionuclides. There is a need to demonstrate effectiveness before applications can be attempted on a wide scale. "Scaling-up" for NABIR involves putting a well-known procedure into unknown territory.

- Decide on your approach to the following two concerns: a) pathogenicity of microbes and b) release of antibiotic-resistant strains into the environment. Both of these concerns have been expressed by nonscientists and can be correlated with verifiable concerns rather than being only fear-based. Do these concerns affect the microbes in your study? Be able to cite previous studies to answer questions about pathogenicity and resistance.

- Acknowledge that issues for scientists may not always be the same as for nonscientist community members – Nonscientists often request predictions from scientists that are not possible given the current information. Concede the limitations of your knowledge: "I wish I could answer that question. I wish we had all the information we need to be that far along." Follow up with a focus on how far the knowledge has taken us. Remember that scientists (as scientists) address public issues by doing science.

- Address issues of mistrust with good preparation and a balanced perspective – a) Talk about what has been done to monitor and control outcomes. b) Talk about both the strengths and weaknesses of microbes as remediators. c) Establish your credibility by knowing your information and by offering to follow up with information when you do not know. d) Be familiar with programmatic goals, but concentrate on talking more about interesting scientific work and findings than about the program. Scientists have more of the public's trust than does DOE.

In the Event

Scientists differ in their communication training and skills as much as any group. For some scientists, public involvement is an uncomfortable experience; for others, it is exhilarating. It is a common experience that our speaking skills seem to be reinforcing to the extent that they are well-learned and debilitating to the extent that they are not well-learned (Zajonc 1960). The following sections discuss issues that a scientist should be aware of even though they may be otherwise hard to "prepare" for. Both observation of and testimony after scientist-nonscientist interactions have shown us a) how large a role "common sense" or familiar information plays for nonscientists, b) how new information can be introduced and built upon by framing and structuring an explanation or answer, and c) how important it is to have an easily remembered tool, such as the Listen-Acknowledge-Feedback (LAF) tool, to keep interactions as conversational as possible.

4.1.4 Parallel Spaces, Parallel Words

Scientists who are successful in correcting common misconceptions appear to create parallel streams of talk, with the "common-sensical" view on one side and, by contrast, the scientific view on the other. They acknowledge the common-sense view and also acknowledged why it seems right. For example, the topic of moving microbial remediation into technology-phase was common in early discussions of

NABIR. The public often wanted the work moved into field sites sooner rather than scientists thought prudent. Effective responses to this concern acknowledged the pressure toward application but described two contrasting environments: the more easily characterized environment in the laboratory, where multiple influences can be eliminated or observed, and the complex environments of field sites. It helps to use gestures and verbal stress to emphasize two very different environments.

Although this seems to be a simple, maybe even simplistic, recommendation, the difference between successful and unimpressive interactions seems to turn on the *acknowledgement of the nonscientist's viewpoint* and *the familiar point of view's integration into or contrast with the new information*. How one accomplishes that integration or contrast is through framing information. In responding to concerns about moving research into field sites sooner, an effective frame puts both the old and the new information under a single umbrella-concept, such as the idea of a "trade-off" – that the lab often makes relationships clearer (because there are fewer variables) but field work probably better captures variations encountered in applications. Another possible frame may be provided by characterizing both old and new information under a problem-solution umbrella: We need both lab and field approaches in some combination to solve the problem of lack of knowledge.

One thing that keeps scientists interested in talking to the public about science is that discussion spaces are rarely entirely "old" or entirely "new." Nonscientists are often partially informed about some aspects of current developments in science or will form mental models based on analogous information (Markman and Gentner 1993). Our transcripts suggest that the problem-solution frame is valuable because it can correct public misconceptions of the scientific issues. However, other simple umbrella-concepts that are familiar to the public are also useful.

In pointing out similarities rather than contrasts, analogies are another way to create parallel thinking. The formal way of expressing an analogy ("A is to B as C is to D") reveals the parallel form. Analogies are useful in translating hard-to-explain complex information in colloquial terms because they naturally contain both old and new information. One side of the parallel presentation should be generally familiar while the other side is new information. The comparison is general, not detailed, and usually turns on one pertinent feature of each side of the parallelism:

> Microbes don't exactly "eat" contaminants. Instead, they interact chemically with metals and rads through an oxidation-reduction reaction, the same sort of reaction that gives us rust on metal.

The best analogies are pointed a particular feature or set of features. Samuel Johnson characterized analogy as a three-legged dog, that can run but only so far – a characterization that is in itself an excellent example of the limited range of analogies.

4.1.5 Repetition and Variation

Because several themes are often being discussed concurrently in various stages of development, a premium is placed on the means of introducing coherence. Coherence in conversation is provided by repetition and variation: returning to a key topic or two, repeating essential terms or bits of information, and paraphrasing a question or statement to make connections to earlier topics. Commonly, experts expect a point-counterpoint form of give-and-take with colleagues and avoid returning to topics already discussed unless there is an entirely new interpretation to consider. The overall structure of a successful expert-expert interaction tends to be more vector-like, with directed themes. However, in conversation with nonexperts, the mode is themes-and-variations.

Both effective teaching and expert-nonexpert dialogue seem to include some version of theme-and-variation. Both word choice and grammatical structure are normally varied in conversations and this expectation carries forward into informal exchanges, as well.

Nonscientists also engage in repetition and variation, particularly when they have not received clear or satisfying information. An issue or question that is not adequately answered often returns at a different, more suitable moment later (cf. Schell-Word et al. 1999).

Nonscientists may repeat their question or comment verbatim, but they are just as likely to paraphrase. "How do you know that putting these microbes in the ground is safe?" can become "What will you do to monitor what's happening?" and "Will monitoring help you tell if the microbes are doing the right things?" This behavior indicates that, for most nonscientist participants, the conceptual content is more important than semantics. That is, meaning can be created through a variety of word patterns.

Limiting ourselves to one version of an explanation may increase our chances of being misunderstood. The dangers are apparent in media sound-bytes. Repetitions allow one version to correct another in the mind of the nonexpert, with the result being a mean or median of explanations. However, for variations to be meaningful, they must be helpful to nonscientists.

Long experience has pointed out some pitfalls in word choice, including the overlap between scientific and colloquial language. Jardine and Hrudey (1997) point out the possible confusions in a garden variety of common words that the public may not know are actually being used as scientific terms. They cite *risk*, *probability*, and *conservative assumptions*. There are also vital distinction that nonscientists probably will not share: *safety versus zero risk*, *significant versus nonsignificant*, *negative versus positive results*, *population versus individual risk*, *relative versus absolute risk*, and *association versus causation*. Our work has yielded another commonly misunderstood term: *complexity* (Schell-Word et al. 1999).

The solution to this sort of problem lies, it seems, in making your own list of confusing and ambiguous words and then taking pains to avoid using them – or, if you must use them, define them not only by word but also by example. It is also important to remember that terms are verbal short-cuts that allow us to refer to a complex of things, ideas, and relationships. Although a scientist may be thinking of a particular subsurface environment when she says *complexity*, the word is an abstraction. The further away one gets from familiarity with her background reference, the more abstract her use of the term seems to others. Arguably, though, her use of *complexity* is one that nonscientists could benefit from understanding, particularly in distinguishing it from "complicated." If you anticipate using the term later in the discussion, a good habit may be to define it in colloquial language, using a visual analogy or example. Because complexity is a valuable concept in answering queries about lab versus field work, a brief, colloquial description of subsurface factors can accompany the term itself:

> From a microbe's point of view, a lot of stuff is happening in soil. The subsurface can have many kinds of minerals, organic materials, and microbes, combining in many different forms and forming many pathways of chemical interactions, all at different rates and with a wide variety of different outcomes. Sometimes pathways go along and combine with other pathways, leaving excess chemical energy that changes some other pathways. Of course, microbes are a part of this process, getting the nutrients out of it that they need. As scientists, we use the word "complexity" to describe this tangle of interacting pathways, and their combinations and recombinations. Now, we can understand the complexity of an environment, but it takes some careful observations and tests and some time. But it's important that we do this in order to understand how some of these microbes interact with heavy metals and radioactive substances down there if we want to intervene intelligently.

Certainly, scientists should not expect nonscientists to leave with a new vocabulary, but scientists can aim at introducing a *range* of ideas that accurately describe a situation scientifically. To achieve this sort of understanding, nonscientists need a rudimentary grasp of the issues from a scientific point of view, provided through their recognition of common-sense (old-information) expectations and of new information that include umbrella-concepts, indispensable terms, and memorable examples.

4.1.6 Manage Your Responses—Listening, Acknowledgement, and Feedback (LAF)

Spontaneity is one of the best and most creative features in meetings between scientists and nonscientists. It is possible, we believe, to over-strategize and fall into a kind of verbal and physical paralysis that prevents free and mutually helpful interactions. In observing and training scientists, we have identified three sets of communication competencies that can contribute to a more conversational tone to interactions: listening, acknowledgment, and feedback (LAF):

- Listening (includes questioning) – Much has been written about the importance of listening, but listening remains too often untried as a communication technique. Listening is both a skill and a discrete experience. Like swimming or playing tennis, it can be improved but first it must be felt. We must listen for more than what we want to hear. People generally try to acknowledge only those topics they are prepared to talk about. But in public discussions, other topics raised by the participants must also be acknowledged if the discussion is to remain fruitful. Do not assume that you and others share the same expectation for the outcomes. Discover their thinking. Delay judgment.

- *Acknowledgment and perception-checking* - When being acknowledged for a contribution, we like to know that someone has understood our point of view. It may help to restate the content of what others say. This may mean reframing negative comments in positive forms.

- *Feedback* - Feedback may include a variety of responses, not all of which are verbal: responding with a new idea, responding with a similar, supporting idea, nodding, or writing a note to follow up on information that is not ready at hand. Follow up with your own content to keep the conversation rolling.

Follow-up

Follow-up is an essential part of any formal (i.e., planned, structured, and scheduled) communication event. It can provide multiple benefits, including answering additional questions, clarifying uncertainty, and providing opportunities for continuing education. Most importantly, however, it helps demonstrate commitment and, hence, builds trust among scientists and nonscientists. For the same reasons, follow-up may also be very important in informal settings, such as at a restaurant where you happen to be talking about your research.

We have identified five major opportunities for helping ensure successful follow-up:

- *Try to provide participants with additional information, or sources of information at the end of the event.* For example, this information may consist of lists of books and other written material, website addresses, or even points of contact within your research project or program. References to materials prepared by other credible sources outside your project and program are especially important because they can help provide corroborating information related to what you discussed, as well as providing other relevant points of view.

- *Be sure to thank all the participants, personally if possible, before they leave.* They invested their time in talking with you about your work, and that commitment needs to be acknowledged.

- *Follow up on any unanswered questions and unresolved issues.* During the event, there will likely be questions that cannot be answered well, or maybe answered at all, with any degree of certainty. There may also be issues that cannot be addressed given the participants who are present, but that could be addressed with a little research after the event. Be sure to capture these during the event, along with the names of those who are interested in the topic, so that you can open a dialogue (e.g., by mail, email, phone call, etc.) and answer the question or discuss the issue. Then follow through and make the contact after you have the needed information in hand.

- *Let participants know how they may contact you, and be open to calls and questions after the event.* Many fruitful contacts and discussions have ensued as a result of being open to further discussions after an event has passed. Do not be surprised if you are asked to participate in other discussions about your research and related topics in different venues. Continued engagement will demonstrate commitment and help build trust and understanding.

Elicit a list of participants who are interested in receiving further information, and send them relevant information as appropriate. Periodic, regular communication (e.g., short information or news items via mail and/or email) is another tool for building understanding and trust. The communication need not be very frequent to be effective. You may find that a note sent quarterly or even semi-annually is sufficient.

5.0 Postscript

As you gain experience talking with nonscientists about your work, you will find that there are probably no perfectly "right ways" to communicate with them, nor perfectly "wrong ways," either. There are simply better ways and poorer ways of communicating, all of which are context-dependent. We encourage you to reflect at the conclusion of each engagement on what went well and what could have gone better and try to understand the outcomes, to learn from the successful as well as the less successful and incorporate the learning into your next opportunity.

Please send comments and questions on this primer to:

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Appendix A

At the “Organism” Level—Multiple Perspectives

Appendix A

At the “Organism” Level—Multiple Perspectives

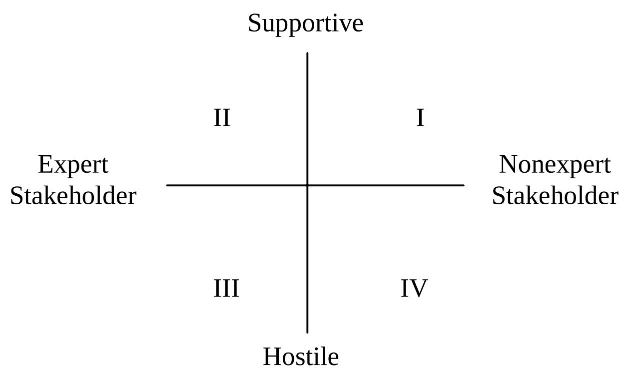
As an expert, you are one element in the meeting ecology. However, when you see an ecosystem, the other participants (the “organisms”) probably see only their share of the ecosystem, that is, they have their own frames of reference. Often, the most significant challenge for a scientist may be not in the conveyance of information, but in establishing working relationships with other meeting participants. This challenge is heightened when it is necessary to respond to meeting participants who have different levels of scientific expertise, who are distrustful, or who raise issues based on emotional self-interest. The primary conclusion to be drawn here is that *how* you talk about science and substantive issues and *what* you say depends on *whom* you are talking with, the backgrounds and experiences they bring, and their goals for the engagement.

During the process, different people will want to talk about different things. Individuals participate in communication events for different reasons. Each event has its own context, participant interests, representation and outcomes. At the same time, we know from our research and the literature that the *process of information exchange*, that is, how and what information is communicated, influences public perceptions of science. When the public is scientifically naive, disinterested, or hostile, the challenges to communicating science seem immense. It hardly seems worth the effort of getting involved when the participants resist the process of creating a common frame of reference for discussion or collaboration. This is evident at public events where it is clear that many participants come only to advocate their particular (sometimes narrow) interests or views. Acquiring information, while important, is not participants’ only—or perhaps not even their primary—concern.

The Science Challenge Interaction Model (SCIM) demonstrates the challenges faced in conveying information or offering viewpoints to groups. It also illustrates how facilitation may help reveal perspectives and achieve understanding. In general, people participate constructively when they feel that their ideas and concerns are taken seriously. This is true for all participants in the process – scientists and community members. However, the challenges that people face to be heard and understood differ depending on their frame of reference. In the ideal group event, everyone can make important contributions in their own way. The challenge is how to set the stage for dialogue and then communicate in a way that enables productive interaction given all of the different frames of reference that are present. The SCIM model provides insight into the collective interactions of the scientist and/or presenter and the community member. The interactions among self-interests and limited perspectives, the interactions common in an ecosystem, are reflected in the LAFF model as features of the science communication process.

We often blame conflict or hostility on another person's ill will, political or personal, or even bad intentions. We fail to realize that we may have done the same thing if we were in the other's shoes. Why? We interpret events differently for ourselves than we do for them. Our behaviors seem to us be defensive responses to the other. We may even see other persons engaging in unprovoked acts of aggression. What happens if we see the behavior of the other as a response to our own actions?

From the point of view of the scientist, others are seen as:



As a scientist, you are expected to provide objective information. Unfortunately, chances are that the public engagement event will have emotional undertones. In addition, the sophistication of the *public* participants will influence the scientific content of the discussion. These dynamics will affect the communication process and your ability to provide useful substantive information.

Our interviews and focus groups results suggest (but we should generalize cautiously) that the greater the technical sophistication of the participants, the more the discussion can focus on scientific content. The lesser their sophistication, the greater the need for the scientist to adapt scientific information to the communication environment. In addition, from the literature we know that hostility or high degrees of emotion affect a presenter's ability to respond to information

Understanding Scientists' Perspective

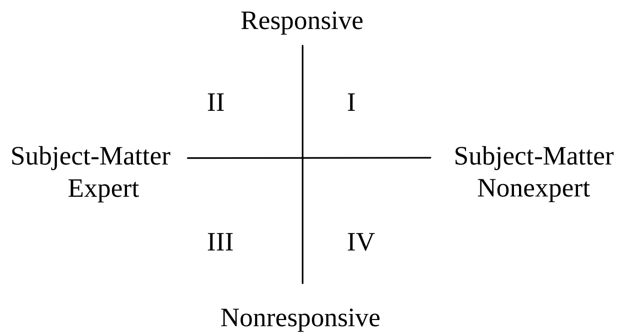
Quadrant I: If you have a nonexpert group that seems to be supportive, your challenge is to build a feeling of safety and invite participation. Focus on listening, questioning, and establishing common ground. Create a positive environment for discussion of substantive issues. Explore the issues together in terms they can understand.

Quadrant II: If you have an expert group that expresses a lot of support, your challenge is to organize and channel their energy toward a positive result. Focus on listening and feedback response options. Your scientific expertise adds substantive foundation to the discussion.

Quadrant III: If you have an expert group that expresses a lot of disagreement, your challenge is to control the process and help build credibility and trust. Focus on listening and acknowledging. Your scientific expertise is essential. When dealing with an informed hostile group, objective information is essential to establish credibility. It is during emotional events that your knowledge is the most necessary. However, it must be provided while acknowledging the frames of reference of the other participants.

Quadrant IV: If you have a nonexpert group that seems to be hostile, your challenge is to develop credibility. Focus on listening and acknowledging. Identify goals, interests, values, and needs. Restate comments in constructive ways.

From the point of view of other meeting participants, the NABIR team can look like this:



People are empowered to contribute constructively when their ideas and concerns are taken seriously. Our focus groups and interviews indicate that stakeholders want something more from the communication process than a series of facts. They have questions that they want answered. They want to be listened to and they want their contributions understood. Members of the public generally do not want to be passive receivers of information, but to be included in a communication dialogue in real and significant ways.

This model reflects meeting participants' views of the engagement process. Public engagement processes often include both subject-matter experts (typically, scientists and engineers) and nonexperts (typically, facilitators who are not scientifically or technically trained). The responsiveness axis (responsive to nonresponsive) reflects a participant's perception of the communication team's receptiveness to their ideas and concerns.

Understanding Participants' Perspective of Members of the NABIR Team

Quadrant I: Responsive Nonexpert—This may be a nonscientist staff member or facilitator, who is nonetheless interested in other participants' concerns and adept at linking scientists' concerns with those of other participants. Regardless of the affiliation of the responsive nonexpert, he or she can be invaluable in establishing rapport with nonexpert participants because they share questions and concerns.

Quadrant II: Responsive Expert—The scientist-participants are perceived by other participants as interested in their concerns and still able to answer a wide range of scientific and technical questions. They are willing to restate questions, “translate” discipline-specific concepts or terms, and listen to participants’ restatements and translations.

Quadrant III: Nonresponsive Expert—The scientist-experts are perceived as knowledgeable about the scientific matters and probably well prepared. However, participants note an “expert witness” attitude, removed from the concerns of other participants in the meeting or unwilling to answer questions. A false responsiveness may actually be perceived as nonresponsive, as well—as when participants suspect an expert of waffling or turning uncomfortable questions aside.

Quadrant IV: Nonresponsive Nonexpert—Participants note that the team member may not be a scientist or a layperson who is informed about bioremediation, the site being discussed, or current concerns of the community. This participant may be present to answer programmatic or legal questions only. To other participants, the nonresponsive nonexpert may convey a tone of bureaucratic judgment or of disapproval of questions that seem too simple.