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Guidelines—A Primer for Communicating Effectively with NABIR Stakeholders

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Foreword

This version of the Natural and Accelerated Bioremediation Research (NABIR) communication primer has been almost entirely rewritten in response to reader comments, research that is new (or new to us), and our own analysis of interactions between scientists and the public. We attempt to synthesize here the most relevant parts of what is known about sharing fundamental scientific research with non-scientists with the intent of helping scientists in their own communication efforts. Here, you will find information drawn from diverse sources, primarily from published literature 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 non-scientists 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 non-scientists. 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.

This version of the communication primer comprises two interlocking parts: Part 1, a practical section, intended to prepare you for public interactions, and Part 2, a theoretical section that provides social and technical bases for the practices recommended in Part 1. The mutual support of practice and theory is very familiar in science and clearly requires a willingness to observe and revise our prior assumptions - in this document, we invoke both. We hope that this offering will represent a step both towards improving practice and maturing the theory of practical science communication.

Summary

The purpose of this report is to help scientists communicate with stakeholders and the public (primarily non-scientists) 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. Then, a practical section provides guidance to prepare for and learn from face-to-face interactions. It covers the expectations, sound and unsound, that most of us have for communication and provides a seven-part system (CLARITY) for on-the-spot interactions. It also contains talking points for NABIR scientists, which are issues and questions that have been shown to be of interest to stakeholders. The last section, Theory, then provides a research grounding for the practical guidance. 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. Four current models that influence science communication are described (transmission, diffusion, social ecology, and dialogue) and a table shows how current science communication practices have been derived from these models. Finally, what research tells us about informal science communication is discussed: public understanding, media influence, trust, mechanics of interactions, and people's strategies for making sense of expert interactions.

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Introduction

The purpose of this primer[(a)] is to help scientists communicate with non-scientists 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 (DOE). 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 non-scientists 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.

That said, we have tried to provide useful practical guidance while still avoiding too much prescription. Although it would make giving advice easier, prescriptions breeze past the many variables, some critical and others not, encountered when scientists talk with non-scientists about their work. Instead, our approach is to introduce scientists, managers, regulators, and policy-makers to what they can

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expect from scientist/non-scientist interactions, and to recommend fruitful ways to prepare for such interactions, and to provide sufficient theoretical background to stimulate interest and give meaning to public communication efforts. 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 are so easily raised when expert meets non-expert. 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 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.

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

I.1 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 dialog 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. Communication between scientists and non-scientists fills a variety of needs, such as raising national awareness about the implications of environmental insults, testifying about scientific data in criminal trials, and defending government funding for scientific programs.

Unfortunately, consistently successful communication among scientists and non-scientists remains elusive. Some efforts, such as 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 arise 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.

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 non-scientist 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 non-scientists 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 misunderstandings 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 non-scientists 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 non-scientists, to interpret information and place it appropriately into contexts that include health, the environment, and society's well-being.

I.2 Who are 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.

I.3 Why Should We Talk with NABIR Stakeholders?

Our experience 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.
- 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" (Paisley 1998, p. 79).

Part 1 – Practice

The Communicating Scientist

These days, there is much written and said about scientific information in the public arena. People complain about information-overload but still want information that they can understand. In the current context of multiple political and social interests, differing abilities to understand scientific content, and very real social implications for science and its applications, how can a scientist prepare to have satisfying interactions with the public? It is our belief that some scientists should interact with the public directly.

This section seeks to provide guidance for scientists who interact directly with the public, the great majority of whom will be non-scientists. By "direct" interaction, we mean talk and interact for the purpose of sharing information about science, technology, their applications, and our ways of life that are affected by them. We do not focus here on interactions via the media (as in television or radio interviews or press releases) although what is said here may well have implications for those contexts. Instead, we concentrate on three areas that we have found to be most problematic – and interesting – when scientists communicate with the public: (a) what not to expect from communicating, (b) what to aim for in building satisfying interactions (the CLARITY approach), and (c) what topics and issues to expect to focus on (NABIR talking points).

P.1 Expectations

Like science, communication seems to generate high expectations and is expected to solve a variety of problems. Furthermore, the further away one is from actual science or communication, the higher the expectations and the less the grasp of the issues. However, like the air we breathe, it is often taken for granted, until a problem emerges. So when we to do it well, it is sometimes hard to know what to do to be more effective. Quite a number of barriers stand between us and communication competency. Some are in language itself, some in the environment, some are in others' minds, and some are in our own minds. In this section, we identify some fundamental features of communication, those features that are important in developing more effective communication. Consider this Communication 101. If this seems very familiar to you, jump to page P.13 and discover some of the things we have learned specifically about communicating science.

P.1.1 Communication Myths

There are some common views of communication that prove to be misconceptions – in fact, they are so durable and seem so common-sensical that we might call them myths. In beginning a practical discussion, it might be useful to dispel the common myths.

Myth #1: Communication is a verbal process. Research shows approximately two-thirds and in some cases over 90% of communication arrives in the unspoken variety, including movements and facial expressions, tone of voice (as opposed to words chosen), and graphics or picture communication.

Myth #2: Communication is a set of skills. Often people believe if they just could learn the skills, communication difficulties would evaporate. Not so. Communication skills help, but we largely improvise situations without scripts. As a result, things go wrong even when we are paying attention. Moreover, the skills useful in one situation or context may or may not rescue us in another. Competence is often a matter of degree, knowing when to apply which skills at what time and to what extent. For instance, one on one, a person may be articulate and open, but an impromptu invitation to address 40 people at a school board meeting may send the same person's brain disappearing into foggy wisps. *("Roger, I know you weren't on the program and don't usually do this sort of thing, but as a scientist could you spend about ten minutes telling the audience about what you've found out about bioremediation…?")* Or the person who speaks eloquently about her research at conferences may be hard pressed to explain it to her father.

Myth #3: Communication means telling.

"I told you to buy low and sell high."

"I told you to clean your room."

"I told you we were meeting at noon instead of 11:00."

"I told you we ordered those supplies last week."

To believe telling gets the job done says nothing about the active role the person on the receiving end plays in this process. It says nothing about what other people already believe about the subject, how much they trust the sender, their states of mind, emotion, or body, or where else they are getting information.

Unless the sender takes into account the receivers' interests, beliefs, and feelings, the relevant background of the current interaction, and generally what everyone involved hopes to accomplish, telling rarely results in understanding. Neither party may hear or translate the message as intended.

Often, people complain they don't have the time to take on the emotional and relational dimensions of messages. In the long run, however, if people take the time to recognize, describe, and address both content *and* emotion, the overall communication will be shorter and be more satisfying.

Myth #4: Communication is good. Most often, communication is neither good nor bad. Like a hammer or computer, it is a tool, used for better or worse, depending on the user and the circumstances. Communication as a tool often helps some people perform miracles, but in other hands, it helps conspire toward unethical or publicly dangerous actions.

Myth #5: Since communication is good, more must be better. Although experts often encourage more communication, in some cases, less rather than more would better serve our causes. In our personal as well as professional lives, separation and distance can prove more constructive—or at least less destructive—than putting people across from one another in a room, or giving them open telephone access, and letting them verbally duke it out. Professionally, adding yet another meeting to communicate when employees struggle for time to write reports, make phone calls, draft grants while documenting and publishing research may not be the best use of a day's schedule. Adhering to a "more is better" rule may break necessary concentration, fray tempers, and strain fragile relationships.

A common complaint we heard in our interviews voiced the opinion that research without application (research for the sake of research) takes too long and often ends before people outside the lab see any results from their tax dollars.

Consider the following example. This comment came after Lou, a scientist at a local federal lab, presented a lecture on bioremediation during a local library lecture. Jim is an elected official and construction engineer. Under the circumstances, what do you think is the best content-feeling/relational response?

Lou: *Well, that's about all I have. Are there any questions?*
Jim: *Yeah. I have a question. How long have you been working on this problem using a bioremediation approach?*
Lou: *Well, we've been working in the lab for about 6 years now.*
Jim: *And what have you come up with…I mean you talked all about what worked with the petroleum spill and the bugs with Exxon…and that's all very interesting, but what are you doing here?*
Lou: *We're still in a pure research phase, still looking at our options here—we know a little, but there's still a lot we don't know.*
Jim: *And how long does this grant go on…10 years, you say?*
Lou: *That's right. It's a 10-year grant.*
Jim: *And you still don't have anything out in the field—I mean you're not using anything yet on the whole groundwater, radiation thing that's going on around here…*
Lou: *The preliminary research takes a long time—*
Jim: *In 4 years that grant will be history and I can't see there's anything to show for it. Ten years of pure research without ever applying what you learn to the field sounds too damn long to me.*
Lou: **?????**

How would *you* answer Jim using both content and emotion?

Possible Answers:

a. Research shows it takes 15 years for research to show a practical outcome. (Note that this answer addresses the issue strictly as technical.)

b. What do you think is a reasonable length of time? (This response may seem reasonable; however, it asks for Jim's opinion, which sounds like a way of getting out of giving an answer. Also, whatever answer Jim could give would be irrelevant in this context.)

c. Ten years *is* a long time, especially when people worry about safety, but too little time would mean we would no doubt miss aspects, maybe important aspects, of the science. (This response would address both the task and Jim's concerns.)

d. If you thinking 10 years is too long, try living with a mistake forever! (Even as a joke, this response would sound defensive and reactive.)

Myth #6: Communication can solve all our problems.

"Oh, if we could only communicate, things would be so much better."

"What we have here (again) is a failure to communicate."

Communication is not a panacea. Common mythology holds that with communication all things are possible: If people could just sit down and talk about their problems, they could work things out. Marriages would be saved and rekindled. Sibling rivalry would disappear. Nations would settle their differences. The public would understand and support science. And peace would reign over all the world.

Highly unlikely.

Communication may cause more problems than it solves. What bliss if everyone were a competent communicator all of the time. But we are not. At times, ineffective communication escalates and is more contagious than fear.

On the other hand, people often communicate very well. Others simply do not want to hear what they have to say. Or they may hear the message and reject it. Do personal relationships break up because people know too little about each other or because they know too much?

Myth #7: Communication breaks down.

"…If we could only fix our communication..."

Communication is not a machine, but an organic, continually changing, ongoing, mutually influenced and potentially transformative human process. The interaction may be a bust and people may walk out, yell at one another, or give the silent treatment. Leave home or change jobs. People may choose to stop talking to one another. Silence often sends powerful messages.

Communication skills and outcomes can be improved through classes, practice, and commitment to not give up. As one who learns much more through my mistakes than my successes, I don't always welcome feedback and the painful reflection often following painful experience, but I do learn from it. Wouldn't it be great if regular oil changes made relationships run smoother new shocks could soften the rocky spots where rubber hits the road—or we could just blow the carbon out of our engines on the road to the coast? I do find regular maintenance helps. Unlike my car, however, the human dynamics of communicating with other humans, constantly surprises, and requires continuous commitment and humility more than tweaking the mechanical aspects of competence. Even if I decide to junk the thing.

Myth #8: To be understood, we just need to be clearer and

Myth #9: Information equals communication.

These misconceptions arise from the view that communication means transmitting information. If the signal isn't clear according to this perspective, make the signal clearer and problems will go away. I (the scientist) am the expert and I will tell you (the non-scientist) what you need to know. This approach again eliminates the receiver as an *active* participant. Audiences arrive bearing questions and answers of their own. They are the experts of their own experience. No matter how well the presenter clarifies information, if the audience's interests come from other directions, clearer information still gives the wrong answers.

Myth #10: Words have meaning.

"The map is not the territory.

The word is not the thing."
Alfred Korzybski, 1948

Michael Crichton mentions in his book *Travels* (1988) that people are sometimes surprised when they fly over the United States for the first time and do not see the lines differentiating Washington from Idaho and North Dakota from Canada. Medical students who slide scalpels through the skins of cadavers for the first time have expressed momentary surprise at not finding red arteries and blue veins coursing through the body.

In much the same way, words are simply symbols representing objects and ideas so we are able to talk and write—perhaps even think—about them. When asked to describe "a table" without a visible table for reference, for instance, individuals might describe their dining room table, end tables in a living room, tables on either side of their beds, a graph in a research paper, or the water table overflowing as a spring in a field behind a house they lived in once. "What would you call this object?" I could ask a culturally diverse group, thumping my hand on what we (in English) call a table. And individuals soon label this molecular configuration using written and verbal symbols from French, Spanish, Norwegian, Arabic, Hebrew, Thai, and Chinese.

In science, similar pitfalls apply since scientific and colloquial everyday language used by the public use the same words, but define them differently. A "garden variety" term used by the public might for a scientist have a distinct and different meaning. Consequently, the public and scientist may understand the word to mean different things. Jardine and Hrudey (1997), for example, found the words, *risk*, *probability*, and *conservative assumptions*, in this category.

Other terminology vital for scientists may have little meaning to non-scientists. Consider for example…

- Safety versus zero risk
- Significant versus non-significant
- Negative versus positive results
- Population versus individual risk
- Relative versus absolute risk
- Association versus causation.

Interestingly, NABIR communication research found that when scientists used the word *complexity*, it conjured up very different meanings than were held in the public mind. For example, a scientist may be thinking of a particular subsurface environment when she says *complexity*. When she uses the term, it often kicks in a complex mental map of images, scientific ideas, unanswered questions, relationships, and connections she sees, senses, and has "filed" under this term. A non-scientist, on the other hand, may simply mean "complicated" in a general way.

Knowing such confusion might occur, experts often develop the habits of defining terms in colloquial language and of developing explanations suitable for different groups of non-experts. Developing several "scripts" for nailing down these definitions for the public—or for scientists in other fields—may also prove helpful since people's desire and attention-spans vary considerably.

K**eep it short—Two minutes maximum**
No word longer than three syllables
Describe using senses—see, hear, touch, smell, taste…

An example of how "complexity" might be explained…

From a microbe's point of view, a lot of stuff is happening in soil. The subsurface or soil below the ground level can have many kinds of minerals and organic material like leaves and dead worms and slugs—and microbes or bacteria. Mixed together, they combine and start forming pathways for chemical interactions with a lot of different outcomes like making carbon dioxide, water, ammonia, and methane gas. Of course, microbes are part of this process, feeding and getting nutrients out of it that they need.

Now…as scientists, we use the word "complexity" to describe this tangle of interacting pathways and how chemicals combine and re-combine in their own natural ways. We know the environment down there has this complexity, but to really understand what happens we need to run careful observations and tests—and these tests take some time to do and understand!

It's important that we take the time we need, because we need to understand how some of these microbes interact with heavy metals and radioactive substances down there. At some point we're going to intervene and change the existing complexity and we want to do that intelligently. We don't want to make a mistake that creates a situation worse than what is already there—just because we got in a hurry and acted too fast.

Does that make sense?

P.1.2 The Expert Biases

Often, the task of scientists who talk science with non-scientists or scientists from other disciplines is to remove the barriers placed there by long-held expectations. Those barriers include 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. Perhaps because they begin with a low estimation of the distribution of specialist knowledge among laypeople (Bromme et al. 2000), experts who discuss their fields with non-experts often display one or more biases of thought and behavior. For instance, experts generally overestimate non-experts' knowledge of difficult concepts and underestimate their grasp of easy concepts (Nickerson et al. 1987; Bromme et al. 2000). Experts who regularly interact with non-experts, however, are better at anticipating non-experts' knowledge base. Other common biases include the following:

- the quantity-of-information bias - providing too much or too little information (cf. Isaacs and Clark 1987)
- talking-down – using no technical terminology at all or paraphrasing information at too low a level for a given audience (cf. Erickson and Schulz 1982)
- false consensus bias – assuming that others share your knowledge or social beliefs (cf. Ross et al. 1997)

The selective use of techniques that violate these 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, non-scientists 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.

P.2 Establishing Relationships at the Margins: When Scientists and Citizens Meet

When two people (a dyad) expands into a group, the third changes the scale. This section discusses communication strategies useful on this larger scale. Although citizens and scientists meet socially, planned communication events often occur by convening groups.

Although scientists are sometimes criticized for being poor communicators, our research shows scientists communicating well in task and project groups. Scientists share a body of knowledge and skills, vocabulary, and investigative methods used in laboratory and field experiments. As they specialize, scientists carry this background and build on it, deepening expertise and knowledge in their chosen fields—biology, chemistry, geology, etc. This depth increases again as breadth narrows with professional focus—to subsoil microbiology or groundwater hydrology, for instance. Task and project approaches to communication continue in much the same way as groups work together within these disciplines.

Groups form the backbone for projects, policy formation, and complex tasks. Although creativity is hard to force, on the broad scale, more innovative ideas and solutions surface when people can gather and talk informally in hallways, doorways, on the internet, and hunched over coffee or beer. As long as groups maintain a workable size and trust one another, stretching boundaries and diversifying the group (culture, expertise, skills, knowledge, gender and personal style, for instance) can create a climate where ideas flourish. In science, some resources can be shared, although the competitive nature of funding access and research results can limit information people bring to the table.

Potentially, groups also create more conflict and may take more time.

In many group situations outside the scientific community, the decision-making and planning skills developed through years of classroom, lab and field projects, cross over well. Scientists find their abilities transfer well into planning, forecasting results and consequences, and applying systematic steps to implement and analyze results.

Some critical decisions, however, are impromptu, occurring without obvious warning—yet requiring quick and decisive action. No one (not even scientists) can plan for every situation or context. Logic and pure information alone go only so far when a parent confronts the school board suggesting that the computers donated by DOE were a “pay-off” to keep the public appeased when the Department of Energy has nothing to show after three years and 10 million dollars in tax money. Or the newspaper editor calls, saying she heard rumors that several wells were contaminated because scientists were carrying out experiments and injecting chemicals into the water.

From an organizational communication point of view, DOE scientists generally come to situations carrying a DOE mindset. Outside the organization, although the public generally likes individual scientists, they often view this organizational mindset not only foreign, but hostile and cold. Developing an openness to others and a willingness to share this expert role at the margins can be humbling, but also surprisingly satisfying. Scientists who live in the community may find themselves wearing both hats as DOE scientists, and as expert community and public stakeholders.

P.3 CLARITY: Lucid Interactions

CLARITY – Creating a clear and lucid perspective that reduces ambiguity. “Clarity” describes one of science’s major goals—to achieve understanding by all concerned—and provides a fitting acronym and talking point in discussing group work.

C **Cooperative Climate + Credibility**
L **Listen**
A **Ask + Anticipate**
R **Roles**
I **Information ← → Interpretation**
T **Transform through Dialogue**
Y **Yield to Process**

P.3.1 Climate Change: Building *Credibility* with Non-Scientists

Just like regional weather patterns, some group climates are also friendlier than others. In some groups, people seemed discouraged and defensive rather than supportive of one another. A competitive climate prevails where individuals vie for control and kudos. Others groups feel cooperative.

Individuals share responsibilities and complete their goals feeling satisfied with the final product and the process. Excellent group work probably doesn't "just happen." In the case of discouraged or defensive groups, allowing individuals to verbally duke it out (or "just happen") without bringing the group back to its original purpose can cost the group its focus and waste its time.

Building Cooperation + Credibility into a Competitive Climate

Consider the following:

At one site, the scientists were working right out there in the public. They had this fenced area and did a lot of digging and injecting materials into the soil as a way of testing. But they were doing it right in the middle of the community—not in a lab in a building. People could walk by and watch what they were doing.

Now the scientists were told when they went out to work, to talk to people. If somebody asked a question, answer as best they could. So people would come up and there would be these conversations about what was going on.

Awhile after this work was still going on, some people started having contamination problems with their wells. A rumor got started that the scientists were injecting stuff into the soil and it was getting down and affecting the water. Finally, someone came back to the scientists who were working their site and said, "you know, some people think you've contaminating the wells with your work."

The reason it got back to them was they'd established relationships within the community just by being there and willing to talk.

So to deal with this, the lab put on a big barbeque and picnic and invited the community to come. At the picnic, the scientists mixed with the people and then talked about their work. They said they were sure something was going on with the contaminated wells then explained what they were doing and how it had nothing to do with that problem. They acknowledged people's concern about the wells, while also explaining how it couldn't have anything to do with those wells.

But the thing that made the difference was that they acknowledged there was a problem and then explained how it couldn't be caused by their activity. But the biggest difference was that they'd built these relationships already and people got to trust them, so it made it safe for people to come and talk about the issue.

From C.S. Interview, 2003

Scientists often interact successfully with non-scientists and scientists from other fields. In this example, scientists working at the community site were so well accepted that at least some of the citizens went to and talked to them about a brewing situation. They had a choice at this point—to ignore the situation knowing they could prove if it ever went to court that they were legally in the clear. They could close the site, fearing other repercussions. They could go to the people involved and demand an explanation, although the ripple effect caused by their statements most likely had already traveled widely and was still going. Instead, they went bigger and more public—and reframed the situation in their favor.

Several interviews held with scientists who live and work in communities with contaminated DOE sites stress the importance of credibility. Being credible requires that people trust your word, actions, and (above all) motives. When credibility is being established, your role as an expert receives an opportunity to establish itself. People will ask the following questions:

How do you know what you are doing?
How can I trust your word?
Will you do what you say you will?
Will I approve of how you did it?

Scientists working successfully with non-scientists consistently give two pieces of advice for establishing and maintaining credibility:

1. **Communicate regularly.**
2. **Voluntarily exceed minimum requirements—go beyond what is expected.**

Regular communication between scientists and non-scientists allows the project staff to get to know community members and share interests and concerns. It may allow concerns to be realistic rather than generated by uninformed suspicion. Scientists entering these situations for the first time often comment how surprised they are to see more variety than they expected.

Generally, we have found the public prefers regular informal get-togethers to big “public meeting” events where scientists lecture and citizens listen. When people can mix and talk, they are more inclined to ask questions and let the scientists know whether an explanation about those micro-organisms in the subsoil was helpful or at least convincing.

Events can happen in libraries, senior citizen meals, service organizations like Rotary, Kiwanis, Lions Clubs, or League of Women Voters, and college campus gatherings, for instance. Or a lab can hold a barbeque and potluck picnic or put up a question-answer booth at the local arts festival or county fair. These occasions not only bring scientists and the public together, but may be as useful for spreading accurate information as holding a town meeting or receiving media coverage. One useful tactic might even be inviting community members to meet in the laboratory itself or out on a field site to see work in progress.

Credibility should be a high priority at gatherings. Community members should leave perceiving the project as valuable and the people working on it as knowledgeable and honest. Designating one scientist as the “communicator” or “local expert” seems to focus attention and relax both project staff and community members. Normally, the designated communicator is not a technician or public relations specialist, but someone who knows the science and can talk about it. Thus, the Communicator or Local Expert should know about the program—including program areas that do not directly relate to the local project. All project staff should be able to describe the project, its goals, and progress and memorize a common collection of short explanations. All project members should remain open to give and take conversation about the project. This means being familiar with the larger picture and ready to talk about the social as well as scientific impacts this work carries.

Tips for Meetings (Wolvin and Coakly 1996, p. 298)

- People are more likely to "show up" if they have a personal relationship with the person calling the meeting or organizing an event—even if that relationship is only name and face recognition.
- People are more likely to show up if they know they will see you again.
- Have written information on hand for people to take away with them. Or give out small gifts like pins, pencils, or small notepads with the program logo to increase name and memory recognition.

P.3.2 Listening to Understand

Most of us are lousy listeners. Listening is harder than it looks. And looks can deceive. The person who appears to be listening—eye contact, facing forward, looking expectant, with body leaning slightly forward—may actually be replaying last night's argument, putting together their shopping list, or planning what they will say when you take your next breath. Even if the person is listening, they may get it wrong or miss important sections.

Spontaneity provides one of the best and most creative features in meetings between scientists and non-scientists. In a desire to leave nothing to chance, it is possible to over-strategize. Sessions can be over-planned so that a discussion doesn't have a chance to get going, or so there are no new ways of looking at issues and problems allowed. In observing and training meeting facilitators and scientist-participants, we find that *listening* heads the list of three communication skills we found important if they were creating situations where spontaneous/straightforward conversation could occur safely:

L = Listening
A = Acknowledging
F = Feedback

Listening (including asking interested questions) – Listening is both a skill and a discrete experience. Like swimming or playing tennis, it can be improved only if the person first gets their head and heart into the game. Listening feels different than hearing and understanding the words. It must be felt. Listening requires opening our ears and minds to reaching beyond what we want to hear. People tend to acknowledge only those topics they are prepared to talk about—often feeling they otherwise have nothing to contribute.

But in public discussions, other topics raised by the participants must be embraced if the discussion is to remain fruitful. Assuming that you and others share the same expectation for the same outcomes in these situations would be a mistake. Assuming you understand what others expect would also be a mistake. Only through listening to others and asking questions with genuine interest in what the other person has to say can their thinking be discovered. And discovering their thinking is the whole purpose here. Delay judgment. Remain open and curious.

Acknowledgement and perception-checking – When acknowledging another person's contribution, let the person finish speaking then let them know you understood what they said by tentatively ("I'm not sure here…") restating the message.

- Try paraphrasing or restating what the other person said—in your own words.
- When the message is complicated, listen to the entire message, then add an entry-phrase to checking perception. To avoid sounding like a parrot or someone practicing psycho-therapy, (it may feel very weird at first) develop a vocabulary of entry phrases, such as…

"If I understand you correctly, you're saying…."	"Do you mean that…"
"Let me see if I have the sense of what you're telling me…"	"Here's what I'm understanding about what you said…"
"OK, let me repeat what I think you're saying…"	"Are you saying that…"
"I'm not sure I'm clear about this…let me see if I've got this right…	"What I'm getting from what you said…"

An entry phrase is not always necessary…sometimes just go for it… "So you feel the bugs we're using are dangerous, huh?"

Try repeating the last word the person said to see if they can continue an incomplete thought.

"See when I think about how slow the research is going, it makes me worried…."
"It makes you worried…."

"Well, not worried so much as cautious…"

"Cautious…"

"Right. What happens if some drug-resistant strain of bacteria is created out of all this and…"

Avoid that popular entry phrase, "Are you *trying* to tell me…" The word *"trying*" may be insulting and implies the listener intends to supply thoughts the sender possibly wasn't thinking.

Feedback – Responding to what others say without trying to steal the spotlight keeps the focus on the other person.

Feedback can compare what the person said with a new idea or pull a similar, supporting idea into the conversation.
Ask a question that allows someone to elaborate further.
Not all feedback is verbal—nodding, scratching your head, laughing, giving a quizzical look or wide-eyed surprise.
Once you have supplied focused feedback, follow up with your own content.

In the theater, actors practice improvisation, where they are handed a situation and asked to perform without scripts, making up the lines as they go along. Conversation is much like improvisation. Although sometimes we can predict what's coming, the scenes we play hand us constant surprises.

Usually, we don't know ourselves what we will say until we are finished speaking. Actors doing improvisation describe that they can either choose to accept or refuse what another actor offers. Declining stops the action—and the show. In dialogue, accept what's offered. Keep the conversation going.

We speak at 90-140 words per minute and think at 400-500 words per minute (Wolvin and Coakley 1996, p. 232).

Without a strong will and concentration, attention drifts and fills in the gaps. Since we can also predict certain word patterns, we can space out some words and still get the gist of the message. Sometimes while drifting, we're gone longer than we intended—especially if we know the person well.

1. Listener, know thyself. Be aware of personal listening "black holes."

- When do you likely to "check out" of conversations?
  - Working under a tight deadline and someone stops by to chat?
  - Watching the Seattle Seahawks play the Denver Broncos on Sunday afternoon TV?
  - When you first walk in the door at work—or in the front door at home after work?
- Who do you have difficulty listening to?
  - Your mother calling just before you go to bed?
  - The colleague at work who talks on and on about problems that never change despite your good advice?
  - Your son from college asking for money?
  - People with strong feelings about scientific issues and minimal scientific knowledge to back them?

Most people tune out family members and lower-status co-workers more often than anyone else because they believe they already know what these others are going to say.

- What biases do you bring to the conversation—
  - What's more important, science or social science?
  - Who makes the best problem solver—a person who is perfectly logical or someone who tends to get emotional?
  - How do you feel about environmentalists?
  - Would you rather work for a man or a woman?
  - Would you vote for a woman running for President?
- When having difficulty listening…focus…and ask…
  - What do they want me to know?
  - What do I not understand?
  - What does this mean to me?
  - What does this mean to them?

2. Be mentally and physically prepared to listen. Listening takes great energy and concentration. People who are tired, hungry, and distracted cannot effectively listen. Like preparing for a long run or a six-hour drive, listening requires a dedicated mind, a body properly fed and rested, and enough time to do the distance.

- Schedule meetings for halo moments—when people are **rested and fed**.

Most family arguments take place just before dinner or just before bedtime.

- Meet where people will be **comfortable**—unless you want to keep the meeting short or wield authority—chairs, lighting, temperature, space, and the balance in power should be agreeable to everyone. Choose a **neutral** place. Provide equal seating arrangements.
- **Use the 20% Rule** (Pettigrew and Martin 1987): If the group under-represents minorities or gender, those members should make up at least 20% of the group. In smaller groups, be sure there are at least two people with common ethnic/racial/gender backgrounds present. Provide support for their voices—not that they will ever agree with one another.
- Rich food and alcohol put people to sleep. Keep **meals** light. **No alcohol** if conducting business. Stay alert.
- Leaving early? Let people know. Set **time limits**.

P.3.3 Asking and Anticipating: When in doubt…

Often, we may think we know what someone means, only to find out later that we have no clue. Or again, we often aren't quite sure how to summarize or paraphrase what is happening between individuals and among group members and still sound "natural." In either case, the value of testing our understanding becomes plain through practice. The following stem phrases (Reddy 1994, p. 51) may be helpful with practice. Try them out and add your own:

"I'm not sure about this, but let me try this explanation out on the group…"

"Here is an alternative explanation you might want to consider…"

"If I were you, I guess I would feel…"

"Let's stop for a moment and look at what's going on here…"

"I'd like to make this observation…"

"Let me describe a pattern I'm seeing here…"

"It sounds like…."

"I think that…"

"It strikes me that…"

"A pattern I have observed here is…"

"What I am experiencing right now is…"

"I have a hunch…"

"It's time to get things rolling here…I suggest we try (the following)…"

Of course, paraphrasing can be overdone. Not every little bit of information needs repeating. However, paraphrase is a useful way of summarizing. It not only helps reduce ambiguity, but also lets others know we are paying attention and can put the conversation into words. Even if we get it wrong, it allows others to correct or supplement their points and feel that they've had an opportunity to get their points across in the way they want.

We know what questions the public has asked in the past and can be ready to answer them. In our research, the public often raised the following four areas as concerns:

1. Citizens were interested in the facts about the program.

- Have there been failures?
- Does this research involve adding organisms not native to the soil?
- Have the micro-organisms been genetically engineered?
- How can bioremediation contain or remediate groundwater contamination?

2. They asked for clarifications and definitions.

- What does NABIR stand for?
- What is biogeochemistry?
- What is the meaning (in common English) of that term you just used?

3. They wondered where in the process the project was right now.

- Why don't you get this work into field testing sooner rather than later?
- When will we see DOE technologies and applications commercialized and on the market?
- What happens if DOE pulls financial support for this project?

4. They wonder about the program's usefulness and how wisely government dollars are spent.

- How are bioremediation results monitored?
- What is the impact on natural resources around contaminated sites (A question especially salient to Native Americans)?
- Can the science really clean up DOE sites?

P.3.4 Roles

To speak and be acknowledged and understood is to become real. By responding to one another and how people respond to us, we learn how we are viewed from the outside. The view others hold of us is called our **ascribed identity** (Martin and Nakayama 2000). That outside view may be very different than the **avowed identity**—the view we hold of ourselves. How we respond to one another forms the mirror we hold up and use to ourselves from the outside and judge who we are from the inside. For instance…

... recently I praised one of my colleagues for her excellent organizational skills. She was a key planner for a large event where we took stroke survivors with speech disorders, their families, and speech pathology students up for a weekend near Mt. Hood to practice communication skills and have fun! From my point of view, she had an amazing ability to keep many details in her head and on her palm pilot, then systematically follow up on them as we planned this major project.

Her eyes took on a quizzical look as she tilted her head to one side as she listened, then with surprise she said, "you think I do?"

From her point of view, she was certain she would forget something crucial and the whole plan would come tumbling down around her.

Human personality and group dynamics produce predictable roles as the group evolves. Some of these roles are formally assigned—leader and scribe or secretary, for instance. These formal roles also may limit how we respond, especially when they are formally assigned to the group. Because **the leader is the leader**, we expect that person to lead: put together the agenda, call the meeting to order, keep the group on track, have supplies ready, and lead the discussion with great attention to both the task at hand and doing the niceties that ensure people are comfortable.

Group members also gravitate toward informal roles:

- Many of these roles are devoted to keeping the group on **task** (initiator-contributor, information and opinion seekers, clarifying and elaborator, secretary-recorder and director).
- Some provide emotional balance to the group (supporter-encourager, harmonizer-tension reliever, gatekeeper, and feeling expresser).
- Others are considered self-centered and disruptive to the group (stagehog, isolater, clown, blocker, fighter-controller, zealot, and cynic).

Many books devote whole sections to explaining these roles, and motivational speakers are fond of lecturing with humor and advice about how to handle these "difficult people."

Being aware that roles exist in groups—even if they are not assigned formally—helps analyze what is going on. Are people trying to give information? Are they trying to understand information? Do they want reassurance? Are they feeling part of the group or isolated? What ax have they brought to grind and how can we pull them into this discussion without polarizing the group?

The public is accustomed to viewing a scientist's role as that of an expert—someone who knows what is going on environmentally and holds answers to complex problems directly related to their quality of life. They also see themselves as intelligent and deeply committed to being part of the solution. Otherwise, why would they bother showing up for events involving scientists and themselves? They may expect not to understand everything. At the same time, they want scientists to talk with them in English they can understand—without talking down—or "dumbing down" that language.

Consider the following discussion at one of our interviews with members of the community.

H. A real fundamental thing. You've got to address the big middle group of people. If you want to write a technical paper, write and go to the conference, present it to the other scientists that understand it. But too often, technical and scientific communities—when they go to the public, they try to impress them with how much they know. You've got to get it down to—we didn't say Rotary…you've got to get it down…you're dealing with high school maybe plus a couple of years on the average level of understanding.

P. Doesn't mean they're stupid

H. No. No. But you've got to frame the presentation…

P. Got to realize…

[several talk at once]

G. *They're not stupid people. These people generally who are in these service groups are people who are very active, bright. You know, in their perspective…*

P. *And believe me; they want you to be so successful.*

G. *They do. Even though they don't trust you.*

P. *They want you to be successful.*

G. *They want you to succeed because they see that if you succeed, this area is going to be better.*

Stepping out of Role. When leader and follower boundaries are allowed to behave like great elastic seams, groups can become exciting places to work—a situation familiar with project and task groups. Too often, however, in structured situations like public meetings, panels or focus groups, we tend to see leadership as separate from ourselves—unless we're the designated leader. When every member shares the role of potential leader should the need arise, group work becomes collaborative and the people energized.

In one situation during a taped meeting with members of the public, the facilitator jumped into content almost immediately. "Thank you for coming and making time in your busy schedules. As you know we're here to talk about how we can meet your needs…Who would like to begin? One of the participants, a scientist, put the brakes on. "Before we get started, "he said. "I'd like to know who is here? I recognized some of *your faces, but I wonder if we could go around the table and introduce ourselves."*

Technically, he stepped out of his formal role as scientist and participant; he put on the facilitator's hat when the person in that role moved too fast. He also shifted the focus balance in the meeting from task to include emotional and social support. The meeting slowed down as people introduced themselves—becoming unique human beings invited to the table for a reason, rather than a lump of folks without visible history.

P.3.5 Invite Information ← → Interpretation

One set of communication skills involves the transmission of information. The other requires seeing the situation from another person's point of view and interpreting what that person wants to know. Giving information taps into the scientific perspective. Interpretation requires the speaker to take a social perspective. One venue sends information in one direction only. The other expects the scientist to interpret the question, examine their own involvement, and enter a conversation. Otherwise, how can a scientist (or anyone else) know the other person well enough to acknowledge this history and distrust behind the question and recognize at what point micro-organism activity might matter to them?

When scientists make choices to enter into conversations with non-scientists or scientists of another discipline, they generally have three options. Will they go to impart information? Will they go to give information and hear what others have to say? Or will they enter a communication experience open to creating something new—a shared understanding, or new meaning or knowledge derived from the interaction?

The first option is the most commonly used. A scientist arrives as the expert on the agenda and talks about their work. Information goes one way. Often, these events are promoted as information going in two directions—since the public will probably ask questions. But because the speaker sets the agenda by selecting the topic and content of that topic, when the audience asks questions they are really just inviting the designated expert to continue giving information. They are rarely allowed equal time.

Speaker Sends → (message) → Audience Receives

The second choice is also often billed as a two-way exchange. Rather than two people interested in the other's perspectives. However, each is usually more determined to get their own messages across in a more parallel transmission fashion.

Speaker Sends → (message) → to Receiver

Speaker To Back ← (message) ← Sends Receiver

A third option opens participants to seeing the subject matter in new ways. Whereas the first two options involve transmitting information, the third option requires at least one of the people involved to **interpret the situation—**to clarify what the other person wants, and how best to communicate in a way where they can hear and understand one another. The third option also opens those involved to the possibility that they may collectively arrive at conclusion they could not have found alone.

As a rule, scientists don't view themselves as advocates. At the most fundamental level, they see themselves studying and observing nature. At its purest, science is a problem-defining and problem-solving method using logical, rational, and measurable approaches. So, scientists are often asked to explain the technical side of problems:

- How do plants utilize sunlight during photosynthesis?
- Explain the theory of relativity.
- What are the consequences of planting genetically engineered corn?
- How do PCBs get into groundwater?
- What is a contaminant plume?

Other views of the same problem, however, do take on advocacy roles. Native Americans with tribal fishing rights to fish the Columbia River push for safe and unimpeded salmon runs. Nature Conservancy advocates demand protection for nearly 200,000 acres currently cloistered from public use because of radioactive contamination. Politicians argue that schools receive governmental subsidies because DOE research programs bring in families and overload classrooms, available educational resources, and bus routes.

Although scientists prefer not to be advocates themselves, they may often be speaking into "a field of advocates" or, as we have characterized the situation, they enter a politically and socially ionized environment.

Certain communication approaches work better than others in these potentially charged situations when conversations are crucial. When the goal is to build bridges rather than gangplanks, the situation calls for someone capable of building trust and discovering similarities among groups.

P.3.6 Transformations

Scientists who are successful in correcting common misconceptions also appear to create parallel streams of talk. They acknowledge the common-sense view and also acknowledge why it seems scientifically sound.

For example, the topic of moving microbial remediation into the technology phase was common in early discussions of NABIR. The public often wanted the work moved into field sites sooner than scientists thought prudent. Responses to this concern were most effective when scientists would accept the person's pressure to getting the science applied in the field, while describing two contrasting environments. In the laboratory variables could be limited or eliminated and their effects observed systematically. In the field, so many influences could be interacting that narrowing what scientists needed to watch for was challenged in a major way.

Communication scholar Kathy Rowan (1994) has suggested a four-step corrective approach when supposed common sense and scientific reality butted against one another. This approach got the explanation across without causing either side to feel like a buffoon.

1. State the erroneous but plausible notion.
2. Acknowledge its plausibility. ("Yes, I can see why you must wonder why we haven't moved this experiment out to a field site.")
3. Demonstrate its inadequacy in the light of evidence.
4. Present the more accepted view AND show why it is the wiser choice.

"We wish we could move things along faster too. What we've found, however, is that the soil is a complex area full of not only dirt, but whole systems of microbes and their food systems, for example. In the lab, we can limit what we study—looking at one of these pieces of that complex puzzle at a time. Eventually, we have a good track record of knowing how different parts of that subsoil environment will react and feel safer about moving out into the field."

Although this observation seems simple—maybe even simplistic—the difference between successful and unimpressive interactions seems to turn on acknowledging the non-scientist's point of view and integrating this familiar viewpoint into or contrasting it with new information. The scientist blends and reframes the information. By responding to the person's concerns about moving research into field sites sooner, then contrasting it with the more prudent decision, the decision becomes a "trade-off" rather than a right-wrong choice. Or it reframes the situation as part of a larger problem-solution process where both lab and field approaches are shown to be important when more knowledge is required.

One thing that keeps scientists interested in talking to the public about science is that discussion spaces are rarely entirely "old" or entirely "new." Non-scientists aren't usually totally unaware of scientific information. They are partially informed about some current developments and form mental models based on what they know and understand (Markman and Gentner 1993). Our transcripts suggest that the problem-solution frame works well because it can correct public misconceptions on scientific issues by extending what the public already knows and understands.

Use of Analogies. By pointing out similarities rather than differences, scientists can also create analogies or comparisons that reinforce this parallel thinking. Analogies ("the brain is like a computer," "the subsoil reminds me of a subterranean world or like a colony you might set up on the moon. It's got places where food is produced…micro-organisms manufacturing and eating the food…water reservoirs…and chemical reactions like you'd see in a bakery or fire extinguisher…") bring the scientists' frame of reference closer to what a non-scientist would find familiar. One side of the parallel presentation should be generally familiar while the other side contains new information. The best analogies point at a particular feature or set of features. The comparison remains general rather than detailed and usually focuses 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—like you see when rust forms on metal.

Samuel Johnson compared an analogy to a three legged dog—it can run but only so far—an analogy it itself.

Theme and Variation. Coherence in a conversation brings points together so we see how they are related—transforming our understanding into a large and more cohesive whole. Scientists who seem especially skilled in talking to people with considerably less background in the subject discussed will often repeat information—varying the explanation each time. With colleagues, a more equal give and take occurs and people avoid returning over and over to the same topics unless they bring an entirely new interpretation to consider. Whereas, a colleague-to-colleague dialogue continually directs themes like vectors because they share an underlying foundation of information and mindset—with non-scientists information is repeated following a theme line—much like a piece of music…the theme recurs, each time with a new variation.

Both effective teaching and expert-non-expert dialogue seem to include some version of theme and variation. Varying word choice and grammatical structure also occur in conversations with friends and family depending on who we are speaking to and how the subject comes up. At least we try not to sound like tape recorders as we tell the same stories more than once.

Non-scientists also repeat information and vary how they present material and questions especially when they don't feel their questions have been answered. An issue or question that was not adequately answered often returns at a different, more suitable moment later (cf. Schell-Word et al. 1999). The question may be repeated verbatim, but people are more likely to rephrase or paraphrase. For example, the following sequence of questions might occur as the person probes for a better explanation on safety.

"How do you know that putting these microbes in the ground is safe?"

"What will you do to monitor what's happening?"

"Will monitoring help you tell if the microbes are doing the right things?"

Understanding the concept becomes more important than how the question is worded since 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—as we see when information gets reduced to media sound-bytes.

When we're allowed to repeat information, and continually edit our versions as we explain what we are doing and what we understand, we stand a better chance of correcting misconceptions—or at least keeping the dialogue going even when the other person may be tempted to give up.

P.3.7 Yield to the Process

It is helpful to think of all communication as a process, either a designed or an un-designed process. A *designed process* includes facilitated groups, a structured meeting with one or more individuals, and a large group session in which certain outcomes are desired. Communication products are simply the outcomes of contexts, responses, constraints, and conflicts – i.e., the design of the communication event or product takes into account the essential elements of structured human interactions. (For a tabular view of this, skip ahead to Table T.1.) An *un-designed process* still involves a structure of some kind, but it may not be a conscious structure. Small-groups, for instance, often go through a predictable process that is not designed into the purpose of the group. Groups have been observed to predictably progress through stages of *forming*, *storming*, and *norming*: after they get together, there are often contrasting views of purpose, procedure, jobs, and outcomes to settle; when the group has settled sufficiently for achieving its purposes, it forms either explicit or understood standards of satisfactory operations. These stages are simply social phenomena, but once we expect to see them, we are not distressed by the apparent (probably temporary) friction.

Both designed and un-designed communication processes involve elements of predictability and of spontaneity. Dialogue has been of interest to scientists in the modern era because of its potential for creativity. Some of the most interesting observations about dialogue have been from scientists. Werner Heisenberg, for instance, saw science as rooted in conversations, where important insights were generated by spontaneous consultation. David Bohm, a quantum theorist, was fascinated with the potentials of dialogue, basing his ideas about human communication processes on the movement and interdependence of atomic systems (Bohm 1996). For Bohm, dialogue taps into a pool of common meanings that are unavailable to individuals such that the whole seems indeed to be greater than the sum of its parts. Engineers regularly work together on projects in structured decision-making and reporting units, which often depend on the spontaneity within the structure for innovative and convincing analysis.

Clearly, the more we design a process for useful interaction or the more we know about patterns in un-designed processes, the more able we are to have productive, satisfying interactions. To yield to the process means, then, to be aware that communication is indeed a process and to work towards identifying the elements that keep it useful.

P.4 NABIR Talking Points—Anticipating Others' Need for Information

Talking points are generic information speakers can have at their command, regardless of the audience. Since people unfamiliar with the project nearly always ask what NABIR stands for and what you are trying to do, we recommend hopping on the NABIR website to review the description of NABIR and its goals. The facts and items on the website include scientific descriptions of particular projects, so the wording may need to be adapted into less technical terms. The following talking points were extracted from actual conversations between scientists and the public and are considered to be the primary questions for which non-scientists need answers.

1. (a) *What happens when there are unwanted or unexpected results?*

Or in a more positive frame, people might ask…

(b) *How have you exceeded the minimum requirements and expectations for the project?*

These are trust questions. According to one NABIR scientist, establishing trust means "following through to…meet requirements, meeting them, and then staying in communication with the community."

- Trust and credibility improve when projects meet minimum requirements voluntarily. Be ready to show where and when that happened.
- Non-scientists may find plans, reports and documentation reassuring.
- Monitoring the project and contingency plans seem even more important. How does the project document these aspects?
- Ask them what they do in their own lives to monitor their own projects and create contingency plans—try engaging them in the conversation rather than an information-transmission session.

2. (a) *Have you been able to apply any of the research from other labs to what you are doing here?*

(b) *Why isn't this information being applied? Why keep it in the laboratory?*

These questions involve applying the results of the research and show concern that projects will be stopped before any practical uses for it can be found.

- When possible, make connections between the project work and either present or future benefits to the community.
- If this talking point cannot be addressed directly, explain the value of prudence, rather than how unexpected results are often useful in learning.
- Concentrate on reported NABIR findings as "progress" in the study of microbial interactions where environments are contaminated with metals and radionuclides.
- Before applications can be carried out on a wide scale, NABIR first needs to see its effectiveness demonstrated.
- Explain that when NABIR "scales up," it prefers putting well-known procedures into unknown territory.
- Ask them if they have any ideas about how the work they've seen so far might be applied…engage them in the conversation.

3. (a) *Are the microbes that you're working with pathogens?*

   (b) *How will you prevent releasing antibiotic-resistant strains into the environment?*

- Non-scientist concerns such as these should be addressed as verifiable and understandable rather than simply fear-based.
- Be ready to cite previous studies that answer questions about pathogenicity and resistance—look for ways to explain these terms and connections using lay language—like the likelihood these organisms might cause disease and antibiotics not working, for example.
- Ask what they've read about the issue or about their personal experience with resistance…enlist them in the conversation.

4. *Acknowledge that issues important to scientists might not be the same ones concerning non-scientist community members.*

Non-scientists often request predictions from scientists when current information won't provide those answers.

- 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."

Try asking about their concerns…it may shift the burden of providing

- Information to a more personal social concern where they carry the conversation.
- Follow up with a focus on how far the knowledge has taken us.
- Remember that scientists address public issues (like global warming…breast cancer…radioactivity…mental health…autism…terrorism…) by doing science.

5. *Address issues involving mistrust with good preparation and a balanced perspective.*

- Talk about what has been done to monitor and control nasty outcomes.
- Talk about the strengths and weakness of using microbes as remediators.
- Establish credibility by knowing your information and offering to follow up with information when you do not know.
- Be familiar with programmatic goals, but concentrate on interesting scientific work and findings about the program.
- Individuals have more public trust than does the DOE.

- Formulate a reply *after* someone finishes making a statement.
- Concentrate on what the person is *intending* to say (listening beyond the words).
- Avoid getting emotionally involved.
- Stay with the subject. Do not encourage tangents.
- Listen when someone proposes something's contrary to your beliefs"

Wolvin and Coakley, P. 246

Part 2 – Theory

Theory

The theory that is relevant to communication between scientists and non-scientists must be drawn from a variety of fields. There is no subdiscipline devoted exclusively to the topic because the issues raised in the practical encounters are expansive: differences in language usage, education and training, culture, socio-economic interests, social justice issues, group and interpersonal dynamics, and risk assessment and perception, among others. Moreover, because financial support for informal, face-to-face, communication between scientists and the public is still infrequent, directly relevant theory is rare.

This part consists of two primary issues: the elements common to public discussions of science (see section T.2) and the contributions and insights from a variety of disciplines to understanding the particular characteristics of informal and direct (i.e., not media-driven) science communication (see section T.3).

T.1 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 T.1):

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

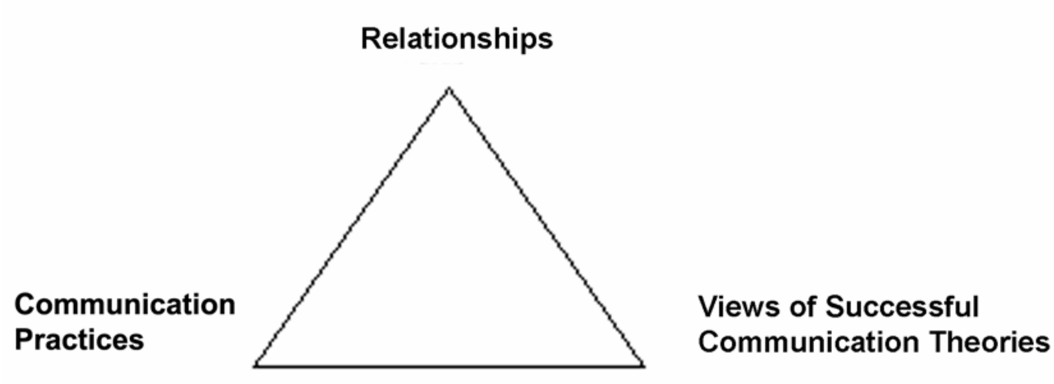

Figure T.1. Paradigm of Public Communication Influences

- participants' views of acceptable communication, i.e., what satisfactory communication looks like or results in
- the form of meetings between scientists and non-scientists, e.g., interpersonal, small group interactions, question-and-answer, lecture, etc.

These factors are discussed below.

T.2 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.

T.2.1 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 suspicion 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 non-scientists are, as well. Many non-scientists 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.

T.2.2 Intrinsic 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.

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 non-rational 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.

T.3 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 are 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 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 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).

T.3.1 Science Communication as Presentation/Transmission

The dominant model of science communication has relied on an underlying image borrowed from radio transmissions: a sender transmits a message via a channel to a receiver. Because the transmission, or presentational, model has information flowing from the sender to receiver, it has been attractive to some science institutions who have assumed that the differential in knowledge allowed only a one-way flow. Whereas scientists or the institutions they represent have been the senders, journalists and public-relations people have been regarded as the channels and the public, or segments of it, as the largely passive receivers. Although feedback is possible, it is noteworthy that it is mediated responses because of the delay of time or of the inability to find a suitable means of asking questions or making comments that reaches as many people as the original message.

The dominant view of successful communication in this approach is information that is conveyed accurately and convincingly. Information is regarded as messages, which are largely self-contained. That is, like news broadcasts, messages are successful if they are accurate and appropriately addressed to a targeted audience. Because there is normally no direct immediate feedback, messages are formed differently than in interpersonal or group communication. Audience-typing, invaluable for the presentational approach, often takes the form of characterizing audience segments by levels of education, but also can incorporate an audience's known interests or concerns. Communication training is in areas of informative and persuasive speech-giving, with an emphasis on understandable language and on the structure of presentations. The common science communication activities and products associated with the presentational model include speeches, presentations, videos, posters, magazine and newspaper articles, books, press releases, and fact sheets.

The transmission/presentational approach is useful when new information is critical or when a viewpoint needs to be fully aired to be understood (as is possible in a book). However, the misuse and overuse of this approach can seriously compromise the building of relationships. This model has the advantages and disadvantages of all reductive approaches. Regarded in isolation from actual practice, it is easy to grasp and easy to explain. Even for communication researchers, the model is attractive because it is more easily measurable than some other approaches (see, for instance, Losee 1999).

In practice, however, transmission-style information-giving with no opportunity for response begins to look like attempts to persuade. Often, messages are constructed with the intent of avoiding information that could raise questions or issues. Thus, the approach may encourage those who present information that is new to audiences to omit essential portions or to skim past information that may be applicable to their lives. Many practitioners and observers of communication practices think that the presentational model has a built-in strategic bias that favors persuasion, despite what a speaker or writer may claim. The unacknowledged issues in constructing messages, they note, are often "how to facilitate attitude change and how to promote consistency between attitudes and behavior in the intended receiver" (Bradbury 1994, p. 360). Moreover, there is also little opportunity for the speaker/writer to check their own assumptions about the receivers of the information. It is easy to misjudge an audience's receptivity to the content or style of your message without eliciting information from them. Transmission of inadequately focused or incomplete information can rouse suspicions about a sender's intent.

T.3.2 Science Communication as Dialogue

It takes two to tango – and at least two to dialogue. The analogy with dance is apt because dialogue moves occasionally in predictable patterns but as often in surprising and exhilarating directions. In this guide, we consider dialogue among people whose purpose for talking divides them into experts and nonexperts. Our observations have surfaced a number of notable features of dialogue between scientists and non-scientists and have incorporated advice on the general features in the Practical section. Among the contributions to practical applications are the following:

- Examine and test your assumptions about communication (see "Myths" in the Practical part of this primer).
- Discover what your interactants think (Q&A goes both ways).
- Be able to choose among communication practices. Freedom of method matches the fluidity of lively dialogue. Having information at hand is also vital.
- Use the stasis categories or other techniques to prepare to recognize patterns, themes, and assumptions (see Section T.5.6).

T.3.2.1 Nature of Dialogue

Dialogue, from Greek *dialogos*, means simply an exchange of words. In the pursuit of meaning, we encounter talk or dialogue at every turn. So important is speech to interaction that, for most of us, it is hard to imagine interactions occurring without talk. Asking questions and listening to others are the archetypical dialogue activities in interactions. In contemporary usage, dialogue is often distinguished from *one-way communication* by being an exchange and from *conversation* by its implication of having an underlying purpose. The term has benefited – and suffered – from a wide variety of uses in western thought since World War I. Linguists and ethno-methodologists, who study patterns of language use in various cultural settings, tend to use the term *dialogue* to refer to features of conversation, such as turn-taking. Others, such as the Russian philosopher Mikhail Bahktin (1982), view all human language uses as evidence of underlying dialogical relationships. Because language is used to address and respond to others in specific and unrepeatable circumstances, language-exchanges are the media for capturing, misconceiving, and changing knowledge. For Hans Gadamer (1993) and other late 20th-century European philosophers and sociologists, the term dialogue describes the relation between the interpreter (receiving and interacting) and a text (an information-provider, whether human or nonhuman, providing information and perspective, either directly or indirectly). The term has also achieved a more elevated sense. Theologian Martin Buber, for instance, used dialogue to mean transactional processes depending upon equanimity, simultaneous mutual independence and experience, and honoring of "the other," that is, the other person in dialogue.[a] The paradigm dialogue for Buber was between two persons or between the Divine and a person (Buber 1971). The sense of the term that has developed in philosophy and the social sciences over the last hundred years is of a process of digging for or building meaning, involving reference to a past, open to the possibility of an exchange of positions on issues and the uncovering or negotiating of common views.

In recent years, however, the term dialogue has been used much more loosely in common parlance as a term that describes a range of behaviors and social purposes, from quarrels to inquiries to lectures. Table T.1 shows a variety of types of dialogue viewed methodologically, that is, as a means of doing work.

Table T.1. Types of Dialogue
(adapted from Walton 1989, p. 10)

Dialogue	Initial situation	Method	Goal
Quarrel	Emotional disquiet	Personal attack	"Hit" out at the other
Debate	Forensic contest	Evidence and verbal skill	Impress an audience
Persuasion (critical discussion)	Difference of opinion	Internal and external proof	Persuade the other
Inquiry	Lack of proof	Knowledge-based	Establish critical questions and evidence
Negotiation	Difference of interests	Bargaining	Personal gain
Information-seeking	Lacking information	Questioning	Find information
Action-seeking	Need for action	Issue imperatives	Produce action
Educational	Ignorance	Teaching	Impart knowledge

(a) Many current views of communication draw heavily from Buber's influential view of dialogue as Honoring the Other. W. Barnett Pearce, for instance, sees dialogue as a form of communication in which people maintain the tension between simultaneously "standing their ground" by holding and expressing their interests and opinions and being "*profoundly open to the other*" (Pearce 1994). Consequently, dialogue implies more than a simple back-and-forth exchange of messages in interaction; it points to a particular process and quality of communication that allows for changing and being changed (Anderson, Cissna, and Arnett, The Reach of Dialogue (1994), p. 10).

To summarize, all uses of the term, whether formal or informal, appear to contribute to a view of dialogue as language used to share - views, experiences, emotions, goals, information – in a variety of methods, goals, and contexts. Dialogue also exhibits certain interactional features, such as turn-taking (one person speaking at a time) and acknowledgement (response to another person's contribution), occurring within a purposive frame of reference.

T.3.2.2 Characteristics of Dialogue Between Experts and Non-Experts

In this primer, we avoid making claims about the probable outcomes of dialogue. Surprisingly often, when undertaken with mutual respect and conducted sensitively, dialogue does indeed result in treating other people with respect and in changing minds. Unlike the Buber-inspired claims for dialogue, we do not presume to look into the soul. For our purposes, the talk we are considering is usually driven by social contexts and practical needs. In terms of the types of dialogue described in Table T.1, we observe elements of persuasion, inquiry, negotiation, information-seeking, action-seeking, and education.[a] So, the practical advice about dialogue in the Practical section of this primer is undergirded by some observations and conclusions of dialogues between scientists and nonscientists: a) the interests and behaviors of nonscientists, and b) the interests and behaviors of scientists.

a) ***Qualities of Nonscientists in Dialogue***

In our observations, the characteristics of nonscientists in dialogue with scientists have been marked by two primary traits: a fluid organization and a return to a handful of familiar general themes. Fluidity appears to be marker of negotiation about language and information, often in the context of trying to apply science findings to local conditions and concerns. Familiar themes are here broken into "commonplace arguments" because they often are part of more developed points of view or clusters of concerns. The themes include trust and transparency, information, consequences (what-if's), and the public's and scientists' respective abilities to act meaningfully on scientific information or social priorities.

Fluidity in Definitions and Presuppositions

It is common to hear that dialogue brings in many different perspectives. But what does that mean in practice? Often, it means that we are trying to get back to other people's uses of key terms that we have to separate questions that they express in an aggregated rather than elemental form, or identify their presuppositions or prior mental associations about whatever properties or processes we are referring to. Clarifying definitions, reaching appropriate or meaningful questions, and fact-finding take up much of the energy that non-experts expend in trying to understand expert viewpoints. Although these topics are discussed again below in Section T.5.6, they should also be considered as elements in dialogue.

Scientists may often find the fluidity of language unwelcome in dialogue. However, two things are worth remembering: technical terms may also be in colloquial use, where they will probably have a broader range of meanings, and terms, even technical terms, have connotations (intellectual and

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(a) Quarrels and debate are marks of contentious contexts and are usefully considered as the products of ideological or power differences. Models of stakeholder involvement and risk communication that account for public degrees of outrage under varying conditions of hazard can provide useful rules of thumb for understanding and acting (e.g., see Sandman 1993).

emotional associations) as well as text-book or regulatory denotations (formal definitions). Unless you want to keep reminding people of an exact definition, it may be more expedient to compromise a pure meaning for an acceptable range.

Occasionally, as in the dialogue example below, the broader range of associations can spark new life into a well-worn term, such as "waste." In this segment, a regulator's definition, a scientist's definition, and the associations arising from the public's inferences about the value of waste all turn out to be somewhat different. Asked about the interaction later, the regulator admitted that he was surprised to hear members of the public see value in waste and found his assumptions about public views enriched by a simultaneous, undogmatic pragmatism:

> Regulator: But again, waste is defined by the regulations, therefore—
>
> Scientist: But, but…
>
> Citizen 1: But waste may turn out to be something beneficial.
>
> Citizen 2: What you're saying is that waste is going to be something that is the nature of the process—
>
> Scientist: Right, right.
>
> Regulator: Well, the word waste is different. (laughter)
>
> Citizen 1: Well, okay. Define waste.
>
> Regulator: Well, I'm not going to do that. But when we look at waste, we look at as a…we look at it as a hazardous waste, as a regulated waste. Waste that requires disposition.
>
> Citizen 2: Okay.
>
> Scientist: But there is another way to look at waste, from the public perspective.
>
> Citizen 1: Ya, right.
>
> Scientist: Which is anything that does harm to their resource. In other words, if it creates a resource devaluation. An example of that is turning good drinking water into egg…rotten-egg-tasting drinking water.
>
> Citizen 2: Right, it may not be toxic, but it doesn't taste good.
>
> Citizen 1: Ya, there is waste that makes compost. It could be psychological perceptions.
>
> Scientist: A physical perception, we could believe that.
>
> Citizen 1: I mean there are people who like drinking smelly water because they think it is healthy, good for you.

Often, questions contain key presuppositions that offer opportunities for examination and then for confirmation or correction. Because people may think faster than they can speak, they may engage in telescoping of multiple presuppositions into straightforward-sounding statements. This will often come out in question-asking. With the question, "Do you think these bugs can eat up all the contaminants in the ground before some of it reaches the groundwater?" An expert is faced with several presuppositions, among them:

- Microbes are "bugs."
- Contamination has not yet reached the groundwater
- Microbes "eat" contaminants.

There may also be implied reasoning embedded in such a question:

> "Eating" may mean (here) "completely eradicating with a trace."
>
> Therefore, microbes used for remediation will eradicate the contaminant without a trace (e.g., by-products).

Unpacking questions is thus one of the primary tasks of experts in dialogue, just as unpacking answers is one of the primary tasks of non-experts in dialogue.

Fluidity of Reasoning

Although dialogue may be focused on a theme, it also often proceeds by leaps of logic and re-visitations of previously covered topics. Group dialogues about environmental science programs can be marked by one or more factors that affect the reasoning that is revealed in discussions:

- Groups often take even a tentative opinion or concern seriously. If an expert dismisses it, the sense of the group may embrace it as a balancing measure. This may be because our opinions and concerns seem reasonable before examination. When they are offered in a group, they may be prefaced with a face-saving apology. To maintain an atmosphere of reasonableness in a group, it is necessary to produce respectful input and responses. How can that be done? Views that are accompanied by evidence or that are broadly held should not be dismissed abruptly. Dismissals of other views come across as abrupt and power-grabbing to non-experts. These can take a number of forms: views that depend not on evidence but on lack of it (e.g., "because it has not be proven to be true, it must be false" or vice versa); or bringing in an authority unknown to non-experts or citing the authority without other evidence or explanation ("Dr. David Ball has an excellent reputation and if he says that's not true, it's not true").
- Non-sequiturs in group dialogues can, in fact, be parts of a pattern of talk. Non-sequiturs may indicate concerns or presuppositions that have been brewing beneath the conversation. Issues and concerns that are truly of importance to members of a group will probably resurface after having been apparently laid to rest. Often, they are paraphrased or shortened to a key phrase. It may be a mistake to dismiss an apparently quirky question or statement as an outlier. Dismissing views as outliers can prolong irrelevant discussion, gain sympathy for unworthy views, or exaggerate modest points.
- The role of emotions in dialogue is often misunderstood or unnecessarily feared. Emotions indicate a full response, drawing on values and experience. In the discussions we observed, harsh emotions were rare, but often accompanied the baring of vulnerabilities – lack of control, hidden knowledge, or conditions in the dialogue that seemed to involve dismissing someone's viewpoint.

Commonplace Arguments from the Public about Science Programs

Despite the leaps and re-visitations that can characterize dialogues, there are some topics that are fairly predictable. Through experience with a number of science programs and in reading many critiques of those program, we have identified a short list of arguments that members of the public often have about science. In practice, these arguments, expressed here as single sentences, may be accompanied by supporting evidence, or may simply be expressed as unsupported sentiments. They deal with issues of trust and transparency, evidence and availability of information, and the public's limited control over circumstances:

Arguments about trust and transparency

Scientists are often affiliated with organizations that have proven untrustworthy or have interests that may not be immediately evident, e.g., government agencies or corporations.

Scientists may have no local knowledge (knowledge of local conditions and problems), arguing from other locations or from general cases rather than from particulars about a local circumstance. Thus, they may be interpreting local conditions in the light of the interests of their institutions rather than with local interests in mind, even while they claim scientific objectivity.

Scientists may claim to be scientifically objective, but may actually be hiding behind institutional purposes and programs, without really being accountable.

Arguments about evidence and information

Scientists operate on information apart from the social and cultural milieu of actual places and people.

Scientists' claim to absolute truth is off-putting, rightly generating resistance and skepticism.

Scientific information may be measured against statistical the likelihood of appropriateness rather than actual experience. Scientists may discount hearsay or personal experience as outlying or non-rational, however vivid or compelling the experience may be. However, truth may be found in personal observations or long experience, as well as laboratory or field experiments of limited duration and samplings.

Scientific studies and conclusions from different scientists at different times are often contradictory.

Scientists claim value-neutrality, even while receiving research funding from interested organizations and conducting research of interest to those institutions.

Scientific information, as applied by government agencies and corporations, rarely factors in economic or social consequences.

Arguments from consequences

The best publicly funded science leads to useful, economically viable applications.

Arguments about agency and ability to act

Experts assume that the public has the power and opportunity to act on the information provided to them (rational actor approach). However, that is rarely the case.

b) Qualities of Scientists in Dialogue

In dialogues with nonscientists about environmental remediation, the scientists we observed exhibited a range of effective skills. Of these, two lessons appear to stand out: one is that they appeared to be sensitive to the differences between expert and nonexpert views of adequate answers, and the other is that they appeared to be alert for the presuppositions that may underlie questions or comments from nonexperts.

Experts are valued precisely because they can provide information and insight not available to nonexperts. However, they may need to tread more lightly when offering professional judgments rather than empirical information. Expert judgments are the products of inferences, based on experience, systematic methods, and the tested understanding of a scientific community. It may be difficult to translate expert best-judgments into the “hard evidence” demanded by laypeople. Consider this: Without always being aware of what they’re expecting, experts may demand a level of trust without demonstration that makes laypeople balk. The ideal condition of scientific certainty is deduction of a hypothesis from demonstrable axioms. Inductive confirmation of hypotheses, based on convincing probabilities, is almost as powerful in building a case. However, appeal to expert judgment is inherently subjective, regardless of how much experience and learning the expert may have. So, when an expert appeals to expert best-judgment, it should be considered, at best, plausible thinking. It is recommended, then, that one accompany expert judgment with a) hard evidence, b) an appeal to the common-sense aspect of the judgment, or c) an acknowledgment that although it flies in the face of common sense, the view has nonetheless proven to be a sound opinion over time. In no case should an expert’s appeal to authority – either his/her own or another’s – be expected to put an end to questions. Such behavior often turns even acceptable expert contributions into unwelcome attempts at power-grabbing in dialogue.

For experts, the deciphering of questions can be a weakness in keeping up an equitable and fruitful dialogue. Questions may contain unstated presuppositions that require the expert to firmly reject an assumption while still trying the answer the question, or vice versa. Moreover, as discussed above, questions can contain several answerable segments, which must be disentangled and answered one by one.

Many other considerations, of course, drive scientists’ contributions to dialogues with nonscientists. Sections T.4 and T.5 approach scientists’ concerns from a variety of perspectives: the constraints and possibilities of commonly used communication techniques (Section T.4) and the social and conceptual divisions and bases for common ground (Section T.5).

T.3.3 Science Communication as Diffusion of Information

A variation of the transmission model draws from a step-wise model of the diffusion of technological innovations. Using an underlying development timeline (from needs through development to decision to adopt or reject an innovation), the diffusion model proposes a parallel step-wise track of communication. Everett Rogers' influential model (Rogers 1983) concentrates on the decision process in adopting innovations (see Figure T.2). In this process, an individual or other decision-making unit learns about an innovation, forms an attitude to the innovation, decides to adopt or reject the innovation, and then confirms the decision in a public way by using the innovation and/or advocating for it. The Rogers model of the innovation-decision process shows communication as the channeling of stages of a decision process.

This model differs from the transmission model in that its outcomes are based on an outside person, a decision-maker, other than the message-sender. It allows, indeed it requires, feedback from and interaction with the message-receiver/decision-maker at various stages, as the decision-maker seeks information. The decision process and the pressure to decide (adopt/reject) is central. As the diagram shows, "persuasion" refers to a decision-maker being persuaded rather than to any necessary stage of communication. It appears, then, that advocacy is minimized, and the adopter's autonomy and response-ability are paramount in the process.

This model has been basic to government agencies' "second-generation" approach to stakeholder involvement ("first generation" being simply the transmission approach to providing sender-selected information). The decision approach has been sufficiently systematic to attract interest and support not only from communication professionals but also from scientists, policy-makers, and many stakeholder

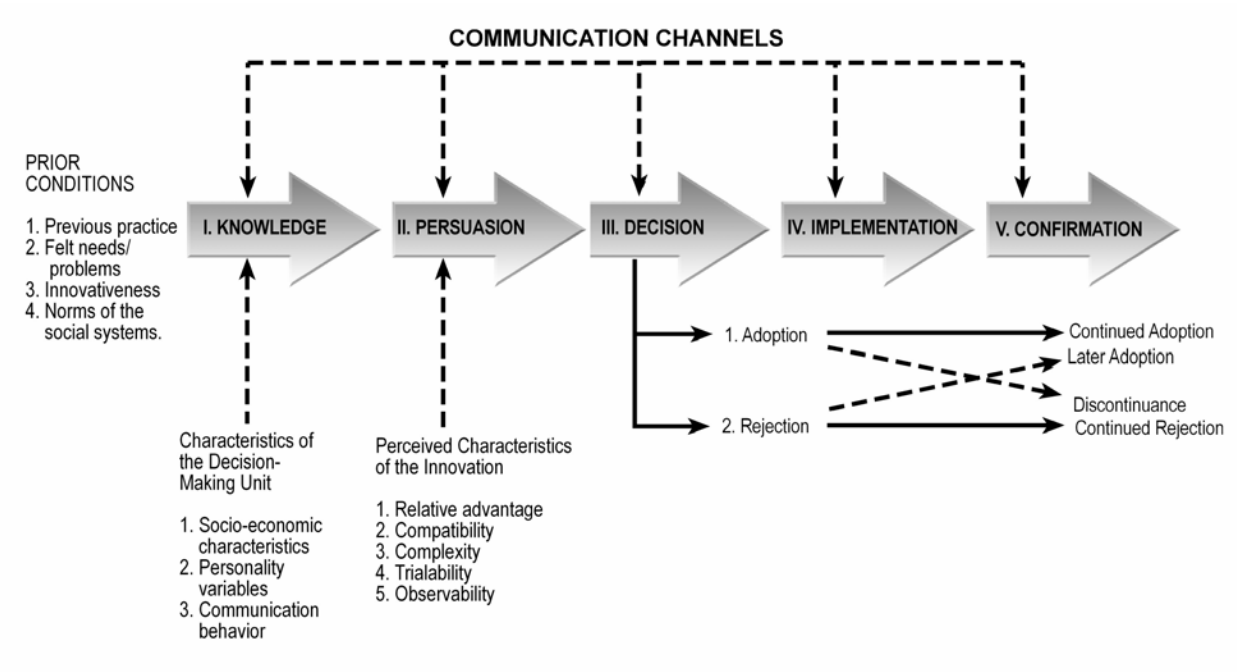

Figure T.2. Rogers Diffusion Model of Innovation groups. It appears to offer the public an opportunity to “buy in” to science and technology initiatives. Depending on how the process is managed, it can offer the public and policy-makers a chance to ask questions and provide comments. Making the public a part of the decision process has, in fact, become an expected part of publicly funded applied science in the United States. Some laws, such as the National Environmental Policy Act, have included public comment as part of the process of issuing an environmental impact statement. Local and state government and federal agencies have encouraged citizen advisory groups to provide input. Techniques for directing citizen consultations and recommendations have been successful in some circumstances in reaching lasting stakeholder agreements (see, for instance, Gregory 2000).

When the linear diffusion model is applied to communication of fundamental science, however, problems can arise, both practical and theoretical. Because the science has not been applied yet, the public may have no decisions to make. If a program uses this model as the base for its communication with the public, communicators can send double messages to the public. “Why are you approaching us,” the public may legitimately ask, “when you do not have anything to show yet?” Moreover, those who are targeted as decision-makers may not have any real voice in whether a technology is pursued or not. Consequently, one of the most important issues for the diffusion model is deciding who can make decisions about an initiative. Those citizens who are not decision-makers are thus often excluded from communications. Carbon sequestration, for instance, may be an important link to managing atmospheric carbon levels, but decision-making about its development is limited to those people most directly affected, e.g., industry representatives or influential environmental organizations. Often, these groups become “designated stakeholders” who may be identified by those who are proposing the innovation. In practice, then, by limiting stakeholders to decision-makers, the diffusion model excludes many people who may have useful input or may object to innovations later. The sample may not accurately predict future acceptability of the innovation. In some instances, stakeholders are included in the elect circle because they have sued an agency or innovation-proponent in the past. Because the model often serves to legitimate some input and de-legitimate others, it can also legitimate the most severe critics in the interests of heading off a law suit.

Also, it should be asked, When is communication considered successful in this model? Is it when adequate information has been provided, or when a decision has been made to adopt or reject an innovation? Despite its appearance of neutrality, the model does accommodate advocacy because the decision-maker’s perception of an innovation has to come from someplace. Presumably, that origin of information will include the promoters of the innovation as well as its detractors. Often, decision-makers can be overwhelmed with information, be unable to decide whether it serves someone’s special interest, or simply run out of time and energy. Adoption of an innovation can arguably be a function of availability or priorities, then, and not a matter of the dutiful weighing of options that Rogers suggests.

Finally, there is a theoretical problem. The diffusion model places communication in an enabling role rather than as a feature of the central action. It is the icing on the cake rather than part of the cake itself. This is actually disingenuous because the approach relies on information presentation and analysis at every stage. It mysteriously tries to separate the cognitive and social elements of the process, i.e., the process of making decisions from how the decisions are presented and the interactions about them. The decision-making process *is* a social process and, therefore, a communicative process.

T.3.4 Science Communication as an Ecological System

Recent years have seen the rise of non-linear diffusion models in communication. Such models view communication as a phenomenon arising from communities, that is, groups that share common interests (even temporarily, as in work groups), a common place of communication (either physical or virtual), and need for a shared language.

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 dialog 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 dialog 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 (Figure T.3).

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).

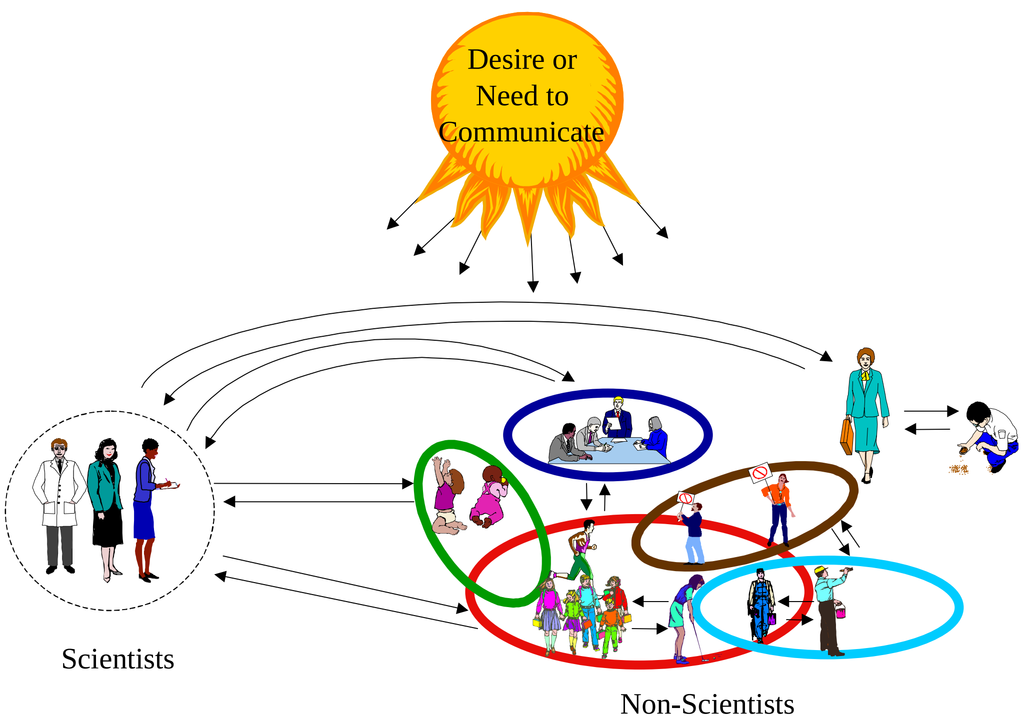

Figure T.3. The Social Ecology of Science Communication

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 dialog 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.

T.3.5 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, our point of view can also narrow our vision by blocking out competing visions.

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.

T.4 Communication Practices

Table T.2 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

Table T.2. 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 effects 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 non-compliance. 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 T.2. (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 connected with critical thinking models in interpersonal communication. 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 understanding. Support for participants' 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 T.2. (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 environ-ment. A pressure to conform. Differing goals among group members, whether expressed or not (hidden agendas).	Notes, flip chart notes, tran-scripts, video or audio tapes, storyboards, hand-outs.

Table T.2. (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 within the group. Success not defined individually but in terms of group. Large groups become more effective when managed through small group's 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 (Gerow 1995), 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 isolation from other groups.	Hand-outs, flip charts, transcripts, video and audio tapes, storyboards, notes, collaborative reports, web sites.

Table T.2. (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 T.2. (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 techno-logical 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 T.2. (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 view-points 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 harmon-ious. Skepticism of process or of facilitator. Inappropriate facilitation—in process, listening ability, assump-tions, etc. Differences in domain-specific expertise or in communication skills among participants.	Flip charts, audio or video recordings, output desig-nated as goal of facilitated meeting (e.g., report).

Table T.2. (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).

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 T.2 suggests that a communication format may very well create the character or tone of a communication activity as well as simply structuring the agenda.

T.5 What Do We Know About Informal Science Communication?

Science communication has been much studied since C.P. Snow pronounced the differences between scientists and non-scientists largely irreconcilable (Snow 1954).[a] In recent years, however, public mandates have brought scientists and non-scientists face to face. The encounters have produced interest, though not many more further encounters, and have suggested ways of remedying the misunderstandings. Attention has been paid to the public understanding of science, the role of trust, and the communication features common among scientist-non-scientist interactions. These topics are considered in the following sections.

T.5.1 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 non-scientists: 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 understanding 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% reporting being very or moderately interested), people also report not feeling particularly well-informed about science (NSB 2000). A National Science Foundation poll (NSB 2000) found only 17% of those surveyed felt well informed and 30% thought of themselves as ill-informed. Moreover, about 75% 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% in the 1999 survey able to define a molecule, 29% able to define DNA, and 16% able 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% of journalists and 80% 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

(a) See, for instance, Roger Kimball (1994), who notes that C. P. Snow's distinction between scientific and "traditional cultures" illustrates the fact that "a mountain of confusion can be built from a grain of truth."

notes, that "the level of self-assessed knowledge appears considerably lower than the level of expressed interest" (NSB 2000). However, such a response might reasonably come from many scientists themselves, who lack the time to keep up, even with their own fields. Although 75% 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% could explain what it means to study something scientifically, about 33% could explain the basics of experimental procedures correctly (including the use of control groups), and – improbably enough – 55% 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 further 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 scientific 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 implications follow from the largely hidden sources of information in the fundamental 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). Much depends upon personal contacts, timely funding, and recognized public needs (issues). The paths of fundamental science and of technology development and deployment are often not smooth, even for those who have access to current information. The public and the media, constrained by available information, can only guess if anything will come of promising fundamental science. (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 their consequences. (3) Questions about the generation and sharing of information are difficult to answer in most modern knowledge-systems, with science being a particularly difficult case. Advancing science depends upon the linkages that operate at all levels of information generation and usage. Drawing up a genealogy of information functions may be one means of addressing the issue of accountability, but stakeholders are overloaded with information in their lives and have little time for background information or context-setting. The public becomes particularly impatient when confronted with contradictory assertions. One recent op-ed piece in the *Washington Post* cited a string of past contradictions in medical studies, all of which were presented with confidence and recommendations for medical care: asthma as a psychological versus physical condition; ulcers as caused by stress or by microbes; the virtues versus the deleterious effects of hormone-replacement therapy. The writer concluded, “Science has a hard time with humility” (Krauthammer 2002). Under these conditions, the public’s default approaches become “Tell us when you have something to report” or “Tell us when you’re sure.” Science communication is often difficult, then, because its raw materials are often limited to radically abbreviated statements of context and findings, with scientists and journalists searching for the magic bullet or hypodermic that will convey the essential information.

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 of knowledge and the social gap between the two worlds will disappear. The public, then, is the recipient of scientific information. The contextual model, on the other hand, relies on evidence that suggests 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.

Although these two approaches certainly contain differences in views about the best approach to science communication, they also differ in their assumptions 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 more like an organism that learns by adapting information to experience. Both views appear to be accurate 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. Similarly, non-scientists may also, on occasion, be overwhelmed by scientific or medical information, particularly when information is not readily useable. However, when scientific information can be applied to recognizable experience, non-scientists are no longer empty vessels but organisms selecting, questioning, and applying information.

T.5.2 What Do We Know About Mass-Media Influence on Public Understanding of Science?

Journalists, for their part, have a variety of behaviors that affect the kinds of information the public receives about science. In particular, their relationship and handling of their scientist-sources is critical to the information that gets to the public. Public knowledge of science as conveyed by the media is affected by two intertwining factors: (a) scientists' control over scientific information as they act as sources for new stories and (b) journalistic practices in covering science.

Science journalists depend heavily on the scientists who are their sources, affording those scientists considerable control over how findings are construed in the open press. This dependence on sources arises from journalists' time constraints (meeting deadlines) and limited access to the scientific information on which stories are based (scientists and their sponsors control which information is released, restricting full outside examination of data and methods). The process of replication and verification, which is crucial to science, does not work well in the reporting of new developments. Source-dependence thus may thus tend to encourage reporting of new spectacular developments that are untested by other scientists.

It is clear, then, why the one-source story has long been the bane of critics of science journalism. Although science journalists are now using more sources for many of their stories, there are still a large number of one-source stories, which often report the findings of a single lab (Blum 1997; Pellechia 1997). Dunwoody warns of the negative effects of a "shared culture" among journalists and scientists, in which the rules of the game are controlled by the sources (Dunwoody 1999, pp. 74-77). For the public, then, the outcomes of source-dependence mean that information deemed relevant and interpretation of those facts are made by the people who benefit from the circulation of the stories: scientists and journalists.

However, because of the critical influence of sources of information, journalists and social researchers point to scientists as those finally in control of public information about science. Sharon Dunwoody has identified three ways in which scientists provide not only relevant facts to journalists but also interpretations of their findings (Dunwoody 1999): (a) Although journalists can choose the story topics, scientists frame those questions that are relevant to the stories and the facts that support the implications that journalists can draw. Journalists tend to draw from available information rather than digging out information entirely on their own and prefer scientists as sources and those stories that give them access to first-person accounts of findings. (b) Once science stories become news, scientists' interpretations of their meaning dominate, often for years. A study of a major scientific meeting found that journalists generally did not stray from information provided by meeting organizers or sources available at press conferences (Dunwoody 1999). (c) Journalists are normally reluctant to criticize their scientist-sources. Investigative reporting of science is rare, perhaps because science journalists tend to believe that science is good and that (more pragmatically) they want to maintain a good relationship with their specialist sources.

However, when the science does not lend itself to a single message – i.e., when there are divergent findings or interpretations – journalists must decide how to handle the differences. Uncertainties are particular problems in new or controversial science stories. The situation is complicated, too, by the fact that scientists may use news stories as ways of swaying public perceptions and even communicating indirectly with other scientific factions, who also read the news (see Price 1992, p. 81). Journalists regard controversy as good attention-getting copy and often tend to highlight controversies and conflicts as ways of cohering a story and making it more compelling. Journalists adopt two strategies in dealing with controversies:

- Objectivity – The journalist adopts a passive stance, concentrating on accurately conveying the views of either side and avoiding issues of validity.
- Balance – "If you cannot distinguish the true statements from the untrue ones, then the best strategy is to present an array of viewpoints. Readers and viewers will have access to all perspectives, according to this norm, making the truth available to them, albeit often mired in a variety of options" (Dunwoody 1999, p. 71).

However, this process can obscure audiences' ideas of the extent and nature of scientific uncertainties. For instance, scientists may present their work as sound and that of competitors as uncertain, without sharing their own work's uncertainties or characterizing the extent of uncertainty in competing work. Indeed, simply by vigorously contesting someone's opinion, well-known sources can enter a debate in which they have little or no expertise. Because they see that evidence (no matter how overwhelming) has been contested, audiences may be left with the impression that findings are uncertain. By being objective, a science journalist may then over-emphasize differences in data or interpretation for the sake of rhetorical contrast and thus create schools of thought where none actually exist. By seeking balance, a science journalist may credit some unscientific viewpoints with a weight equal to that of scientific viewpoints. "Although the journalist's take-home message in a balanced account is that truth resides somewhere in the story, the reader may get a very different message: All points of view represented in the story are legitimate – sometimes equally legitimate – ones" (Dunwoody 1999, p. 72).

Surely, this is a complicated filtering process for scientific information – unsystematic, personal, and, for those clever or experienced enough, strategic. Moreover, the process is given to highlighting scientific developments (some might even say the most splashy developments) at the expense of scientific ideas. However, there is actually an even larger frame of reference than source-dependence that everyone – scientists, journalists, and the public – must adopt for developments or ideas to prevail: the power of public issues. Science coverage is often issue-driven, that is, it focuses on issues of political, and thus of public, interest. What journalist would not pounce on a scientific development that addresses a publicly recognized problem (e.g., pollution, disease, or terrorism) and that offers hope for a surprising and dependable new alternative solution? To successfully enter the mainstream of public information, scientific ideas must be considered publicly relevant. To fold scientific developments or ideas into the mainstream involves persuading the public of their value. Communication is the gathering of resources for that effort of persuasion.

Indeed, once science developments and ideas are disseminated in the popular press, their fate follows patterns familiar to those who research other mass media phenomena in politics or entertainment (see Moscovici 1984 and Gamson 1988). From a communication standpoint, this involves using sets of ideas and symbols that are useful in constructing meanings in a particular culture at a particular time. So, scientific ideas, like attractive political ideas, go through a process of *anchoring* (classifying an idea in a familiar set of categories) and *objectifying* (converting the unfamiliar and abstract into the familiar and material) (Wells 1987). Once a development or idea is anchored by being related to a set of familiar developments and objectified by being made material (easily done with applied science or outcomes of experiments), it must be given a publicly palatable interpretation by becoming an "issue package," i.e., a story with a recognizable current frame of reference (Lievrouw 1990). At this stage, certain scientific developments are preferred to others for journalistic purposes: some make compelling stories and others do not. The most compelling stories are those that address a currently recognized public issue (otherwise, one must make a case that something *is* an issue) and that involve the elements of a story, such as memorable characters, conflict, or vivid, exciting settings. However, this is probably still not enough to get a science story widely disseminated. As discussed above, stories need to fit into the needs of journalists and into media practices, e.g., stories should allow journalists to maintain good relations with and future access to their sources. Often, the story needs to be promoted by an institution, e.g., a university or a government agency, to distinguish it from other stories and lend institutional credibility to a scientist. Moreover, widely disseminated science stories often need to invoke compelling cultural values and, ultimately, fit within the cultural framework of the public's basic fears and hopes, e.g., by being examples of how nature is being tragically assaulted by civilization, how people afflicted with grievous diseases can be compassionately aided by a new application of science, how people can work faster and with less effort, or how a nation can protect itself from attack through scientifically developed detection systems.

Does this mean that mass media influences, with scientists largely in control of information and journalists in control of stories, control the public's understanding of the importance or benefits of scientific developments or the degree of risks? The answer to this question is much more complicated than understanding how science stories are generated and make it into the public awareness. As citizens, we employ a filtering and judging process that appears to be fully as complicated – but more rapidly executed – than that of scientific reporting. Studies of mass-media influence have generally found that the public's view of the importance or risk of a scientific development is influenced by a variety of factors, not simply by the most recent media accounts. The public are active, not passive, processors of media-generated information. Even if one assumes that the public is more passive than active, the availability of numerous media-sources and opinions via broadcast media, newspapers, and the internet would make it difficult to frame news once-and-for-all. It appears, then, that we the public adopt both a deficit and a contextualist view of our relation to scientific information, just as we do to political information: our deficit is in our lack of access to information and lack of power in initiating action, yet we gather science information as we do information about other concerns in our world and weigh the input for relevance, immediacy, validity, and rightness.

Scientists and journalists, then, oversimplify the effects of their facts and stories to their own peril. In comparing the evidence of mass media effects with the expectations of scientists and science organizations, Susannah Hornig-Priest has identified three myths that scientists often hold about media coverage (Hornig-Priest 1995):

- "The mass media have a strong and direct influence on public perception of risks."

Although one school of thought in communication, agenda-setting theory, suggests that the frames of reference provided by the media determine the subsequent range of discussions, Hornig-Priest's own research on responses to media stories shows that public concerns operate quite independently of the emphases in the news. Although the media may set the issues of the day, they have less effect in defining the sub-issues. Whereas the issue may be protection of the environment, the sub-issues might include such factors as degrees of control over solutions and outcomes, economic and health effects of solutions to environmental problems, and the priorities and trade-offs in balancing environmental preservation and other social benefits. The greatest influence of media may actually be on long-term opinion and attitude formation.

- "The mass media tend to give too much credence to extremist activists and systematically exaggerate risks, thus unnecessarily alarming the public."

Although in some instances, media coverage may raise fears among scientists and their sponsors about public reactions, journalists (as we have seen) are largely dependent upon their sources for information. This viewpoint may arise from the belief that an empirically verifiable set of facts, such as those gained through scientific research, cannot be interpreted, (or even restated) in any but scientific terms. Any other restatements or interpretations risk distortion of the science. However, as Weber and Word (2001) have pointed out, information made public inevitably enters a public field of discourse and becomes "ionized" – anchored and objectified in frameworks created by others.

- "If the media didn't raise a lot of questionable risk issues, the general public never would."

One-sided messages, such as scientific information provided as factual and indisputable, is usually only effective with a small number of subsets of audiences: those with little knowledge of an issue or those who are predisposed to agree with the information presented. Moreover, even those who are predisposed are more easily persuaded of other views later on if they have been exposed only to a single message in the past (see the classic studies of Hovland et al. 1949 and of Lumsdaine and Janis 1953). If messages can be contradicted or amended by other information, a multifaceted approach is better than one focusing only on information preferred by the originating scientist, journalist, or institution.

T.5.3 What Do We Know About Public Trust?

Scientists may still be the most trusted among the professions, but science organizations are often mistrusted, for their lack of accountability: their management of information, the confusing state of funding, and their aloofness in providing palatable science education to the public. A report written for the Royal Society of the UK following the BSE infections of the 1990s cited four chief sources of public anxiety about science:

- People feel that science is uncontrolled and guided by vested interests. Many people perceive inadequate regulation of "new frontier" science, and feel powerless to influence science on ethical grounds.
- In general, the public wants more transparency about scientific information. People sense that information is limited to power groups such as scientists, corporate conglomerates and government, none of which they can trust. Sources of funding are never easy to ascertain.
- The chief source of public information – the media – have a confused role. Are they media hype merchants, or merely servants of the interests of the scientists?
- There are shortfalls in science education. Not only do people misunderstand issues such as risk and the scientific process, but science education needs to change in order to attract future researchers.

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 (good-will). 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, competence, caring, and predictability. Other researchers have generated similar lists: e.g., competence, objectivity, fairness, consistency, good-will (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 good-will, and the congruence of their outer and inner persons, i.e., that they are who they appear to be. Moreover, they are principled persons, 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. This long-known tendency (see, for instance, Pruitt and Rubin 1986) has been called "the asymmetry principle." Not only are trust-effacing events more noticeable and carry greater weight, bad news tends to be more credible and reinforces existing distrust. "When it comes to winning trust, the playing field is not level. It is tilted toward distrust" (Slovic 1999, p. 698). 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 the future.

In matters of science and technology, on what bases do the public trust or distrust scientists and science organizations? Recent discussions among sociologists of science have linked trust to knowledge differentials between the lay public and the experts. Some sociologists hold that the lay public are essentially captives of expert opinion and thus can only realistically decide which group of experts to trust. The public are told about risks that they cannot see, are given limited information, and must extrapolate degrees of hazard from indirect sources of information. This condition is one of high systems/information uncertainty and low input into decisions (called "post-normal science" by Functowicz and Ravetz (1991). Trust, then, is based on social factors outside the actual content of the science itself, e.g., on the perceived motives of the expert organizations or performance history (cf. Giddens 1992; Beck 1992). Other sociologists hold that the public can indeed compare scientific knowledge claims to their own knowledge (also called "local knowledge") gained from frequent personal observations and experience (Wynne 1996). However, their knowledge often holds little interest for scientists and is rarely translated into influence over scientific projects.

In our practice, we have found that non-scientists exhibit behaviors consistent with both of these views. Sentiments of trust are often based on the past performance of science organizations or on the scientists' interest in and commitment to the local community. However, personal, experiential, and shared knowledge also plays an important role in expressions of skepticism, suspicion, and feelings of frustration and powerlessness in the lay public. Besides knowledge differentials, trust is also affected by a differential of social and intellectual legitimacy, which the public often perceives as an question of social control (Whose voices will be heard and which kind of knowledge will be credited as legitimate?). It is unfortunate that discussions of social legitimacy have often become cheering contests for scientific knowledge versus local knowledge because the reality is anything but a simple dichotomy. In fact, public trust of scientists and science organizations, when they intervene in local communities, is suspended between issues involving both differences in knowledge and power. Organizations that define themselves as "knowledge organizations" ignore local claims to knowledge and authority at their own risk.

Trust and Expert Knowledge. In many respects, non-experts often have little choice but to trust experts – a situation that can contribute to resentment and suspicion (Johnson 1999). Because we are all non-experts in nearly all specialties, we are all familiar with dependence on specialists. Even if we are experts in a field, we probably intuitively understand what may increase distance, distrust, or resentment. As non-experts, 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. For instance, how do we know that a medical specialist is recommending surgery for our benefit and not for his? Moreover, in an age when an increasing amount of science is funded by for-profit corporations, trust is strained by the possible conflicts between profits and people.

In setting up dialogues between scientists and non-scientists, we have heard members of the public express similar concerns about local government science programs. The trust-related concerns about what the experts are doing is frequently expressed in a variety of forms, but takes a handful of themes; among them are the following:

- the relevance of scientific knowledge for people's lives in a community - One local resident told a scientist, "I think most of us want to know how anything you do applies to me."
- the disjunction between the issues that scientists work on and those that affect the public – A local resident noted that "scientists in the lab have perhaps a perception of their needs and the stakeholders, in general, being stakeholders, have a perception of their needs. There needs to be an interface to be sure that the research going on is then equaling that need. And then you have a support base for moving forward." Another resident asked: "'What do we need and why do we need it?' That should be driving science. There's a lot of needs that I see that still aren't even being met regarding some toxicological issues and things like that." (4, 1L, 29-30)
- the desire to see time-frames for outcomes from an investment in science programs – A scientist responded in a focus group to a question about time-frames by noting the difficulty in matching a scientific frame of reference with one that the public or press can relate to: "Do we think that we will completely, uh, fix the site in 20 years or 30 years, something like that? I mean that's - it's so difficult to predict something like that. It's something that's of concern to public affairs. So, how do you answer something like that? I mean I couldn't answer it." He confessed to being "unsettled" by the question and brought up the difficulty of scientists in having adequate public communication: "How do you have that kind of…like communication with, uh, uh, community involvement, public affairs? You know, how do you relate it? Or the answers to subjects like that?" (4, 1L, 46)

Trust and Local Knowledge. Besides the strain put on trust by dealing with experts (and competing experts), there is the strain that arises when scientists appear to be discounting local and personal knowledge that does not come from scientists – people's observations and experience of their jobs, local environment, or even their bodies. Brian Wynne has observed that lay people experience not value-neutral or meaning-neutral interventions from scientists into their lives, but interventions that are based on normative assumptions about them and their lives that are often inaccurate or indifferent to reality (Wynne 1996, p. 68). Whereas our personal knowledge is local and personal, scientists are perceived as bringing standardized assumptions into a complex uncontrolled environment. Although their knowledge may have been obtained and tested in numerous field situations, their conclusions have probably been forged in the controlled conditions of laboratories. Indeed, the power of scientifically derived conclusions is in its claims to predictable knowledge based on known variations. However, local variations may not be known or appreciated among scientists. Thus, public gratitude may be mixed with public frustration: Are scientists and their organizations really listening? Are they using local knowledge?

For non-scientists, uncertainties are different than for scientists. Non-scientists see uncertainties about science occur

- in information created outside their own knowledge-generating system (uncertainties created by degrees of knowledge deficits)
- in degrees of risk/hazard
- in how much say non-scientists (or which non-scientists) have over the process and outcomes of a scientific project and
- research results that are not clear about the study's "ignorance" or "indeterminacy" factors – Wynne defines "ignorance" as those areas that a research project ignores, as necessarily excluded from a focused study. "Indeterminacy" is the open-endedness common to biological systems, in which it is unclear how an agent will actually behave (Wynne 1992).

For scientists, uncertainties cluster around research design and directions. Besides research variabilities captured statistically, scientists are also subject to various degrees of task certainty, that is, the degree to which the research is clearly occupying a relevant niche in the field. This uncertainty can affect how much scientists share with non-scientists or those outside their field. Higher task certainty means that scientists are less likely to adjust their research to outsiders. Directions are set from within the project or program. A lower task certainty means that directions can be influenced more easily by others (Bunders 1987).

Among the themes we have heard from non-scientists are

- the need for demonstration of inventive scientific approaches in environmental cleanup,
- the need to clarify the purpose of a scientific program and its methods and expected outcomes, and
- the desire to interact with actual scientists and share information about local conditions and needs.

Taking Precautions. A much-discussed topic that is closely related to trust is precaution. Precaution is the preemptive actions taken to avert harm. Because there are warnings but no damage yet, precautionary actions often take place in the absence of specialized knowledge (information and skills applicable to a potentially or actually harmful circumstance) and without the power to control a possibly dangerous situation. Precaution often accompanies and enhances trust. Scientists in a bioremediation field project, for instance, conducted in full view of a local community, found that they allayed residents' fears, in part, by showing them their contingency plans in case of accident or uncontrolled releases of microbes.

Both conditions are responses to conditions of limited knowledge (uncertainty) and limited ability to act. The object of precaution, however, is slightly broader than that of trust. Whereas trust normally is thought to refer to persons ("Can this person [program, agency, corporation] be trusted?"), precaution embraces both persons and circumstances by asking the question, "How can I increase my likelihood of safety?" As these questions suggest, precaution is the active counterpart to trust, which tends to be passive and receptive. Because taking precautions involves taking actions, it is a more popular option than being at the mercy of experts' plans. It also conveys a sense that the public's primary concerns, such as avoidance of harm, are being addressed.

Precaution is most often discussed in the abstract as the "precautionary principle," a concept of national and international regulation of potentially harmful scientific programs or applications. Taking precautions, as a government or geopolitical policy, can be found in treaties, laws, regulations, and position statements from the last 30 years.[(a)]

Philosopher Neil Manson, after reviewing a variety of versions of the precautionary principle, found that every version shared a three-part logical structure (Manson 2002, p. 265):

(a) The best-known examples are probably the Rio Declaration and the Framework Convention on Climate Change; however, the principle has also been part of other treaties, declarations, and regulations of note: e.g., the treaty that established the European Union (Article 174); the stated policy of the European Commission ("Communication from the Commission on the Precautionary Principle," Brussels, Feb. 2, 2000); and the Cartagena Protocol on BioSafety. Regulation in the United States was conducted on a precautionary basis until 1980, when the United States Supreme Court admonished the Occupational Safety and Health Administration (OSHA) for exerting too much conjecture about risk in the case Industrial Union, AFL-CIO v. American Petroleum Institute, also known as the Benzene case (see Wiener 2002 for a short summary of appearances of the precautionary principle). The formal use of the precautionary principle as a mode of policy-formation has come under intense criticism in recent years.

Critics of precaution base their critiques on its limitations as a formal principle of policy. They note the tendency of the precautionary principle to commit "false positives" – negative judgments about technologies or applications that may begin suspiciously, in considerable uncertainty, yet develop benignly. Also, they note that precaution may lead to over-reaction. This may take the form of precautionary actions that were very costly or unnecessary, or it may discourage useful innovations from being developed or even pursued. If it provides dubious outcomes, its critics argue, it provides even more dubious help in resolving the disputes that it is responsible for starting. Taking precautions as a first rule of policy leads to disputes about which precautions should dominate. The Bush Administration holds that the economy is primary, and environmental groups hold that environmental integrity should be primary. The principle thus raises the issues but cannot be applied to resolve them because it "provides no mechanism to reconcile disputes about how to make trade-offs between competing values" (Pielke 2002, p. 433).

> The first part is the damage condition; it specifies the characteristics of an e-effect [environmental effect] in virtue of which precautionary measures should be considered. The second part is the knowledge condition: it specifies the status of knowledge regarding the causal connections between the e-activity and the e-effect. The third part specifies the e-remedy that decision makers should take in response to the e-activity.

What Should We Do About Trust? 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, non-scientists 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).

T.5.4 What Do We Know About Scientist/Non-Scientist Interactions?

The prima facie understanding of the difficulties in expert/non-expert interactions is that the scientific content is too complex and technical for public comprehension. Thus, commenters and researchers tend to assume that the central factor in the relationship is disparity in knowledge (e.g., Garvin 2001). However, there are several important factors, embracing both knowledge and common social practices, that influence how non-experts form judgments about information from experts and vice versa: differences of language, the public's lack of direct agency (i.e., control or meaningful input), and the pervasive use of information as persuasion.

Differences of Language. To complicate the matter, expert knowledge is revealed primarily in specialist concepts, more or less articulated abstract ideas, which often evolve out of common language. In turn, common language picks up concepts and vocabulary from frequently heard or reported scientific usages. Terms used in science, such as "conservative," "complexity," or "inheritance," for instance, are cognate (i.e., common with) everyday usage but carry different or more specific meanings. It is often unclear to what degree the concepts underlying the lexical usages overlap, so establishing common ground can be difficult. Scientists and non-scientists, then, can suffer a mutual deficit, in the sense of being uncertain about the grounds for the other's conclusions. However, experts cannot ignore non-experts' understanding, either:

- Experts are no teachers, and in most contexts they have little time and do not intend to systematically dissolve the qualitative and quantitative difference between their professional perspective and laypeople's ideas about the topic in question. On the other hand, clients, customers, and patients are supposed to make "informed choices." For example, the final decision about an operation has to be made by the patient and not by the doctor. In this case there is a mutual dependency as experts also need information from their clients. As there is usually not enough time to establish mutual understanding from scratch, the expert's a priori ideas about the knowledge of the lay-community are of critical importance. (Bromme et al. 2000)

Lack of Agency. Experts in particular should appreciate that the public may be keen about advancing the interests of science and, indeed, be capable of understanding a great deal, but without being able to do anything about the science or its applications. This lack of agency might encourage a lack of interest, particularly in topics that are difficult to explain and understand. Although a considerable body of research has been done on *decision-making* in conditions of uncertainty, non-scientist members of the public may have few or no decisions to make, particularly in being exposed to programs in fundamental science. 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.

- Often, however, people are not poised to decide anything. Rather, they just want to know what the risk is and how it works. Such substantive knowledge is essential for following an issue in the news media, for participating in public discussions, for feeling competent to make decisions, and for generating options among which to decide. In these situations, people's objective is to have intuitive theories that correspond to the main elements of the reigning scientific theories (emphasizing those features relevant to control strategies). (Fischoff et al. 1993, p. 194)

The Ionized Field of Public Discourse. It is often thought that scientific information – obtained in controlled settings, emphasizing controlled findings, reproducible, and analyzed and discussed carefully and rationally – should enter public discussion as claims to fact. However, scientific information is often introduced to a wider audience than it might normally be because it is relevant to a public issue. Even fundamental science that is not being conducted on topics in the news may be treated as special pleading if it comes from an organization that has a questionable reputation. In discussing material developed by the DOE, for instance, we found that the public considered even some fact sheets as exercises in persuasion rather than simply information (Weber and Word 2001). Because they were suspicious of the motive behind the information, facts placed in their field of discourse became charged with the force of controversy. Even non-scientists who are not overtly political place scientific information into social frames. After listening intently to scientists engaged in site-remediation activities at a contaminated weapons lab, an alarmed non-scientist asked what they were going to do when they were finished with the task, whether they realized that they were putting themselves out of a job and the local community out of a valuable social and economic resource. Public discourse requires that scientists give heed not only to scientific concerns but to non-scientific concerns – a requirement that may come as a surprise when a scientist wants simply to speak as a scientist. A scientist in a group discussion noted that scientific and technical training educates one to focus on certain kinds of issues to the exclusion of others: "They really are issues; it's just that we don't think they are because we think technically that they are non-issues, technical non-issues."

T.5.5 Sense-Making

Given these complicating factors, how do expert and non-experts make sense to one another about science? Perhaps the primary activity of non-experts in getting information from experts is to make sense of the encounter, understanding what is being said and relating the information to their own needs and environments. Social psychologists have identified a number of elements used in making sense of situations. Karl Weick, for instance, has noted that people's sense-making involves coordinating three essential elements: a frame of reference (more abstract), numerous details of evidence or verbal cues (that make little sense when standing alone), and relationships (either emergent or created) among the bits of evidence and between evidence and frames (Weick 1995, p. 110). This kind of social (situational) framing is essential to the public understanding of science because meaning arises from the relation among bits and evidence and between evidence and frames of reference.

For instance, one might reasonably characterize the public's perceptions of science as a trade-off between the frameworks of *danger* and *opportunity* (Margolis 1997). 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. "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). In other words, *felt* dangers are cues that are significant in triggering the public trade-offs, whereas they are not part of scientists' frameworks. If we think in terms of sense-making, differing frames may account for one peculiarity of scientist/non-scientist conflicts: 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).

Certainly, it is not often important that experts and non-experts fathom all the depths of their differences or similarities. It is enough that they can establish common ground somewhere. As we have noted above, exchanges between experts and non-experts are usually not exclusively or even primarily about scientific information. The exchanges are permeated with background considerations – social, political, and cultural – that may be impossible for either expert or non-expert to fathom.

T.5.6 Tools and Problems in Sense-Making

Public sense-making may thus give rise to behaviors and thinking that may compensate for the lack of technical knowledge, which is part of the science frame-of-reference. Taming the knowledge/power differential and equalizing the standing of participants in a discussion is one vital step in sense-making (Dervin and Frenette 2001). Faced with a trade-off between danger and opportunity and a knowledge gap (therefore, a power gap), non-scientists reach for solid ground in evidence that they 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,” which is simply a recognized frame of reference, 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 available to the sense (sensible), e.g., visible effects such as automobile emissions or cutting trees. Studies in common sense qualitative reasoning have found that what we call common sense comprises some surprising lines of thought. It is normally (a) incomplete (focused on only a few pieces of information), (b) concrete (tending toward relating pieces of evidence rather than developing frames of reference), (c) highly experiential (rather than abstract), (d) focused (reducing uncertainty and ambiguity in favor of closure and exactness), and (e) pervasively quantitative (that is, impressions tend to be reduced to exact values, presumably in order to reduce ambiguity) (Paritosh and Forbus 2001).

The drive for focus, concreteness, personal observations, and lack of ambiguity seems to dominate, at the expense of qualities that might provide more framework and relational information, for instance, making comparisons with others’ experience and resolving contradictions and ambiguities with more information. The differences in how experts and non-experts in a field view issues seem to focus on differences (a) in distinguishing causes from effects and (b) on perceptions of the frequency of events. Thus, common-sensical judgments that seem plausible even to educated people can lead to mistaken ideas. For instance, in a series of studies of non-experts’ understanding of global climate change, even highly educated non-experts displayed a spotty mastery of the facts. In two misconceptions, in particular, subjects elevated chlorofluorocarbons to a larger role than energy use in inducing climate change; they also missed the key role of carbon dioxide, emphasizing ozone depletion instead (Bostrom et al. 1994; Read et al. 1994).

How can experts and non-experts change their frames of reference or introduce new bits of significant information (cues) into their sense-making? Our observations are that they use three tools of sense-making: learning through correction of misconceptions and exposure to other frames, reducing the complexities that separate them, and adopting orderly, usually intuitive, means of information-seeking and evaluating.

Opportunities for Learning. Discerning whether someone is learning from an explanation or demonstration can be difficult. It is difficult enough in a classroom setting, but it is more so in a relatively less controlled setting, such as speaking to non-scientist members of the press, policy-makers, or interested citizens. Neither the scientist nor the non-scientist can test for the other’s understanding of an explanation, terminology, or background concepts. Instead, the best that can be done is informal, socially adept questions or observations of responses. In social interactions, we do not look for mastery of concepts, detail, or terms. Instead, if we are seeking evidence of comprehension, we tend to probe the other person’s attitudes or understanding by “reading” the evidence of their language or by inducing a response from them to our own questions or comments. In this way, we can gauge, albeit imperfectly, their existing degrees of knowledge and perhaps their attitudes. By comparing our impressions of their initial state of mind to that after some exposure to our input, one might be able to make a guess about whether learning has occurred or might occur.[(a)] Indeed, what such encounters may provide are indications of others' willingness to learn and an increasingly informed series of questions.[(b)]

Our experience conflicts with the approach of many textbooks, which adopt a sequence that first provides a novice terminology, just to get started, and then some conceptual underpinnings, and then concentrates on essential dynamic processes, perhaps with case studies or problems attached, and finally covers more sophisticated terminology and concepts, which are built on earlier lessons. Clearly, this approach will not work for public encounters. Instead, informal interactions between scientists and non-scientists tend to focus on reasons, problems, and people:

- Why is something being done (or studied), or why does it need to be done (or studied)?
- What are the pathways to achieving the desired outcomes (knowledge, etc.)? What are the biggest roadblocks? What pathway is the most promising?
- Whom does this affect?

Placing new information about these topics into someone's repertoire may actually be easy. However, information is not all that passes between people in science communication. Most often, we also confirm or supplement existing personal networks of information, and this process is the most problematic. To communicate in the hopes of teaching – or at least exposing someone to a body of information – means encountering, whether you know it or not, other people's in-grained more or less fixed ideas, which are part of their frame of reference. It also may mean encountering your own fixed ideas.

The presence of fixed ideas need not be debilitating because the process of learning appears to be, in part, a process of recognizing them in ourselves and others. Learning involves at least two cognitive phenomena that reveal differences and create common mental structures: probing for mental models can lay bare existing conceptions and differences in understanding, while analogies and metaphors use a process of reasoning that creates more links to common familiar experience.

Mental models are intuitive theories of how the world works; they are personal, often complex, and often unarticulated. They are like self-conceived pictures of how things, social or physical, function. Ask someone how cigarettes cause cancer and you will receive an explanation based on a mental model of how bodies can be corrupted with carcinogens. Psychological studies have examined the role of mental models in a wide range of fields. Although narrower in scope than frames of reference, a mental model of a scientific or technical process can reveal much about one's understanding. Mental models are particularly helpful in identifying misconceptions in one's understanding of processes. Bostrom et al. found that, though people know the physical properties of radon (colorless, odorless, and radioactive), some people believe radioactivity to be a permanent contaminant (Bostrom et al. 1992).

Consequently, they might either overestimate radon's risk or despair of correcting a household radon problem, assuming that the problem is hopeless. In discussions on bioremediation that we have

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(a) The first requisite of sense-making, say communication scholars Brenda Dervin and Micheline Frenette (2001), is being able to describe one's own experiences, understandings, and meanings.
(b) In the spirit of these sensible constraints, some veterans of scientist/non-scientist interactions hold that listening, though not to be mistaken for learning, may be the true accomplishment.

monitored, non-scientists have difficulty understanding how researchers can be sure that once microbes' metabolism is accelerated, they will return to their previous numbers and approximate home locations. Their mental models of population explosion and decrease seem to imply migration rather than a return to origins.

The implication of an underlying analogy has led some cognitive scientists to posit that analogy lies beneath many mental models. Analogy is a powerful tool in description and is often used in conveying new information, partly because it makes use of existing information or frames of reference. Linguists George Lakoff and Mark Johnson have emphasized the elemental, formative character of metaphors and analogies in forming concepts (Lakoff and Johnson 1983). The primary form of both analogy and metaphor is "T is like B," where T is the "target" idea and B is the "base" idea. "He is like a giraffe," for instance, uses the base idea (the giraffe) to describe a person (the "target") who may not be familiar to a listener. Analogies promote comparison of essentially similar (often visual) properties but few attributes of either the base or the target. For this reason, some scientists are loath to use them – and may discourage their use when they are volunteered by a non-scientist. However, analogies are essential in learning and should be corrected rather than discouraged. This is because complicated scientific information can be conveyed in its essential properties by analogy, which can function as a mini frame of reference for future discussions between scientist and non-scientist. Comparing sub-surface microbial communities to bird sanctuaries, for instance, gives a sense of the nature of microbial communities – their need for sustenance, their dependence on and creation of their environmental conditions, and the reasons for populations to grow and decrease. Clearly, analogy can evoke powerful and lasting images, often drawing on primitive and abstract relationships. The image of familiar ecological communities, for example, draws from the abstract metaphor of groups-within-groups, which in turn is a version of the container metaphor, both being basic cognitive forms (Lakoff and Johnson 1980; Gentner 1983). Generally, because of the constraints of time and language, analogies can allow a common frame of reference to develop quickly and, by importing more complex relations of ideas into a discussion, can hold mutual interest.

Reducing Complexity. We have heard some scientists express misgivings about creating common ground between scientists and non-scientists. Those interactions, even when they seem to be successful, necessarily reduce both scientific and social complexities to common statements and common knowledge domains. That is, although they can indeed create a common frame of reference, is that a good thing? So much science is lost, these scientists say, that we run the risk of misleading the public.

For instance, scientists often express frustration at non-scientists' ignorance of the scientific method and the processes of gaining scientific information. Non-scientists are not often acquainted with scientists' everyday balancing of certainty and uncertainty and are often mystified by the vague demarcation between scientific fact and the unwillingness of scientists to say that something is true. Common parlance uses confidence and certainty as internal (psychological) categories. For some, the idea of degrees of certainty sounds suspiciously like saying that something is factual to a degree. In business, uncertainty and indecision are often considered synonymous. Moreover, uncertainty implies ambiguity and lack of closure, i.e., no certain facts from previous work and much more work ahead. Thus, public pressure on scientists is toward certainty and away from ambiguity and complexity. The pressure is to change the uncertain to the known, the complex to the straightforward, and the arcane to the familiar. The pressure is also to have a committed vision from scientists and a committed response to questions. “Certainty,” says sociologist Dianne Vaughn, “tends to vary inversely with proximity to scientific and technical work” (Vaughn 1999, p. 930). However, scientific work is often a process of reducing but not fully allaying uncertainties. A better, fuller explanation is always possible.

The reduction of complexity is surely one mark of science communication. However, scientists should not view this process as somehow “unscientific.” Before presentational constraints are met, scientists and other experts have to deal with an everyday workplace that can produce unruly knowledge and interpretive flexibility (Vaughn 1996). Some science is, by its nature, more unruly than others. Unruliness describes the fluid and unexpected features, the surprises that occur often *in vivo* and regularly *in vitro*. Learning occurs not only in controlled settings but also from experience. Science that is unprecedented, studied for the first time, may be unruly. Interpretive flexibility arises from conflicting perspectives of meanings and is characteristic of science that studies complex conditions.

However, when the work must be reported, a process of focusing and condensing occurs to emphasize features that show the underlying orderliness of the research design. Whether speaking to scientists in other disciplines or in reducing the process and binding up experimental loose ends in a journal article, scientists, like other professionals, tend to focus and condense. Although the unexpected may be eagerly reported, it is put in its place and evaluated for relevance and significance. Scientists, like other experts, want to produce orderly displays of knowledge that remove equivocality and assert something defensible.

The process of reducing complexity that we observe between scientists and non-scientists has also been observed taking place between various disciplines and subcultures of scientists. Peter Galison, a physicist at Harvard University, observes that scientists from different backgrounds or experience form *trading zones* in order to share information and look for common interests (Galison 1997). Indeed, trading zones are the glue that holds a discipline together, since most disciplines are composed of autonomous, diverse subcultures. The differences between the work and professional cultures of scientists and non-scientists appear to be at least comparable, and Galison’s observations of trading zones are typical of scientist-non-scientist interactions. Trading zones comprise three kinds of activities:

- Creation of a boundary-spanning language – Galison identifies this as either a “pidgin” or a “creole,” where a pidgin is a reduced set of commonly understood terms and a creole is a combination of common language and pidgin.
- Creation of common domains – These could be either physical (a common meeting or working place) or social (a virtual web domain, for instance, or mutual affiliations).
- Use of various other transfers, appropriations, and adaptations – Using or converting an out-of-discipline term, for instance, can establish linkages.

It is reasonable, too, that trading zones will operate by some informal rules that reduce the effort to reach a common understanding, which at times can be considerable. In interactions with scientists, non-scientists may indulge in a good deal of tacit agreement, implying a mutual understanding or acceptance of what is being said. However, they may also interrupt and, disconcertingly enough, introduce new topics (side-bars) into the conversation. Studies of efforts at collaborative communication suggest that this is a common effort when people seek to decrease the difficulty in following a new line of thinking (Clark and Wilkes-Gibb 1986). Returning to familiar conversational ground, by making a joke, referring to personal experiences, or redirecting a scientific discussion to a policy discussion, re-establishes common ground and the mutuality of the interaction.

Stases. By observing interactions between scientists and non-scientists and reviewing the transcripts of those interactions, we have observed that the public's questions of scientists are neither unstructured nor irrational (Schell-Word et al. 1999) even though they may appear to be arbitrary. In fact, the issues raised, comments offered, and questions asked formed a pattern much like an ancient method of rhetorical issue-definition, called stasis theory.

In rhetorical theory, the *stases* of a discussion are those issues on which talk is likely to focus. According to rhetorician Lawrence Prelli, "The Greek term stasis, the Latin term status, and the English term issue all refer to the same phenomena" (Prelli 1989, p. 44). The stases anticipate an audience's potential assumptions and thus their issues and concerns (Fahnestock and Secor 1988). However, they are not narrowly predictive, e.g., guessing at exact wordings or an exact sequence of topics. Instead, they are broadly anticipatory, allowing one to prepare for plausible comments and questions, which may take a variety of forms. Together, the stases form a heuristic or rule of thumb.

Rhetoricians have settled on four areas that yield essential issues in discussion or debate: problems of fact, problems of definition, problems of the nature of a thing (i.e., What sort of thing is this?), and problems of appropriate action (Prelli 1989). These points of stasis are the matters around which opposing lines of reasoning or understanding will probably form. In the original use of stases, those preparing for debate or court could use these points for reflection and preparation to anticipate alternative and opposing arguments. Drawing from past experience of the range of viewpoints on a matter and role-playing, speakers could anticipate objections, work up answers, and develop counter-arguments.

For the purposes of interactions between scientists and non-scientists, stases allow the participants not only to anticipate but also to recognize the categories to which individual comments or questions may belong. In our study of stases in scientist-non-scientist interactions (Weber and Word 2002), the patterns suggested that there are patterns of informal interactions, that these patterns appear regular enough to suggest strategies, and that these strategies involve discovering and evaluating information and issues, both those potentially recognizable to all participants and those new to at least some. In informal scientist-non-scientist interactions about a government science program, we have observed the following stases:

- Fact-finding – background, methods, findings, purpose of research
- Place in the process – stages of development, current stage, hurdles for future work, projected final products or actions
- Requests for definitions or clarifications – terms needing definition, revisiting topics raised earlier for more information or alternative explanations, requests for examples or illustrations
- Observations on value – the quality of the program, the rightness of research, applications or procedures (either programmatic or scientific), the worth of the outcomes, the relative benefit considering costs and time spent.

As elemental units of issue-discovery, stases may occur singly, in pairs, or interwoven in groups. For instance, clarifications often follow either questions/statements that are value-directed or that require information on the place in the process.

Table T.3 compares scientists' and non-scientists' 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/non-scientist interactions. Both scientists and non-scientists 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 lesser extent, to predictions, and for non-scientists to ask for facts and predictions and to make statements about values and policies.

Table T.3. Common Questions by Question Type and Frequently Raised Topics

	Risk	**Prediction and Results**	**Policy Implications**	**Costs**
Fact-Finding	Are there dangers? Is there past evidence of danger? What are the benefits of the research?	What will be the applications for this research? What sorts of development can we expect in the meantime?	What is the purpose of the program? What is the funding? How is it determined and allocated? Is this a long-term or short-term commitment to the community/ region? How will you share the information you gather?	How much is budgeted/ spent for the research? What costs the most? What are the funding priorities?
Defining/ Clarifying	What do you mean by a risk? How serious are the risks?	How likely is it that your current interpretation of data will change? How will the research findings affect us? Is this work like anything we might be familiar with?	Is genomics [or some other controversial topic] part of the program? Programmatic acronyms/terms defined. How closely aligned are programmatic goals with community (local) concerns?	Definitions of terms, e.g., funding cycles, contractors, etc.
Determining place in process (implementative, procedural, positional)	How certain are you of future risks? How are you [will you be] monitoring? Are there contingencies for stages of the research?	When will your goals/future developments be achieved? When will there be applications? Will the research be commercialized?	Whom will this research benefit? Can/should the work go faster? Is the research politically supported? Who has the authority to support or suppress the program?	What has been accomplished thus far for what has been spent? What remains: in program goals? In funding to reach goals? Provide an estimate of past/future costs and accomplishments.
Evaluating	Are risks greater than the benefits? Should the research be continued? Is there a chance of environ-mental damage or unwanted outcomes (the cure worse than the ills)?	Are the outcomes acceptable? Are the means to the outcomes acceptable? How important is this research compared to other research?	Why should we trust DOE? What are the regulatory constraints on this research? How are they being observed? Is this science for science's sake, or does the program have demonstrable applications as goals?	Will this program be cost-effective, e.g., in generating valuable, commercializable applications? Is this work taking money away from higher priorities?

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