When Science Meets the Public

Proceedings of a Workshop
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Acknowledgments

This book is the product of a workshop held at the annual meeting of the American Association for the Advancement of Science in Washington, DC, on February 17, 1991. The workshop was organized by the AAAS Committee on Public Understanding of Science and Technology (COPUS&T), led by chairman Sheila Grinell and staff officer Patricia S. Curlin; help came from COPUS&T members Valerie Crane, Michael Templeton, and Talbert Spence, in conference with Sharon Dunwoody at the University of Wisconsin—Madison. Support from the AAAS staff came from the staff of the Education and Human Resources Programs Directorate. At the workshop and later, while editing the proceedings, I had the help of Steven W. Allison and Michele Finkelstein, as well as institutional support from Cornell University's Department of Communication. Production of the book was ably assisted by Maria Sosa and Gloria Gilbert. Thank you to all those who helped.

Foreword

Sheila Grinell

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The workshop documented in the following pages was organized as an experiment. Members of the American Association for the Advancement of Science's Committee on Public Understanding of Science and Technology wanted to test the hypothesis that all science communicators—newspaper reporters, TV documentarists, museum exhibit builders, science club organizers, corporate and university information officers, and the researchers who work with them—can benefit from joint discussion of the common ground in science communication. In designing the workshop, we began to explore that commonality and to examine the uses that members of the public make of our various efforts.

Science information reaches the public through media and institutions that are isolated from one another, that often have commercial motives, that reach different audience segments, and that use different communications strategies. The people who work in these institutions become experts in their own fields, but often have little contact with other media. There are few opportunities to share significant research results or critical experiences across the science communication media; there are few opportunities to explore effects and alternatives from the point of view of society as a whole. Our workshop was organized specifically to fill this gap.

The response to the workshop convinced us that science communicators and researchers want to share a larger view of their work. Over 100 people from different media or with different research interests came to the workshop to hear and question 20 panelists with different perspectives. The exchange was invigorating and remarkably consistent, and there were requests for more. Hence, additional workshops are being planned, each of which will explore an aspect of science communication across media and will be sponsored jointly by AAAS and by the British Association for the Advancement of Science.

We hope that this volume, and the subsequent workshops, will stimulate fresh and useful thinking about how science works its way into public discourse. We hope that they contribute to the ongoing refinement of research questions and the enhancement of practical techniques in all

Introduction

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Many people support "public understanding of science"—but they don't always agree on what the phrase means. Since the early years of the 19th century, when large numbers of scientists, educators, and other community leaders began to notice that science was becoming too specialized for many nonscientists to follow, leaders of the scientific community around the world have called for more and better efforts to encourage public understanding of science. Scientists have created and supported a wide range of communication efforts—from demonstration halls and public lectures in the mid-1800s through mass-circulation magazines for armchair scientists in the 1980s, from natural history museums of the 1880s through interactive science centers of the past generation, from chatty television shows like Don Herbert's "Mr. Wizard" through multimedia extravaganzas like Carl Sagan's "Cosmos," and from programs at youth clubs through adult education classes—all in an effort to keep nonscientists informed about the developments of science.[1]

This history is relevant to those of us who believe that science can help solve many of the social problems faced by the world today. We are concerned about the clear gaps in the public's knowledge of science, and public understanding of science is for us an important goal. Some of us want a public better able to judge between competing technical arguments on such topics as energy conservation, solid waste disposal, pesticide risk, and social welfare policy. Others of us want a public more capable of distinguishing between logic and trivia in debates about government budgets. Some of us want more young people, of all genders and races, to include science in their dreams about how they will spend their lives. And still others of us want mainly for the public to comprehend the beauty and intellectual challenge of the ideas that we believe are central to science.

Yet no matter what motivates a concern for public understanding of science, the issue is one of the most intractable and important facing our society today. From the founders of Britain's Royal Institution at the turn of the 19th century, to the proselytizing scientific lecturers who traveled across England and the United States in the late 1800s, to Harvard president (and chemist) James Bryant Conant's 1947 call for understanding science, to C.P. Snow and his 1959 warning about the development of two separate cultures, to studies in the 1980s by the British Royal Society and the American Association for the Advancement of Science (AAAS), the issue of public understanding of science has remained central to the complex relationship between science and society.[2]

Like science itself, the study of public understanding of science is fragmented. In one strand, researchers have been looking for more than 50 years at science journalism, asking how science is reported as news—and how that reporting could be improved. Another strand, evaluations of how well museums present information, stretches back at least to the 1920s. In more recent years, a separate literature has developed on science literacy, including both studies of the public's knowledge of particular scientific and technological topics as well as prescriptions and plans for addressing the lack of knowledge on many topics. And in the community of historians, sociologists, philosophers, and others who take science itself to be their subject, public understanding of science has been one of the emerging issues of the last two decades.[3]

Because of this fragmentation, it has been unclear whether the many separate fields with an interest in public understanding of science—including both practitioners and researchers in the areas of journalism, museums, science education, and science studies—could come to any consensus. Do they agree on what the public knows about science and technology? Do they agree on what the public *should* know about science and technology? Do they know how best to convey information about science and technology to the public? Are there areas of overlap or, worse, contradiction between different approaches to public understanding of science and technology? Does anyone know if the right questions are even being asked?

To explore these questions, the AAAS's Committee on Public Understanding of Science and Technology (COPUS&T) organized a workshop in February 1991, at which the talks and papers collected in this volume were originally presented. COPUS&T believed that museums, newspapers, magazines, children's clubs, television shows, government offices, and all other institutions devoted to public understanding of science were in fact dealing with the same issues. It believed that the researchers who look at each of these institutions, and the practitioners who turn the ideas of these institutions into physical products, are each working with the same materials. The goal of the workshop—and thus, of this volume—was to see whether these disparate groups could speak the same language and contribute to each other's fields. COPUS&T suspected that common themes would emerge and that progress in all the fields that make up public understanding of science would be served by making those common themes clear.

The fundamental belief held. Not only did all the groups speak each other's language, but they came to remarkably similar conclusions. Those conclusions can be summarized by a single statement: Whether one is concerned about production or research, about television or museums, about literacy or critical thinking, new ideas in this field will come only when we take the perspective of the *audience*. It is the audience that practitioners are trying to serve. Though supporters of public understanding of science may have many interests of their own, these interests are not necessarily the interests of consumers of information about science—the audience. To understand what information is important, to understand what techniques work, to understand how and why and where and when to achieve public understanding, we need first to understand the audience.

This audience-centered perspective leads to a criticism that is implied in many of the papers in this volume, though it is rarely stated explicitly: We are wrong to devote energy to jeremiads about the state of science education or about the need for greater public understanding; we are wrong to focus too much on studies of how journalists and museum curators go about their work. These topics are important only to people who are already convinced that public understanding of science is critical to the future of our society.

Instead, the papers in this volume urge people concerned about public understanding of science to focus on the audience side. Most fundamentally, these people must ask: What does the public perceive when it encounters science? Only when that question is answered can practitioners, researchers, and others proceed to—and eventually answer—questions about what methods of production are most suitable, or what training is appropriate for science communicators, or other questions that have occupied this field for years.

The papers in this volume are divided into five major sections. The first section (*The Need: Why Should We Understand Public Understanding of Science?*) contains an eloquent call to reassessment by physicist Philip Morrison. Continuing in the long tradition of eminent researchers who have devoted significant efforts to public understanding of science, Morrison considers the role of science in modern culture. By comparing science with sports, another central element of modern culture, Morrison shows how widespread understanding can be—if only we learn to recognize what understanding means for the public.

Morrison presented his ideas ("more than a metaphor, less than a model," he said) at the beginning of the workshop; they struck a chord and many speakers referred to them throughout the day. Thus it is important for us to explore their implications. Sports is widely understood in our culture because virtually everyone is at some time an amateur participant in sports. But we don't have a good "amateur" role for most aspects of science—we need to develop one. Similarly, sports offers many opportunities for passive spectators to watch professionals (and amateurs) at play. Although the accounts of science that appear in newspapers, magazines, television shows, and museums help nonscientists observe science, they don't offer the same kind of immediate feedback that watching sports does. So Morrison is challenging us to find ways for the public—the audience—to experience science in the same vicarious way that it experiences sport. Then, perhaps, we will create a culture of science as pervasive as the culture of sports in our society.

The second section (*The Concept: What Do We Mean by Public Understanding of Science?*) asks us to set aside our preconceptions about what the public "needs" to know. Instead, three very different papers challenge us to step outside of narrow interests and into the perspective of the broad, general public—or, more accurately, the many broad, general publics that constantly emerge, realign, dissolve, and reemerge in our society.

John Ziman, an eminent British physicist who has devoted much of his career to understanding the role of science in society, reviews the results of several research projects initiated in Britain after the 1985 Royal Society report on public understanding of science. He shows that each of these projects, in different ways, has found that public understanding makes sense as a concept only when it is defined from the public's point of view.

Valerie Crane, a communications researcher who works with television stations and museums across the country, draws on many of her own research projects to see what happens when one takes the audience's perspective. Too many times, she demonstrates, producers of material intended to improve the public's understanding of science and technology forget to consider the public's needs. Instead, they make decisions based on their own priorities, their own interests. The result? All too often, the audience tunes out (literally). Crane includes recommendations for how to approach public understanding from the audience's point of view.

Finally, Marcel LaFollette, a leading researcher in the world of science and technology studies, reviews the perspectives that have governed much of the previous work in public understanding of science and shows how that work has failed to resolve the issue. She attributes much of the failure, once again, to the lack of commitment to taking the audience's point of view. LaFollette's comments were originally given as an ad hoc summary at the end of the workshop, which is perhaps why they are the most explicit of all the comments in this volume at urging a rethinking of approaches to public understanding.

The third section *(The Data: Studying the Audiences for Public Understanding)* offers three case studies. Each is very different, but each gives us an example of how to consider the public's perspective—the *audience's* perspective—when talking about public understanding of science. These papers are valuable not just for the results they report, but also as models for how to study the audience's perspective. Unlike the other chapters in the book, these papers were originally prepared for publication, not just oral delivery; they are more technical in nature.

Brian Wynne gives an analysis of how sheep farmers in the Cumbrian hills of England responded to government communication efforts after radioactive contamination from the 1986 Chernobyl accident made their sheep unfit for market. By forcing us to take the perspective of the farmers, Wynne shows us that their knowledge of sheep farming, market realities, local geography, and other issues is every bit as much "expert knowledge" as all the book learning and experimental data of the government scientists. What's more, the farmers' knowledge was in many ways more appropriate to the immediate context than the "experts'" knowledge. Wynne is saying that we must be careful when claiming to know what is *best* in any situation.

Kara Marchman and Janine Jason describe the careful planning and strategy of a major public health campaign. By laying out the methods and results of the Centers for Disease Control's AIDS campaign, Marchman and Jason show how the opinions of small groups of knowledgeable experts must be tested against the realities of how messages will be perceived and then recast in order to achieve the desired goals. Public relations and advertising specialists have long known the importance of researching public perceptions, but Marchman and Jason show just how wrong one can be if one fails to learn what the audience is getting from a message.

Finally in this section, Eve Hall, Shalom Fisch, and Edward Esty of the Children's Television Workshop (CTW) provide another example of how to find out what the audience is really getting from all the carefully crafted multimedia messages about science. In a thoughtfully designed experiment using the mathematics show *Square One TV*, the CTW researchers tested the goals of the television producers against the progress that students actually made in using complex problem-solving behaviors. Though the results were impressive, the real message of this chapter is the importance of testing productions against the goals that were originally set for them. It is easy to let a slick and glossy production claim that it is doing the job; only by being critical and testing the results will one really know if one is reaching the audience.

The papers in the fourth section *(The Applications: The Art of Explaining for Public Understanding)* began as a roundtable discussion about how various practitioners of public understanding of science try to produce good explanations. Each practitioner agreed that creating good materials begins only when the producer starts from the audience's point of view. Whether one is writing articles for the readers of a newspaper science section or signs for a family visiting a museum, the goal must be to learn what the audience knows and wants and to begin creating from there. The chapters here are brief, but they represent the hard-won, hands-on knowledge of people on the front line of public understanding of science efforts.

Sharon Dunwoody, who teaches and does research on science journalism, provides a short introduction to the problem of explanation; Jonathan Ward, an independent television producer, reviews television techniques; Libby Palmer, who directs an after-school program of science activities for Girls Incorporated, describes the group's methods for engaging girls in science; Tom Siegfried, a newspaper science writer and science editor, summarizes the elements of successful newspaper explanations; Robert

Sullivan, associate director for public programs at the National Museum of Natural History, describes the goals and techniques of science museums; and Katherine Rowan, who teaches and does research on science writing, analyzes what kinds of explanations work in different contexts—whatever those contexts may be.

The final section *(Summary: New Directions For Public Understanding of Science)* is a brief statement by Shirley Malcom, head of AAAS's Directorate for Education and Human Resources Programs, about what is learned by bringing together these papers on public understanding. Malcom is explicit in her challenge to us: One must go to where the audiences are, speak their languages, and understand their vision of science if one is ever to be successful at engaging the broad public into the enterprise of science.

Two appendices by Patricia S. Curlin of AAAS provide information about the AAAS's Committee on Public Understanding of Science and Technology, which sponsored the workshop from which this book emerged, and also list selected resources that will allow one to continue exploring the issues raised in the book, including organizations and publications.

As noted above, most of the papers in this book were originally presented orally. Although they have been edited to read more smoothly and reorganized to make the book's argument clearer, readers should take the papers—and the ideas—in the book not as finished products, but as spurs to further work.

NOTES

Bruce V. Lewenstein is assistant professor in the Departments of Communication and Science & Technology Studies at Cornell University. He is the head of a science communication sequence for undergraduate students, and he does research on the history of science popularization.

1. For introductions to these efforts, see John Burnham, *How Superstition Won and Science Lost: Popular Science and Health in the United States* (New Brunswick, NJ: Rutgers University Press, 1987); Jack Meadows, "The Growth of Science Popularizations: A Historical Sketch," *Impact of*

Science on Society, 1986, 36:341–346; Morris Berman, *Social Change and Scientific Organization* (Ithaca, NY: Cornell University Press, 1978); Steven Shapin and Barry Barnes, "Science, Nature, and Control: Interpreting Mechanics' Institutes," *Social Studies of Science*, 1977, 7:31–74; Sharon Friedman, Sharon Dunwoody, and Carol Rogers, eds., *Scientists and Journalists: Reporting Science as News* (New York: Free Press, 1986); and David Evered and Maeve O'Connor, eds., *Communicating Science to the Public* (Chichester/New York: John Wiley & Sons, 1987).

2. Berman, *Social Change*; Burnham, *How Superstition Won*; James Bryant Conant, *On Understanding Science* (New Haven, CT: Yale University Press, 1947); C.P. Snow, *The Two Cultures, and a Second Look* (Cambridge: Cambridge University Press, 1964); Royal Society of London, *Public Understanding of Science* (London: Royal Society, 1985); and American Association for the Advancement of Science, *Science for All Americans* (Washington, DC: AAAS, 1989).
3. See, for example, David Dietz, "Science and the American Press," *Science*, January 29, 1937, 85:107–112; E.S. Robinson, *The Behavior of the Museum Visitor* (Washington, DC: American Association of Museums, 1928); National Science Board, "Public Science Literacy and Attitudes toward Science and Technology," *Science Indicators—1989* (Washington, DC: National Science Board, 1989), pp. 161–177; AAAS, *Science for All Americans*; and Marcel C. LaFollette, *Making Science Our Own: Public Images of Science, 1910–1955* (Chicago: University of Chicago Press, 1990). Additional literature can be traced through the bibliography in Appendix B of this volume.

I. The Need

Why Should We Understand Public Understanding of Science?

Chapter 1

Creating the Culture of Science

Philip Morrison

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I must begin in profound apology: In this chapter, I am not proposing a theory about public understanding; I am not even quite suggesting a model. I think what I am saying is more than a metaphor; perhaps I could say it is a tendency. I hope you will approach it in that vein. There lie within it more possibilities, though I have had not the time or the wit to prepare a real study.

"Creating the culture of science" was proposed to me as the title of this chapter. "Culture" is a magnificent term, very important in our times; it has happily come to represent a wide diversity of activities, of human relationships, of aims, of intentions, of circumstances. It is one of the most packed words in our entire vocabulary. To produce a definition of it, of course, is more than would be suitable. Such a definition is likely to engage us in 10 years of debate, as scholars have done for 100 years in other fields. So I have a much easier path; my path is one a theorist typically follows. I don't understand the issue thoroughly at all; I'm only beginning to touch it. But I think I can see an example. I point to that example and say it is less than a model, but more (I hope) than a metaphor; it is somewhere in between. How my example differs from science will be what we have to look at. But the virtue of the example is that it is sufficiently diverse, with many handles, knobs, whistles, recesses, even hidden crypts—so we can take comfort in the fact that something may be there for us as well.

A Thing Called Sports

The thing that is "more than a metaphor, but less than a model," is part of most modern societies. It has antique roots in Meso-America, in China, in India, and in Hellenic Greece, and other times and places you can recall for yourself. We call it sports. You cannot look at any American medium of public communication without seeing it—not television, not books, not even the sheets that mark the supermarket. Wherever you look, you find considerable attention to this well-defined, highly complex, domain—the domain of sports.

To explore this thing called sports, I first looked at a few empirical facts, the kind gathered mostly just by living in the United States, where you certainly learn a great deal about sports willy-nilly. Indeed, learning about sports in the United States would be hard to avoid. But I also looked in the *Statistical Abstracts of the United States*, that wonderful government volume, to try to put together facts about how the American people spend their time. We hear a lot about how people spend time, time being now the only commodity with a limit. Growth in the supply of time is not yet foreseen. Every other supply grows, but the flow of 24 hours a day and seven days in the week remains well limited. Filling that time up is what the enterprisers of the media are trying to do, and they pretty well succeed!

The most conspicuous result appeared in the numbers at once: the ratio of spectators to participants, in the number of person-hours (I would say man-, woman-, and children-hours) spent in sports activity, is large. Among adults that ratio is about 20 to 1, twentyfold more time spent as spectator than as participant. That is characteristically a process of modern times, of the wired or the etherized society, because now we have the ability to be spectators so well. Even the 50,000 in the big stadium are quickly multiplied by hundreds once you turn on the television. That was not true 100 years ago. There was a substantial ratio back then—spectators for team games and competitive games were always more numerous than participants—but not so great. That number of 20 to 1, of course, is due to a large population and, also, the degree to which we take immediate information from afar. In overall amount, it approaches the better part of an hour per head per day for adults, an interesting number.

The print media, of course, add their share to the spectator side of the ratio at every level, from the mimeographed handout to the elaborate book. But people who watch in the ball park—they are people who engage in sports in real space—are few compared to those who view vicariously, though usually in real time. (Most of this time that I'm talking about is so-called real time, delayed by time zone differences in some cases.)

If you add up all the time of people we all know, the outdoors persons, the park-goers, fishermen, boaters, joggers, racetrack fans, and the many others, the conclusion remains. Sandlots, touch football games, true amateur sports, are important. They touch you; they are important genetically in society, though not so important somatically, so to speak. But it is within school days that full involvement in something that could be recognized as sports (or on its margin, physical education) begins to loom statistically large. Physical education employs between 5 and 10 percent of all schoolteachers. Most of what they organize is participatory sports, plus something for recess and for the major teams (which take time away from more widespread student body involvement). The young take part in sports, I've estimated, for about half an hour a day, something less than the amount of time the grown-ups spend as spectators. That's the division of the two; it would be interesting to keep this image in mind, to compare it with what happens in the sciences.

Qualities of Sports and Science

The qualities of time spent at sports are easy to list. They are also easy to compare with science. I don't have to cite authority for the categories I'm using, for I do it out of experience.

The first evident difference is quick closure, characteristic of almost all sports. There is a decision, a winner, a score, at the end of a finite, usually calculable period; if not always, mostly it is so. In science, of course, that is rarely true.

Second, strong personal distinctions are much easier to make and much more central than they are in science. In fact, the tendency to develop "stars"—we use the same word—and heroes in other activities is in many ways modeled upon sports.

Third, logical analysis, even quantitative analysis, with counting and calculation of rates, is extremely common in the world of sports, even for spectators: batting averages, miles per hour, speeds at different distances. This is quite remarkable, very different from even the text of sophisticated magazines of public science, which avoid the sort of numbers that are commonplace in the sports pages!

Then comes the drama of real-time competition, where the conclusion remains uncertain until it unfolds. That is extremely important to the sports spectator, as well as to the participant. Once the result is known, much is lost; a replay does not have the appeal of the first time, even though it is identically the same image, even though the viewers may not have seen it before. They know that the outcome is given; that wonderful sense of expectation, no easy thing to simulate, is lost.

I believe the last major difference between sports and the public understanding of the sciences (as subject matter) is the fact that sports is almost wholly perceived with the unaided human senses. Like most art, it is visible, audible, and tangible. You know what happens without instrumentation, without intermediaries, with an immediacy that is very important, even for spectators far off from the scene. It is true that citing the abstract score of a distant game is often done, without reference to anything but numbers; you then have only the result to help you ruminate on the consequences. In some sports, one even waits for the scoring produced by a panel of judges (it seems to make for tedious watching, yet it fascinates many people). Though the judging is often somewhat arbitrary—for mostly they do not explain what the point systems are—people sit and wait for the announcement of the jury. Great hurrahs arise when somebody gets 9.5 and somebody else only 8.7, from nine judges who varied from 1 to 6 in individual scores! (I suppose it is like gambling.)

Viewing and Participating

I have to ask, What does a viewer or a participant gain? The enthusiasm of most watchers and almost all participants amounts to total immersion, to that rewarding state called "flow" that is on the one hand never boring and on the other hand never anxious. That has been identified and talked about quite a lot in the last 10 years, after the work of M. Csikszentmihalyi at the University of Chicago.[1] It is perhaps the most important single personal reward for participators and for spectators alike.

But what of the social or public aim? To cite another metaphor, take bread and circuses. Sports are not bread, but they are pretty close to circuses. A higher motive which must be present is that sports promotes physical health and activity by adding motivation. The schools, the runners, the exercisers think so at least, and I believe it is true. Cultural aims are attached, pinned like flags and banners and flowers all over this effigy I'm conjecturing up. Loyalties, vicarious moves, parallels for behavior, transformations of ethics and true devotion—all these are imputed to sports. We all know that the playing fields of Eton were said to be the foundations of the victory at Waterloo. I'm not prepared to demonstrate that, but I am prepared to cite it as an example of what people claim they can see in these activities.

Let's ask those same questions about the public presentation of science. What is it for? Of course, society needs to recruit participants in science, needs it badly; much of our livelihood in peace and our victories in war lie in science and technology, as indeed our defeats and our depressions may also be found there. Public science is a modern extension of cricket at Eton, a very powerful one. It serves a social role. That's fine for the "attentives," the fraction of us for whom the culture of science is now alive; though still exclusionary, that group represents an important category of people. Here it is not physical health that is sought, or indeed much physical involvement at all; it is something more social on the one hand and more intellectual on the other. There is no doubt that science and its uses change daily life for everyone—those who feel themselves to be part of the change and those who can only peer or buy or be sent away. My conviction, and I think that of many people, is that the health of a democratic society depends upon the fact that we expand the list of those who feel some active role in technological and conceptual change. More people should feel some participation, some critical evaluation of what is happening to them as the world changes, as much as one can expect to participate in this extraordinary world. The sports fans share famously in the home team victory; they even demonstrate in the streets when the Braves win. No one yet has demonstrated over the finding of the Higgs boson by cheerful rioting on Cambridge Common, but it may happen! Sports fans all recognize the virtuosity of a star by extension from their own modest efforts. I think that is very important. Maybe that sense of extension from participation to stardom is something we can transmit for science.

The Nature of the Comparison

I do not claim that sports is a full model; rather, it is a glimpse of another cultural complexity. I am not trying to assert that science is or should be parallel to sports. But I think we learn something by examining, in a detached way, another domain that is quite different and yet shares a great deal with public understanding of science.

I see a lesson—not an easy lesson, but a real one. All the features that I mentioned—quick closure, profound competition, real drama in real time, personalization—come much harder to science than to sports. I find myself in a quandary; I myself somewhat reject the strong personalization that goes with sports and is often imputed to science and technology, the heroic aspect of it all. But I think my rejection is in error; I am coming to see that all drama and all public activity that engages people seem to embody some sense of personality. That sense may change, it may extend to teams, or it may even seek an ideal model. But I now think that I am wrong to resist so much the feeling that Einstein is a figure we must have in the course of studying 20th-century physics. Such features are not absent in science, and art can magnify them. The art of the interpreter, the communicator, the author, the producer, the actor, and the laboratory director—all can magnify these attributes to bring them closer and closer.

In terms of quantity and in terms of analytic inference, it seems to me that science and sports are very much parallel at the level of public concern. A lot of complexity, a lot of tactics, a lot of numbers, and a lot of perhaps poorly understood probabilistic judgments are present. A little deepening of public understanding is worthwhile. Just as science has designers of instruments and inventors of new theories, so sports has designers of equipment and trainers of the coaches themselves. They command an enormous variety of approaches—variety of duration, of level, of discipline (from archery to underwater swimming), and of affect from open hilarity to tragic events, as from a quick 15-second replay to years of effort, from small children tossing a ball to the devoted years-long work of international over-the-road cyclists. All that, we scientists could match. We have those same levels, but we don't spread the emotion, the affect, even the ideas anything like as far as is done in sports.

The most difficult comparison, the nub of the difference, is that science lacks (more and more as time goes on) any directly perceptual subject matter. You cannot see, hear, feel, touch, taste, or smell the principal objects of contemporary science—the atoms, genes, or population data. They lie at the end of the instruments; they lie in the inferences; they lie in the bookkeeping of genetics or of analytical chemistry or of energy balances. If you don't have those instruments, the data, and some feeling for the process of inference, you have a hard time seeing what is going on. People try hard to redefine energy and make something simple out of it. It has been done by Einstein, as we know—energy is the unwinding of a spring, the burning of a match. Those two things do not have in common any tangible physical correlate. What they have in common is a quantitative abstract analysis. (I agree, they have the mass equivalent finally, so today we have a full physical basis for linking them. But it is a link tiny beyond perception, and it really represents a limit.)

One of the most important challenges is to work hard at that perceptual barrier, to try to make more inviting all the instruments and the ultrahuman scales of time and space and chance and motion that are characteristic of our understanding of the macro- and micro-world beyond the world of sense perception. That challenge must come very high on our list. I think it can be done. Perhaps a large audience cannot yet tie in directly to that experience; but the experience can be planned and made to grow through preschool, schools, and far beyond.

Engagement alone can't do what we wish; engagement is absolutely necessary, and too much neglected, but it is insufficient. We will have to aim at something of real participation in the cognitive aspect of science, in drawing attendant conclusions from argument and experience. I think no result in particular is by itself important. It is everything that is more important; that is, everything summed up is more important than any one feature. No particular finding is more important than simply the try at inference. Nothing less will do. I do not believe we can solve the problems that are implicit in all this discussion of "public understanding" by insisting upon the right answers to questions, even to very important ones. Right answers to questions are not science, even though certainly we seek them. Science is not a collection of sound dogmas: One gene is not one enzyme—and if it is, one day it won't be! Science is a living and imaginative, but testable, process. (Of course, we pay due attention to the record of the past, to what we know. We don't want to come too naively to an expert game.) I would rather see someone take apart a perpetual motion machine, a simple-minded one, to puzzle it out, even if he did not succeed, than to have him learn carefully the first law of thermodynamics and merely repeat that it renders the perpetual motion machine impossible. That is not our way. I would rather see someone work with people's footprints in mud than to hear her simply recite the truth that humans are not as old as dinosaurs. No human had to flee any toothy dinosaur. Why? How do we know? What is the basis for that? If we don't deal with those deeper questions, we simply have one more myth contesting another, and we know very well that in Texas such myths are carved in stone.

Finally, I think that anything less ambitious than an effort to introduce some level of participation, even into the detached presentations and far-off interviews that we mostly have to rely upon, is going to be fatally injured by two flaws. First, if it is less ambitious, it is unworthy of our high aim of engaging people in genuine science, of letting science become real. Second, and perhaps still more important, it just won't work!

NOTES

Philip Morrison is a theoretical physicist and astronomer with a long history of engagement in science teaching at every level from preschool toys, to textbooks for high school and college, and on to public television. He has reviewed books about science in *Scientific American* each month since 1965, as well as children's science books (with Phylis Morrison) every December. He was presented the first AAAS-Westinghouse Award for Public Understanding of Science and Technology in 1987.

1. On the concept of flow, I recommend Mihaly Csikszentmihalyi and Isabella Selega Csikszentmihalyi, eds., *Optimal Experience: Psychological Studies of Flow in Consciousness* (Cambridge/New York: Cambridge University Press, 1988).

II. The Concept

What Do We Mean by Public Understanding of Science?

Chapter 2

Not Knowing, Needing to Know, and Wanting to Know

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Any question of measuring progress in public understanding of science has to be asked in relation to prescribed *boundary conditions*. We must decide where this progress is starting from and where it is supposed to be headed. Boundary conditions presume a *frame*. There has to be some agreement about what features of the world are *not* going to be discussed or are to be taken as constant. To construct a coherent frame requires a *model*. We have to find an aspect of the world that can be depicted in simple, interrelated concepts.

There are three types of questions that can be asked about public understanding of science. Each is posed and framed according to a different model of science and of its social role. These models are not just slightly different perspectives on the same scene; they are so different in principle that they produce nearly contrary precepts and policies. Let me go through them in turn.

The Deficiency Model

The first of these models is so familiar that it is usually never questioned. According to most scientists, the great majority of ordinary people have very little understanding of science. The outstanding feature of the situation is deemed to be public *ignorance*. The primary question is, "What do people not know—and for goodness' sake, why not?" The problem is perceived as a *deficiency*, which must by all means be overcome. The basic measure of progress in public understanding of science is taken to be how much more science people can be made to understand.

Do we need to go any further? Concern about the knowledge gap between the world of science and the world at large is nothing new. The British and American Associations for the Advancement of Science were founded in the early 19th century to fill this gap. Many scientists of distinction have given of themselves to write, lecture, and broadcast to extend their work to the "attentive public." Many talented writers and broadcasters have made it their business to explain in simple terms what the scientists were doing. Much of the effort reported in workshops on public understanding of science is consciously or unconsciously motivated by this model.

Nevertheless, there has always been regret that these efforts did not seem to be having much effect. This uneasiness came to a head in the report of the Royal Society's Committee on Public Understanding of Science, chaired by Dr. Walter Bodmer, which appeared in 1985.[1] The background to the whole subject was explored very thoroughly, and yet we could find very little serious research on what was going on. The Bodmer report was the cue for the British Economic and Social Research Council, backed up later by the Advisory Board of the Research Councils and by British Gas, to set aside funds for a major program of research. Our task in the Science Policy Support Group was to organize a competition for peer-reviewed proposals, coordinate the work of the various project teams, and make sure that the results of the research were widely disseminated.

Some of the projects were started in early 1987 and are now complete. Other projects started later and are still under way. The scale and diversity of the whole program can be gathered from the project titles (see Figure 2.1). The researchers came from very diverse disciplinary traditions—anthropology, education, history, philosophy, politics, psychology, and sociology, not to mention such interdisciplinary areas as "media studies" and "science, technology, and society." It is worth remarking also that quite a number of them were originally educated to a high level in one or another of the natural sciences.

This diversity of starting points and approaches might have produced a very confused and incoherent outcome. Surprisingly, however, the research results converged on a few general messages that were not originally obvious and that were, indeed, somewhat contrary to received views. In particular, the research revealed some of the difficulties that arise when one tries to use the deficiency model as a guide to understanding and practical action.

Figure 2.1. Public Understanding of Science Projects and Principal Investigators (United Kingdom)

1. A National Survey of Public Understanding of Science in Britain: John Durant, Science Museum
2. Young People's Responses to Scientific and Technological Change: Glynis Breakwell, Surrey University
3. Frameworks for Understanding Public Interpretations of Science and Technology: Brian Wynne, Lancaster University
4. Science and the Identification of Strategic Research Areas: Peter Glasner, Bristol Polytechnic
5. Nature's Advocates: The Public Role of Scientists in Conservation Movements: Steve Yearley, Queens University, Belfast
6. Audiences, Disseminators, and the Local Understanding of Technical Issues: Alan Irwin, Manchester University
7. Genetic Disorder: Self Help, Knowledge and Dissemination: Hilary Rose, Bradford University
8. Science Knowledge and Media Influence in Classroom Discussions of Social Issues: Joan Solomon, Oxford University
9. The Production and Presentation of Science in the Mass Media: Anders Hansen, Leicester University
10. Science in the Museum: An Ethnography of a Science Project: Roger Silverstone, Brunel University
11. Primary Teachers' Processing of Scientific Information: Jon Ogborn, Institute of Education (funded by British Gas)

The first difficulty is that "science" is not a well-bounded, coherent entity, capable of being more or less "understood." This finding is not in any sense a subversive attack on the marvelous and immense body of knowledge and practice produced by natural and social scientists, engineers, physicians, and technologists. It is a reminder that what counts as science is defined very differently by different people—or even by the same people under different circumstances.

Scientists themselves do not have a clear and consistent notion of what "science" covers, and often disagree profoundly on what it is telling us about the world. To give some obvious examples, scientists are just as divided as the public at large on whether psychology is a science, they still seem very uncertain about the biological evolution of the human species, and they offer patently contradictory "scientific" advice on healthy eating. Should our instruments for measuring public understanding of science therefore take no account of knowledge of the social or behavioral sciences? How should they score responses on interesting topics that are still highly disputed? Where would they draw the line between a plausible conjecture and the wisdom of experience?

In other words, "science" is not a special type of knowledge that only starts to be misrepresented and misunderstood outside well-defined boundaries by people who simply do not know any better. The deficiency model, which tries to represent the situation simply in terms of public "ignorance" or scientific "illiteracy," is thus unsound in principle and does not fit the results of our research.

The Rational Choice Model

The standard justification for improving public understanding of science is utilitarian. The basic question becomes, "What do people *need* to know in order to be good citizens—even to survive—in a culture largely shaped by science?" If they had no means of fulfilling this need, they might find themselves quite unable to make any sense of important practical questions affecting their lives—small questions like the goodness of eggs, and large questions, like the safety of nuclear power. In fearful ignorance, they might even turn against science altogether, heedlessly throwing out the baby with the bathwater.

The social model that frames this sort of question is one of *rational choice*. It focuses on those points where a particular piece of knowledge might be expected to play an important part in people's lives—that is, when they have to make practical decisions to which this knowledge might seem relevant.

At first sight, this model might seem just a gloss on the deficiency model. Indeed, some utilitarian criterion like this is essential if we are to select items for public dissemination out of the practically infinite body of scientific knowledge. The measure of progress in public understanding of science would then be the extent to which people had already been given a sufficient understanding of the science that they might need on later occasions—or at least, the extent to which they might be prepared for such occasions by having a good general idea of the nature of science and of the scientific world picture and thus be capable of getting hold of the relevant scientific understanding as and when it was required.

The difficulty with this interpretation can be judged from some practical dilemmas drawn from our case studies:

- Should a Cumbrian farmer follow the advice of the agricultural scientists about grazing his sheep on pastures contaminated by Chernobyl fallout when it becomes clear that these scientists don't understand at all the familiar "science" of making a living out of a hill farm?
- What prior knowledge would really be of use to a person afflicted with a dangerous disease who must choose between two alternative courses of treatment?
- Where would you turn for further information about suspected environmental pollution—to the public library, to the county council, or to the firm that seems responsible for the danger, but that must surely know much more about it than anyone else in the neighborhood?

You can see that these are everyday questions that cannot be addressed properly, let alone answered, in terms of a rational choice model. Yet any assessment of progress in public understanding of science must surely include an account of how people—and society at large—can be helped to cope with such situations.

But the very language in which these questions are formulated may suggest a more calculated rationality than the events of life normally evoke. Ethnographers have begun to realize that an analysis in terms of rational choice is not sustained when one looks carefully at the way that people talk about their motives and actions under such circumstances. This second model, also, does not generate a fully satisfactory frame for policy regarding public understanding of science.

The Context Model

What seems to be missing is the *affective* component in social action. The question to be asked is, "What do people want to know in their particular circumstances?" In other words, a discussion of the full *context* of understanding has to be central to the analysis.

This discussion is obviously very complicated and will need to be carried much further before we can generalize reliably from it. But the research results we have been getting show very clearly that the theory and practice of public understanding of science should not underestimate the *incoherence*, *practical inadequacy*, *incredibility*, and *inconsistency* of formal scientific knowledge, as received and used by the public. Once again, this is not an attack on the scientific enterprise or its technological products: It is just a statement of the way in which this enterprise is actually presented to and perceived by people who are not themselves directly engaged in it.

There is not enough time here to present any of the research evidence for this disturbing statement,[2] but it may become more acceptable if I explain each of these points in a little more detail.

- *Incoherence*: People do not draw on stable, if fragmented and/or ill-conceived, *models* of the world, along the lines of textbook accounts of scientific knowledge. The little they retain of what they were taught at school is overlain and supplemented by the diverse representations of science that they encounter in the media and in many other aspects of life. What they pick up is not simply a filtered version of formal scientific knowledge: They have something that has meaning actively constructed by the processes and circumstances under which it is communicated and received.
- *Inadequacy*: The use that people make of formal knowledge in any particular situation depends on their needs of the moment and represents only one element in a complex and varied response. Not only do people rely heavily on the tacit, uncodified, but highly expert and rational knowledge that is shared in most work communities; they also engage with, select, or construct the scientific elements according to their own interests, involvement, personal and social histories, and other circumstances.
- *Incredibility*: People do not accept passively the knowledge presented to them by scientific *experts*. The credibility of a source depends strongly on its perceived interest in a particular context. This applies to individual scientists, scientific institutions, public bodies, and private enterprises.

- *Inconsistency*: Personal conflicts on social issues between scientific experts inevitably downgrade the privileged position of scientific knowledge. But public and private discussion helps people combine their scientific knowledge, ethical views, and tacit understanding of life into personal positions on controversial matters. In effect, people resolve the contradictions that arise by incorporating items of formal science into the whole knowledge complex and making those contradictions *disappear* as such.

These, in outline, are the principles that seem to govern the way that people receive and use scientific knowledge. They have emerged from closely observed studies of people in particular situations—at work, in school, in the doctor's consulting room, or on their own doorsteps. As Beethoven said of good music, these principles are both surprising and expected: they are surprising if you come to this subject straight out of the lecture hall and research laboratory; they are expected if you reflect on your own experience of everyday life, thought, and talk.

To show the practical value of the context model as a correction to the deficiency and rational choice models, let me refer to one of the findings of the survey work carried out by John Durant and Glynis Breakwell.[3] This work showed a positive correlation between knowing about science and being interested in it. Despite all the conjectures to the contrary, the great majority of respondents reported themselves as "very interested" or "moderately interested" in news about discoveries and inventions—much more interested, in fact, than in news about sports, politics, or films. The paradox is that they also report themselves as worse *informed* about science and technology than about sports or politics. In other words, this general "interest," in the abstract, is likely to be much less influential than specific material "interests" in getting adults to understand science better.

This research also indicates that public understanding of science might be improved by taking more account of the social context in which understanding of science is acquired or exercised. The survey work showed, for example, that both attitudes toward science and involvement in scientific activities are significantly correlated with parental encouragement—particularly with parental attitudes to science—irrespective of the age, sex, or social status of the respondent. Attitudes of friends toward school, youth culture, and achievement also correlate with variation in both attitudes toward science and the performance of science-related activities.

In attempting to measure progress in public understanding of science, we must always remember that scientific knowledge is not received impersonally as the product of disembodied expertise, but comes as part of life, amongst real people, with real interests, in a real world.

NOTES

John Ziman was professor of theoretical physics at Bristol University from 1964 to 1982. Since then he has worked on various scholarly and political aspects of the social relations of science. He was chairman of the Council for Science and Society for about 15 years and has been director of the Science Policy Support Group since it was founded in 1986. In addition to his scientific publications, which earned him election to the Royal Society in 1987, he has written a number of books and papers in the fields of science studies, science policy, and science education, including *Teaching and Learning about Science and Society* (Cambridge: Cambridge University Press, 1980), which broached some of the issues surrounding public understanding of science.

1. Royal Society of London, *The Public Understanding of Science* (London: Royal Society, 1985).
2. For some results from the studies coordinated by the Science Policy Support Group, see John Ziman, "Public Understanding of Science," *Science, Technology and Human Values*, Winter 1991, 16(1):99–105; Roger Silverstone, "Communicating Science to the Public," *Science, Technology and Human Values*, Winter 1991, 16(1):106–110; and Brian Wynne, "Knowledges in Context," *Science, Technology and Human Values*, Winter 1991, 16(1):111–121.
3. John Durant, Geoffrey Evans, and Geoffrey Thomas, "The Public Understanding of Science," *Nature*, July 6, 1989, 340:11–14; and Glynis Breakwell and S. Beardsell, "Parental and Peer Influences upon Science Attitudes and Activities," *Public Understanding of Science* (submitted).

Chapter 3

Listening to the Audience: Producer-Audience Communication

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My goal in this chapter is to present some ideas about what we mean by "public understanding." I think that's an important exercise because discussions about public understanding have often focused on one of two issues: why we need more of it and how we go about producing more of it. But I'm not sure that those are the topics that are most important. Instead, I'm going to suggest that we (those of us committed to improving public understanding of science) need to look at public understanding from the perspective of the audience.

While I'm going to discuss this shift in perspective by using local television news broadcasts as my main example, I believe the conclusions I will draw are relevant to many other kinds of public understanding activities. I can make that leap of faith because much of the work we do at Research Communications Limited (a company I started 10 years ago) goes beyond local news. Much of our work is done in adult programming, including documentaries, news, and entertainment. We have done a lot of work in the commercial world, as well as with the Public Broadcasting System (PBS). I often say we "put the public back into public television." We also evaluate children's programming, including both math and science shows. We do a lot of educational media, including various PBS series, the Annenberg Project college courses, and other science courses. We also do evaluation work for science exhibits in museums and for

Omnimax films. So the conclusions that I will draw in this chapter about local TV news are based, in part, on what we've learned in a lot of other public understanding contexts.

The Nature of Audience Research

All too often, the results of research studies on public understanding activities never reach the producers whose work was being studied. That's a very frustrating situation, because these are the people who are crafting the messages. So our goal in any study is to increase the involvement of producers in the research in order to get producers to act on the research findings. We want to be involved in the dynamics of producer-audience communication. Our commitment is to affect the relationship between the producer and the audience so that the content is conveyed more effectively.

To achieve those goals, we focus our research on how to communicate a story effectively. That's a challenging task, because many producers don't want to admit that they have an audience out there with whom they must connect. This is especially true in public television, where producers often think they shouldn't even think about audiences, much less listen to them.

Several years ago, I had five well-known, prestigious international producers in our test facility in Chestnut Hill, Massachusetts. They were sitting behind the one-way mirror, watching the people who were coming in for a group test session. As they watched, these producers were saying, "I'm not sure I even want these people as our audience." The members of the group, who represented a typical viewing audience, were wearing their work clothes, uniforms, and dirty t-shirts. They did not look like an audience that the producers thought had anything useful to say about their documentary.

I was hesitant as I went back to the producers after the sessions were over, but the audience had been very insightful and had a lot of interesting things to say. I asked the producers, "Do you have any questions?" They sat there for a minute, and then they said, "These people know more about what makes television work than we do. They watch a heck of a lot more of it."

So it is possible to listen to audiences talk about what makes television stories work and how they understand the messages they receive. But it is also important to listen to producers talk about what they want to learn and how they see their programs. These two groups of people live in very different worlds. It is often very difficult to find the link between what the producer thought he or she was communicating and what the audience actually saw or interpreted from what it saw. Our commitment is to try to get these two groups to see the world in the same way, so they can communicate more effectively.

Our job as audience researchers is not just to measure the marketplace accurately, not just to generate numbers. An important part of the job is coming back and communicating the results to the producers and trying to effect change. Sometimes, of course, we meet resistance. Journalists, for example, think that nobody should be telling them what to report; they're afraid that it might affect the integrity of what they have to say. I agree. I have never come into a newsroom and said, "You shouldn't have covered that story." Instead, I try to show producers and reporters how the audience has responded to the stories they've prepared.

As the example I quoted above suggests, experienced producers and others at the management level quickly understand that the audience does have something interesting to say. But if research doesn't begin to affect the dynamics in the newsroom itself, it won't go very far. Researchers need to talk to the people who are producing every day. When we finish talking to management, we sit down with people in the newsroom and watch newscasts together. We walk them through the whole process of how people perceive these stories and what they perceive the messages to be. This is actually very empowering; newsroom staffs love it, because they realize, "Wow, I never thought that's the way the audience might respond to the story."

The point here is that audience research must do more than just come to an understanding of why some stories work and others don't. The research needs to engage the producers in ways that will help them understand the audience—*before* they put something on the air.

Linking Producers and Audiences

The results I will present deal with one way of affecting the producer-audience relationship. These results came from some studies we did of local television news broadcasts. I've chosen to focus on local TV news because of its impact. If you look at the audience for local news, especially the cumulative audience over a week's time, it is quite astounding. A majority of viewers in many markets have been exposed to at least one local newscast within a week's time, and many are regular viewers. That makes local news a very important arena for those of us concerned about public understanding of science; the people who produce it are probably putting more science messages out there than anybody.

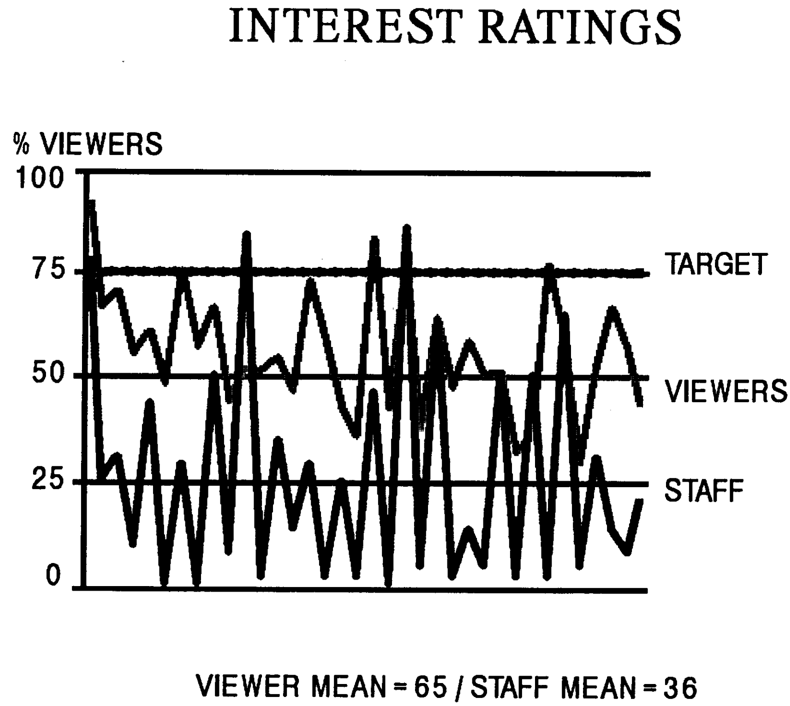
For some years, we had been doing research on how audiences perceive various stories, and we had been sharing the results of those studies with newsroom staffs. But we were still looking for more effective ways of helping the newsroom staffs incorporate the results of these studies into their own daily perceptions about stories. We had guidelines we would provide to the newsrooms, but we had no way of knowing how viewer perceptions compared to the producers' perceptions. About 18 months ago, at the suggestion of one of our clients, David Goldberg (now news director at KHOU in Houston), we tried having the entire newsroom staff watch newscasts and rate them moment by moment, in the same way that we have the audience rate the newscasts. Just as we interview focus groups to learn more about what interested them and what did not, we interviewed the newsroom staff to find out why they rated particular stories to be interesting or uninteresting. By comparing the two sets of results and playing those comparisons back to the newsroom staff, we found that we could help them see the difference between their own perceptions and the perceptions of their audiences.

The results of our research are based on six studies, in six markets around the country, that we've done in the last year and a half. These studies involve a total of about 450 professionals who produce the news and about 1,200 viewers who participated in test sessions. At each location, we looked at all three network affiliate local newscasts for a total of 18 newscasts. We looked at over 250 stories, 10 percent of which were stories on science-related information.

We gathered data by asking viewers and staff to tell us how interesting a story was, on a moment-by-moment basis. At regular intervals during a show, we asked viewers to indicate on a mark-sensitive card, "Are you interested? Would you stay tuned?" This allowed us to track interest levels in stories. We plotted the percentage of viewers across the entire newscast. For example, in Figure 1, 90 percent of the viewers are saying that they want to stay tuned after they see the open at the top of the show. You can see that interest drops after the introduction to the first story. On the same graph, you can see that a majority of the staff also find the show open interesting, but their interest drops precipitously as the first story progresses.

The pattern across our studies tends to be the same: There is a dramatic difference between the ratings produced by a "typical" news audience and by newsroom staffs. On average, we see a 20-point difference between the news staff and the viewers. That is a striking difference; it's as if these two audiences were watching different programs. The 20-point difference is not an artifact caused just by the staff being tougher on stories. We calibrate the means of the two sets of data, so that we are comparing relative levels of interest, not absolute levels. In the example shown in Figure 3.1, this would mean that the viewer mean of 65 and staff mean of 36 are indexed to 100, and then we compare how the two groups rate stories. We find that, on average, half of the stories are still rated significantly differently by viewers and staff. And of those stories, in about half viewers rate them higher than staff, and in about half staff rate them higher than viewers.

Figure 3.1. Viewer interest in news shows on moment-by-moment basis.



We also looked at the top three stories ranked during the newscast. In a single study of three affiliate stations, that gives us 18 stories (9 for viewers and 9 for staff). We find that, on average, a story in the top three for staff is only in the top three for the viewers about a third of the time.

As I said earlier, the point of doing these comparisons is to help the newsroom staff understand the audience's perspective. That's a difficult task. But I'm convinced that it's necessary, and that the principle holds not just in local television news broadcasts, but in exhibit production, documentary television production, radio and newspaper journalism, or any other kind of public understanding activity.

Science Reporting

The same issues arise when we look specifically at science reporting in the newscasts. In our set of 18 newscasts, for example, there were a total of 28 stories on science topics. Health and medical topics were the most frequent type of science reporting in local newscasts (16 out of 28 stories), followed by 6 environment stories, 4 general science stories (e.g., a story on a solar-powered car), and 2 animal stories.

Again, in these stories, we wanted to compare viewer and staff response. We had thought that staff would be particularly interested in science and therefore would rate these stories higher than they had the newscast as a whole. We were wrong. Only 26 percent of the science stories rated above the average newscast interest among the newsroom staff. For the viewers, on the other hand, 61 percent of the science stories were above their average newscast interest scores. (This display of interest confirms other studies we have done that show that the general public is interested in science, especially topics like health and medicine, which have a high degree of salience for them.) Comparing calibrated means between newsroom staff and viewers, we found that 75 percent of the stories were rated significantly higher among viewers (again, correcting for relative differences between the audiences). The viewers found science reports on local news more interesting than did newsroom staff, at least on the moment-by-moment basis that we were using.

An important component of our research is to go back and do extensive, in-depth interviews to examine the operative guidelines that viewers and producers were using to evaluate the stories on a moment-by-moment basis. We're trying to discover, both with the viewers and with the producers, what's going on in their heads while they're watching the newscasts. When we analyzed the interviews, we discovered some interesting contrasts.

The Newsroom Perspective

First, there's a tendency for the newsroom staff to talk about production elements; they'll note that the production crew recorded a live shot of some news event, and they will focus in on that as accounting for high appeal. Viewers rarely mentioned production issues; that's not foremost on their minds.

Second, the staff's reactions depended on their own particular skills. Photographers would talk about pictures; editors would talk about seamless editing; assignment desk staff would say, "That was the story to cover that day," and so on. Job function had a lot to do with how the staff responded. We found nothing analogous for viewers.

Third, the staff would often discuss a story in terms of a reporter: Their overall evaluation of a story very much depended on their evaluation of the reporter's performance. By contrast, viewers rarely talked about reporters, focusing instead on the information presented.

Next, "media events" provide a very interesting contrast. The newsroom staff often responded more positively to media events than the audience did. The audience had powerful, built-in "hype" detectors; they knew that something was a media event, and they often felt that these events weren't newsworthy. Although newsroom staffs often complain about media events, the events are often present in newscasts and are seen to be more interesting to staff than to viewers. Probably, the staff assigns weight to these stories merely because they are assigned to cover them; again, you can see how their jobs are influencing how they are viewing the newscasts.

Finally, we found a contrast in how the two groups responded to the competing newscasts. The staffs were very concerned about every move the competitor made: "We missed that shot; the other stations had that shot," or "We didn't get that. We should have been there first." Viewers, on the other hand, prefer video that tells the story effectively. If it doesn't, they don't care if it was live or not.

The key point in this exercise is not to put down producers. Instead, I want to emphasize that most of us do not know how the audience thinks. We have to get out there and listen to the audience if we're going to understand how we are going to communicate more effectively.

The Viewers' Perspective

Since we've spent some years at Research Communications Limited listening to the viewers' perspective, I'm going to move on now to focus on some of the general things that we've learned. (I'm moving away from the studies of the last 18 months and am now drawing on our 10 years of experience.) By doing so, I want to underline some of the key issues for those of us trying to understand what we mean by public understanding.

Preexisting Interest

We've found in our research that one of the strongest predictors of audience interest is preexisting interest in the topic. This is true whether we're talking about the documentary program, a news story about science, or any other type of presentation. Pointing to preexisting interest is often controversial, and the stress that I put on it is often misinterpreted. I do not mean that if "quantum theory" is of limited interest to an audience, you absolutely must not ever talk about quantum theory, or that if "the environment" is of higher interest, then you absolutely must talk about the environment. Instead, I want to stress that in order to structure what you are going to say to viewers, you must understand where they are "coming from." You must consider their interests when you decide how to approach the subject and what the focus of the story is going to be. You say very different things to viewers if their preexisting interest is high than if you know they have very little interest in the subject matter.

For example, on several occasions, we have conducted formative research studies for major PBS series. In a number of cases, we found, early in the testing, during pre-production research, that the conceptual framework for the series absolutely did not match viewers' expectations. The framework often matched the expectations of the funders, but it did not match the expectations of the audiences that would actually be watching the shows. And, sure enough, those series eventually did not do well with audiences.

One series that did do well was *The Brain*. A critical element in its success was the way the producers approached the subject during prebroadcast development. One of the best techniques is to anticipate the questions that the viewers will have, and you can cultivate that skill through audience research. The developers of *The Brain* realized that people didn't want to see a lot of icons and computerized graphics of the brain; they wanted to know what it means to be a schizophrenic. Compelling stories about schizophrenics brought messages home to audiences, in a way that experts, charts, and graphs could never have done. The other information was present in the program, but there was balance in the presentation. Looking for the viewer's perspective is absolutely critical as you are developing stories.

Who Cares?

Once you've identified an interesting topic and a conceptual framework, you need to consider how to tell the story. A major problem for many news stories is that they often fail to answer the question, "Why is it important for me to know about this story?" In our research, we see that problem manifested in interviews in which the viewers say, "Who cares?" That's obviously not good if the viewer comes away from the story and still has no idea why he or she should care. In today's viewing environment, if you do not establish why viewers should care at the outset, they will search for stories that do establish why they should—probably on some other station. Despite this threat, much television reporting, including science reporting, starts out with, "Today this is what happened, and this is where it happened." That's the point at which the audience says, "You haven't given me a reason to care."

In our feedback sessions with newsroom staff, we show the newscast and stop the tape as soon as the introduction to the story is over. We then ask, "How many of you want to stay tuned and watch the rest of the story?" If the writer has anticipated this question, the staff can answer the question. Then we can match that answer with the audience's response. Don't assume that because a story is fascinating to the producer, it is necessarily fascinating to the audience.

Background Information

The next issue deals with information. We have found that many viewers feel they are not getting the background information they need in order to understand a story. I think there's a lot of confusion about how smart an audience is. The audience is very smart and usually understands what makes a story work. But that doesn't mean they match the education level of the newsroom staff. On average, only about 20 percent of the viewers are college educated; by contrast, the staff in the newsroom is usually 100 percent college educated. So producers should not assume prior knowledge about complex issues. But they should assume that if they give adequate background information on the story, the viewer is capable of grasping its content. News producers also often assume that if they covered an issue a few weeks ago, the viewer already knows part of the story. Data on viewing habits show that there is only a slim chance that the viewer has seen a specific news story a few weeks before.

Providing definitions of terms is also important. I've evaluated stories on radon where the viewers all said, "What is radon? You know, I've listened to three minutes on radon but I haven't a clue as to what it is." How can they possibly do anything with the information about radon if the producer hasn't given any background for understanding the topic of the story?

Providing New Information

Another manifestation of the problem appears in stories that many stations (and this is to their credit) may assign to a relatively long three-minute block. Often a reporter will tell everything in the first minute of the story. And then, in the second minute of the story, the reporter repeats the same information, only this time using quotes from experts. Then, in the third minute, the reporter covers essentially the same information all over again, with graphics. There is nothing new, no threading and building of information as the story progresses. Surprisingly, we've discovered that newsroom staffs are quite tolerant of this kind of story; if they like the story at the outset, their interest does not flag. Viewers, on the other hand, are very sensitive to redundancy that does not advance the story. When the flow of the new information ends and there is no more building of the story, they lose interest very quickly. Remember, our goal is to take the audience's perspective. That means that when we evaluate stories, it is critical that we understand that the audience wants the story to continue to provide new information throughout.

So What?

Related to the problem of lack of background or new information is the problem of lack of context. A lot of times we have found that, at the end of the story, viewers have no idea what to do with the information; they don't understand what the consequence is to society, what the information might mean in their lives, or what the large picture is. But this kind of perspective is increasingly important, given the tremendous onslaught of news information that reaches us everyday. Understanding the implications of developments in science is perhaps the most important aspect of science reporting, yet it is the least developed.

Human Interest

One way to provide context in stories is to present them in a manner that shows that news consists of events that happen to people. Stories need to connect science to everyday life. There are many opportunities to do that;

often they are missed. The key is to tell these stories with people. *The Brain*, as I mentioned earlier, was a wonderful example of a show with high-density content that also conveyed the impact of a phenomenon on people's lives. It demonstrated how various technical issues play out in terms of human lives.

Compelling Video

Finally, technical issues reveal real differences between the perspectives of viewers and producers. We've found that viewer interest drops off significantly when stories use "wallpaper video," the type of video in which an image is repeated because it's the only available video, even though it doesn't support the narrative. One of the most difficult challenges for television, especially in science reporting, is to provide consistently compelling visuals. But it's an important challenge to meet. In contrast, we've found that newsroom staffs are much more tolerant of wallpaper video. Often they think it's just fine, because they're listening and getting everything from the words.

Implications

When you start looking at stories from the viewers' perspective, you discover what is important to viewers: developing salient, topical themes; establishing why they should care; providing important background information; answering the "so what?" question; and linking the video and narrative.

As part of our work, we provide suggestions to producers. First, a producer or reporter needs to be aware of what works for an audience before he or she sits down to write a story; that's true regardless of the medium for which the producer is writing. We prepare guidelines that come out of our own research, and some of our clients have put them on calling cards and attached them to their computers, so that when their reporters sit down to write their stories, they are actually asking some of the questions discussed in this chapter.

Second, reporters and producers need to start thinking about stories from a viewer perspective, not from the perspective that they bring as scientists or as reporters. Some newsrooms have actually changed their daily morning meetings so that somebody in the newsroom becomes the viewer and asks questions as feature story ideas are proposed. If the producer or reporter can't answer those questions, the producer goes back to do his or her homework; until the questions are answered, the story doesn't get into the lineup.

The theme here is that people engaging in activities related to public understanding of science need to shift from the role of speaker to the role of listener. We need to teach producers to listen to their viewers, no matter what medium they are in. Producers need to listen to understand audience interest, to be aware of audience knowledge, and to meet audience expectations.

A lot of listening comes by doing audience research. Listening can be a threatening experience. Producers can get defensive, saying, "Well, we've done the best possible job covering this topic that could be done." That may be true. But when producers say they've done the absolute best they can do, we sometimes leave them with the Latin phrase, *Fac optimum melios*, which means, "Make your best better." Listening to the audience helps them do that.

NOTES

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Chapter 4

Beginning with the Audience

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In "East Coker," T. S. Eliot says, "There is, it seems to us, / At best, only a limited value / In the knowledge derived from experience. / The knowledge imposes a pattern, and falsifies, / For the pattern is new in every moment...."[1] He then goes on to say that the attempt to look at where we have been tends to assign a value to that past, tends to validate it—perhaps, he implies, falsely.

Eliot provides some instructive lessons for discussions about public understanding of science. These discussions tend to include lots of answers, many of which are derived from experience, from the patterns and successes of the past. As a consequence, we've paid too little attention to looking forward and to identifying the questions that are unasked or unanswered. It is time for us to step back and consider some of the broader issues, ones that concern not just us, as individuals who represent one type of public understanding of science activity, but that concern also the broader community of scientists and policymakers.

In our discussions, there have been a number of common threads, the most important of which is the need to *identify and question our models*, to examine them honestly. Although the most elementary step in communications analysis is to define the message, either before or after it is delivered, for science communication that effort is often lost beneath waves of information about technique.

It's an understandable failure. Many science communication efforts are so wonderful, so glossy, so much fun to watch or to participate in—

they make us laugh, they keep us entertained—that they surely must be the "Best Sort of Communication." It's time to acknowledge, however, that those glib characterizations may be too rosy. It's time to ask tough questions about the world of science communicators that we're trying to unite.

One barrier to accomplishing that unifying task is the diversity of activities traditionally included under the umbrella term of "public understanding of science." The workshop that led to this book, for example, encompassed discussions that ranged from using television cartoons to teach mathematics to analyzing news reporting on science. Too often, these activities are all lumped together in our analyses and discussions. For each effort, from journalism to education to entertainment, we need to confront the truth and discuss the communicator's models and motives more honestly.

Another barrier is the lack of analytical connection between science communication efforts and the world of politics and government. In my own work, I have been attempting to bring together what is known about science communication—its motives, messages, and methods—with the pragmatic issues of science policy, such as oversight, regulation, management, administration, and budgeting. The health and future of science in the United States and other countries depend on the support of society—on a positive relationship between science and the citizenry; hence, they require a better connection between the goals of science and society and, also, a more accurate appraisal of the needs of the various audiences in them. Many science communication efforts seem to be driven more by the communicator's goals, desires, biases, or ambitions than by the audience's needs.

One indicator of failure in this area is the tendency to use the terms "public communication," "mass media," and "public understanding" interchangeably. The first is a goal, the second a method, and the third a desired or wished-for outcome. Public communication of science is any effort, large or small, to communicate information about science outside a specialist audience, either directing the communication at a particular audience or exploiting the mass media as a conduit to audiences of widely disparate tastes and backgrounds. Yet, curiously, it is the small, targeted effort that often falls to the bottom of a hierarchy of importance. The choice of media for government-funded science communication efforts sometimes seems ruled by a reverse elitism that regards a mass audience as infinitely more important than a small one. This bias toward mass-audience efforts stands conventional social theory on its head: Instead of defining an "elite" activity by limited access, it regards the mass communication effort as not just superior, but preferable. Time and time again, scientists and science communicators urge that activities be directed not to small community programs, not to programs that may reach small, economically disadvantaged audiences, but toward programming designed for millions. We need both types of programs, of course, but it is time to reexamine the neglect of programming directed at smaller audiences. Shirley Malcom, director of the AAAS Education and Human Resources Programs Directorate, makes just this point when she suggests that we attempt to reach people with messages about science in the places where they work and live (see Chapter 14): "Ordinary people go to the movies, rent videos, do sports,...go to the mall, to the grocery store....We must meet them on these terms."

The third term, "public understanding," can also have an unfortunate ring when communicators do not really care whether the audience truly understands the subject, but are only attempting to persuade the audience of their point of view—that is, to see science only as the communicators see it. This attitude, too, can be changed.

Perhaps we've just been looking in the wrong direction. Assessments of the success of efforts aimed at the public communication of science too often focus on the breadth and glitz of coverage and on the communicator's technique, rather than on whether the audience's needs were served. In her chapter in this book, Valerie Crane observes that, in television, the audience doesn't seem to care about production values (see Chapter 3). Television producers therefore tend to impose their own needs and goals—to implement lists of "shoulds" and "oughts" that reflect their biases, and not the audience's.

Perhaps we've also been too defensive. Experts in science communication have frequently exhibited an overprotectiveness that discourages criticism and that regards all communications about science as sacrosanct. These efforts can seem to be such "good works," initiated for such laudable goals, that we resist appearing to be critical, even when the emperor's new clothes clearly do not cover the flaws. It's time to encourage criticism and to speak the truth—we owe that to ourselves and to the audience.

Academics, of course, are just as guilty of this type of arrogant, self-assured stance as anyone. The essence of university teaching is the teacher's assumption that what she has to say is "good" for her students and that she knows best how to package it. On occasion, professors get some immediate feedback (such as the student asleep in the front row).

On occasion, students will tell us how useless or (if we're successful) valuable a lecture or class was. But most of the time, the signs are subtle, and we fail to seek out criticism. Our research on public communication of science has exhibited some of the same narrowness, the same biases found among the producers.

For million-dollar efforts, conducted through the impersonal, million-person means of public and commercial television, obtaining useful feedback is, of course, difficult, but the techniques of measurement are improving. One topic that demands renewed attention is the selection of standards. I mentioned Crane's assessment of how far production people may be from their audiences. By whose standards should the big programs be evaluated? Can they be evaluated fairly by people who don't necessarily espouse the same goals?

Many projects and production groups, such as Children's Television Workshop's *Square One TV* (see Chapter 7), do engage in careful self-evaluation. Their efforts represent an example of an attempt to be scrupulously honest about self-evaluation. But many others are not so scrupulous, and many groups do not welcome external evaluators. The tendency of science museums, for example, to rely only on their own internal evaluations of science exhibits reminds me of asking a country club to assess its own social usefulness or its own admissions policies. Do we really know whether the audiences in science museums receive the information that they want, or do we know merely that the visitors understood the concepts chosen by the curators? Do science museums seek out people on their own terms or simply attempt to "educate them up" to theirs? And how can we guard against political and social bias in the content?

When such questions are applied to communications ostensibly directed toward cultural and ethnic minorities, the failures become even more apparent. Too often, genuine concern for social reform obscures a lack of interest in, respect for, or celebration of the differences within the audience. What questions would most people really like to have answered about science? Are they yearning to learn the uninterpreted "facts" produced by science? If so, we know little about which facts they're interested in.

Failure to discern the audience's needs—and indeed a lack of concern about the audience at all—can be traced to some of the most well-publicized and widely praised efforts at bringing scientific information to the public. For example, there is a common assumption that "quality" productions are not commercial, not supported by the private sector, but only subsidized by the government or foundations. Yet, in parallel with that assumption has been the premise that these programs will somehow influence commercial efforts. Because there has been no deliberate evaluation of that "cross-pollination" and because government subsidy removes these communications from market forces, the accuracy of that assumption has yet to be tested.

Ironically, the same scientific community that praises government-funded public television efforts like *NOVA* will harshly (and, I believe, unfairly) criticize news reporting in newspapers and magazines governed by the marketplace. The *Time* magazine story that won a AAAS/ Westinghouse Award for Science Journalism this year was read by millions of people all around the world.[2] As a member of the judging panel for that award, I can speak for that article's quality; it was sound, excellent, hard-hitting reporting. It was also an article that celebrated science, but did not refrain from tough criticism of it. Moreover, the *Time* story appeared in a context that exemplified how most people learn about what's happening within science, for it was surrounded by news on the economy, stories about movie stars, and political reports. The story placed science squarely within the context of real life.

My research on science reporting in popular magazines shows that this is a normal context for such presentations. In the early 20th century, slightly over 3 percent of all nonfiction articles in U.S. mass-market, general-content magazines discussed science. These articles appeared among a constellation of stories about a whole host of other things.[3] A recent study of editorials in U.S. newspapers over the last few decades shows the same thing: Science formed a very small percentage of all topics addressed in the editorials. Most important, science was not isolated; it appeared alongside editorials on crime, foreign relations, and local politics. These types of presentations demonstrated subtly, but efficiently, that science is a vital part of the modern world, not just a subject of interest only to a political elite.

Unfortunately, academic scholars of science communication also have failed to attend to the audience—to identify the various publics for science and their needs. Instead, there has been a disturbingly complacent acceptance of the "attentive public" model, used to justify a hierarchical communications strategy. Many years ago, sociologists Bernard Rosenberg and Norris Fliegel commented on the sociology of artists.[4] They separated the interested publics for artists not into a pyramid, but into four interactive and sometimes overlapping categories: *friends*, *buyers and collectors*, *viewers*, and *critics*. We could envision a similar typology for science: (a) the "friends of science," including the scientists themselves; (b) the buyers-managers of science, such as R&D administrators, government officials, and members of Congress; (c) the viewers—the general audience unconnected to the communicator, but more objective and independent in their assessment of science; and (d) the critics—the people who criticize science communication efforts, but criticize in the same loving way that an art critic criticizes a painting.

I'd like to argue for a more normal standard of evaluation, one that asks, "What's being measured?" and "Whose yardstick is being applied?" Do the evaluations measure the totality of the communication to a wide, indiscriminate audience? Or do they simply measure a single performance? How might we measure the empowerment that comes with knowledge and that can come with learning more about science? And how might we create an "index of quality" for public communication efforts? Good indexes are composed of indicators that can be measured objectively, apart from the object or characteristic being measured. For public communication, in the past, the choice of yardstick has been left to those who instigated, sponsored, or even conducted the activity. A new index of quality might look to such factors as factual accuracy and sensitivity to science's historic, economic, social, and ethical aspects—and it must include sensitivity to audience needs.

Let me close with another passage from T. S. Eliot's "Four Quartets": "What we call the beginning is often the end," he says, "and to make an end is to make a beginning."[5] The papers collected in this book offer an opportunity for a new beginning for science communication studies, one that engages in tough critical thinking and that takes, as its starting point, the audience.

NOTES

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Technology and Culture (Chicago: University of Chicago Press, 1991). Her book *Stealing Into Print: Fraud, Plagiarism,* and *Ethical Misconduct in Scientific Publishing* will be published in September 1992 by the University of California Press.

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2. Michael Lemonick et al., "Smash: The Ultimate Quest," *Time*, April 16, 1990, pp. 50–56.
3. Marcel C. LaFollette, *Making Science Our Own: Public Images of Science, 1910–1955* (Chicago: The University of Chicago Press, 1990).
4. Bernard Rosenberg and Norris Fliegel, "The Artist and His Publics: The Ambiguity of Success," pp. 499–517 in Milton C. Albrecht, James H. Barnett, and Mason Griff, eds., *The Sociology of Art and Literature* (New York: Praeger Publishers, 1970).
5. T.S. Eliot, "Little Gidding," *The Complete Poems and Plays*, p. 144.

III. The Data

Case Studies in How Audiences Understand Science

Chapter 5

Sheep Farming after Chernobyl: A Case Study in Communicating Scientific Information

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The 1986 nuclear accident at Chernobyl and the resulting international radioactive fallout provoked unprecedented confusion, demands for information, and economic and social dislocations that extended far beyond Ukraine. The radioactive cloud also exposed stark discrepancies among national approaches to radioactive contamination and public health.[1]

Problems of communication and credibility have pervaded the disjointed actions surrounding the Chernobyl accident. The accident dramatically underlined a problem already gaining more general recognition: the difficulty of communicating technical knowledge about risks or lack of risks.[2] Scientists and government officials find themselves rationalizing real and considerable effects, the products of diverse interventions that are often based solely on abstract scientific justifications.[3]

The perceived credibility of scientists and governments greatly influences the effectiveness of communicating complex information on hazards to lay people. This chapter identifies some factors affecting the credibility of experts by describing a case study of one group—the hill sheep farmers of Cumbria in the Lake District of northern England, 150 of whom were still restricted in 1991 from selling their sheep freely.

In addition to receiving some of the highest levels of fallout from Chernobyl in all of Western Europe, the English Lake District is a good subject of study because its restricted sheep farming area is very close to the huge Sellafield nuclear fuels reprocessing complex. Sellafield's management and radioactive discharges have been widely criticized since the early 1970s. Many of the Lake District farmers have relatives and neighbors who work at Sellafield, and most can remember the 1957 fire in one of its nuclear reactors—the largest reactor accident in the world before Chernobyl.

The bleak mountains and narrow, deep-cut valleys of the English Lake District are economically marginal for cultivation but can support sheep farming. Contrary to the initial scientific pronouncements, the radioactive cesium from Chernobyl was not immobilized in the soil. Instead, it remained active far longer than expected, resulting in persistently high levels of cesium in sheep and annual resurgence effects.[4] Following reassurances from experts—first that there would be no problem, then that unexpected restrictions would last only a few weeks—by 1989, these experts declined to predict how long the restrictions might last.[5]

Responses of the Lake District sheep farmers to radiation from Chernobyl were critically affected by the following scientific advice:

- Political decisions to ban the sale of sheep after high levels of cesium 137 and 134 had been found in sheep from the area;
- Forecasts about the likely length and scope of the ban, which critically affected farmers' decisions;
- Official assurances about the origins of the contamination, given local suspicions that Sellafield might be implicated;
- Numerous revisions in restrictions, in light of changes in scientific and other knowledge; and
- Rules for compensation, designed to alleviate financial losses resulting from the restrictions, but which only some farmers received.

Not surprisingly, the issue of compensation was the focus of the most explicit conflict between farmers and officials: Sixty-five unresolved claims from Cumbria were still being fought in 1991. However, the experts' lack of credibility with the farmers on the other points undoubtedly fueled the fires of complaint and incredulity over compensation.

Abstract scientific knowledge may seem universal, but in the real world, it is always integrated with supplementary assumptions that render it culture bound and parochial. The validity of this supplementary knowledge crucially affects the overall credibility of "science" or "experts." Furthermore, the mode of communication of scientific knowledge itself conveys a set of tacit cultural and social assumptions or prescriptions. Efforts to communicate that ignore this fuller social dimension are likely to be ineffectual or even counterproductive.

These general conclusions drawn from the lapses in scientific information and communication in Cumbria are supported by descriptions of specific British responses to the Chernobyl fallout, the particular impacts on the Cumbrian sheep farmers, the farmers' interactions with various scientists and officials, and the farmers' own accounts of the experience.

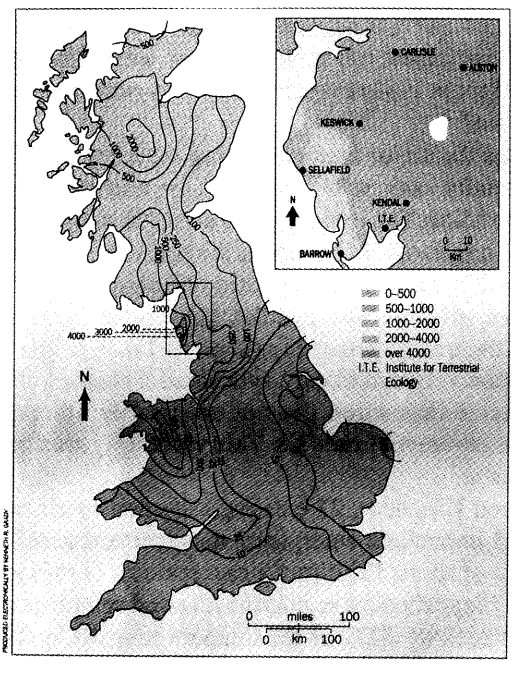
Chernobyl Fallout

The main cloud of radioactive contamination from Chernobyl passed over the United Kingdom on May 2 and 3, 1986. Virtually no precipitation disturbed the cloud on its circuitous, six-day, 4,000-kilometer journey, until heavy thunderstorms on May 2 rained radioactive particles unevenly across the United Kingdom. The Cumbrian fells suffered unusually high levels of rainfall—as much as 20 millimeters in 24 hours; the North Wales fells (where restrictions on selling sheep were also introduced and remained in effect in 1991) experienced heavy rain as well, although less than in Cumbria.[6]

Rainfall was the major factor affecting the local deposition of radioactivity, especially radioactive cesium. One millimeter of rain can deposit as much radioactive cesium as 24 hours' dry deposition, so that 20 millimeters of rain in one day deposits the equivalent of roughly 20 days' deposition in drier areas. Furthermore, because rainwater encounters uneven terrain, rivulets and puddles can create large differences in radioactivity, even over distances as short as 1 meter. Thus, actual levels of contamination varied markedly over small distances, and the variability of radioactive deposition did not necessarily correspond with the differences in amounts of rainfall. This variability was not fully appreciated at the time.

In the United Kingdom, 27 existing radiation-in-air monitoring stations provided immediate emergency management data.[7] Within a few weeks, a series of about 300 direct measurements of radiocesium (radioactive cesium) deposited on vegetation allowed scientists at the Institute for Terrestrial Ecology (ITE) on the southern edge of Cumbria to estimate contamination contours in England, Scotland, and Wales.[8] The fallout map shown in Figure 5.1 indicates that the Cumbrian hills—especially the southwestern part near Sellafield—received the highest radiocesium fallout in the United Kingdom, over 4,000 becquerels per square meter. (A becquerel is a unit of radioactive decay equal to one disintegration per second.) Another map of radiocesium deposition calculated months later from rainfall data, rather than deposits in vegetation, produced a different picture, with southwestern Scotland receiving over 20,000 becquerels per square meter of cesium and the Cumbrian and North Wales fells about 10,000 becquerels per square meter. An unrecognized "hot spot" in the Yorkshire Pennines was also identified retrospectively by this method.[9] The discrepancies between the radiocesium contamination maps, given their different methods of production, also gave circumstantial support to the suspicion that Sellafield was a source of contamination as well.

Figure 5.1. Distribution of cesium-137 on vegetation in Britain following the Chernobyl radioactive fallout (in becquerels/square-meter).



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These maps, however, were produced after the first few weeks of confusion and anxiety. In the beginning, the government issued only bland assurances. A farming journalist described the experience:

> The whole two-year event was characterized by great reluctance on the part of MAFF [Ministry of Agriculture, Fisheries and Food]—and indeed other government departments—to inform.... We had to wait for four weeks for the first press release and seven weeks for the first briefing. It was incredible—the silence was deafening.[10]

Punctuating the silence, however, were repeated government dismissals of the whole event. On May 6, Secretary of State for the Environment Kenneth Baker assured Parliament that "the effects of the cloud have already been assessed and none represents a risk to health in the United Kingdom."[11] Levels of radioactivity were "nowhere near the levels at which there is any hazard to health."[12] He stressed that the cloud was moving away with levels falling rapidly and that there would thus be a steady decline of already insignificant, if raised, levels of radioactive contamination.

John Dunster, head of the official government advisory National Radiological Protection Board (NRPB), was more circumspect, forecasting on May 11 that the Chernobyl disaster might lead to "a few tens" of extra cancers over the next 50 years in the United Kingdom. However, he also avowed that "if the cloud does not come back the whole thing will be over in a week or ten days."[13] Baker announced on May 13 that "the incident may be regarded as over for this country by the end of the week, although its traces will remain."[14]

The very same day, however, the Ministry of Agriculture, Fisheries and Food (MAFF) found samples of lamb meat taken from the Cumbrian fells recording levels of more than 1,500 becquerels per kilogram of cesium-137. This was 50 percent greater than the United Kingdom and European Economic Community (EEC) "action level" (level of radioactivity requiring official intervention) of 1,000 becquerels per kilogram. Nevertheless, official pronouncements continued to claim that contamination was decaying from already insignificant levels. The Department of the Environment (DoE), which had taken over the government coordination of information, even discontinued its daily bulletins on radioactivity levels on May 16, reasoning that levels were now insignificant.

On May 30, MAFF announced its findings of "higher readings" of radiocesium in hill sheep and lambs, but asserted that "these levels do not warrant any specific action at present," on the assumption that hill lambs were not yet ready to be sold and their high levels would soon decrease.[15]

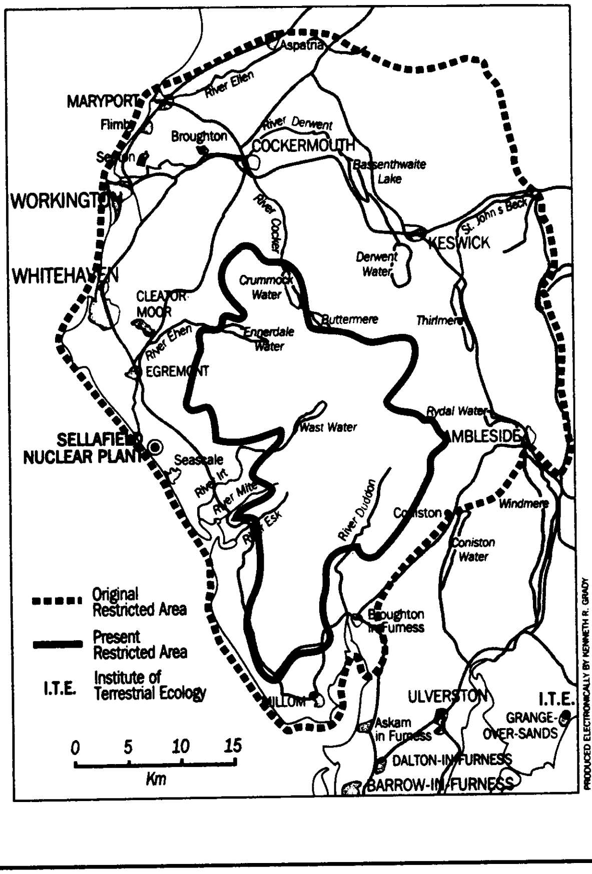
On June 20, however, in complete contradiction to previous advice to the public, Secretary of State for Agriculture Michael Jopling announced an immediate ban on the movement and slaughter of sheep in designated parts of Cumbria and North Wales. Even this utterly unexpected intervention was laced with reassurances that the ban would affect virtually no one in practice, because radiation would fall to acceptable levels before lambs were ready for market. The ban was thus imposed for only three weeks, based on the following confident assumption of declining radiation:

> Monitoring results present a satisfactory picture overall and there is no reason for anyone to be concerned about the safety of food in the shops. However the monitoring of young unfinished lambs not yet ready for market in certain areas of Cumbria and North Wales indicates higher levels of radiocesium than in the rest of the country.... These levels will diminish before the animals are marketed.[16]

However, levels of radiation in sheep increased rather than decreased. On July 24, the ban in Cumbria was extended indefinitely (see Appendix).

The areas restricted on June 20 contained over 4 million sheep and nearly 7,000 farms. Four days later, parts of Scotland were added to the restricted region. The Cumbrian restricted region was whittled down from 1,670 farms to 150 farms by the end of September 1986 (Figure 5.2). This area remained restricted in 1991. In June 1987, some farms in North Wales, Scotland, and Northern Ireland were restricted for the first time. At the height of the bans, about one-fifth of the sheep population in the United Kingdom, or 4 million sheep, was restricted from sale or slaughter. Nationally, about 800 farms and over 1 million sheep were still restricted as of March 1988.[17]

Figure 5.2. Map of Cumbria showing restriction on sale of sheep following the Chernobyl radioactive fallout.



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The Bureaucratic Labyrinth

Throughout the aftermath of the Chernobyl accident, farmers felt betrayed by bureaucrats and scientists. Four interrelated aspects of this betrayal stand out:

1. Scientists ignored local variations in radioactive fallout effects and in farming procedures that were central to farmers' experiences;
2. Experts were evidently ignorant of local farming realities and neglected local knowledge;
3. Bureaucrats critically interfered with the usual informal and flexible decision-making style of hill farmers, imposing an unrealistic degree of formalization and requiring inflexible prior commitments to marketing a set number of lambs at preselected markets; and
4. Government officials expressed a level of certainty in official statements that simply did not ring true with the farmers, who were used to adapting to uncertain and unpredictable forces, rather than assuming that they could control them.

The expected rate of decay of radioactive contamination in sheep was a critical factor in the whole episode. Official statements from several organizations during the seven weeks between the accident and the initial restriction order on June 20 conveyed the expert view that radioactivity levels in all environmental media would continue to decrease steadily. The MAFF statement on June 20 explained that new, clean grass replacing contaminated grass would stop lambs from ingesting radioactive cesium, so that, with a biological half-life of cesium in lambs of about 25 days, 21 days would see levels in meat roughly halved.[18]

However, monitoring showed no decrease in levels of cesium, and some lambs began testing at even higher levels than they had before. The original 21-day ban was therefore extended indefinitely. Farmers became desperate because their limited pastures could not sustain the contaminated lambs. The sale of spring lambs provides hill sheep farmers with their only significant yearly income. The sheep are allowed to produce more lambs than the poor pastureland can support for very long, so the lambs must be sold before they start to overgraze. Because spring lambs are taken to market starting in August, the restrictions prevented hundreds of thousands of radioactively contaminated lambs from leaving the hills at a time when the grazing had become utterly inadequate. Hill farmers feared that there might be slaughter of all contaminated sheep, not just the unsalable lambs, which would have meant total disaster for the long-term breeding cycle, in which lambs are habituated by their mothers to specific areas of the immense, unfenced fells.

Although the initial scientific wisdom was clearly incorrect, MAFF, expecting all restrictions to be lifted, continued to advise farmers to hold their sheep a little longer, rather than sell them short as contaminated.[19] Despite contradictory evidence, the scientists still believed firmly that radioactive contamination in hill sheep would soon decline, and their advice to farmers was founded on this belief. The policy of short-lived restrictions was based on the assumption that, after the initially contaminated grass was consumed, radiocesium would be immobilized in the soil, not incorporated into the new growth of grass.[20] However, this model for cesium distribution originated in research on lowland, clay mineral soils. The upland soils were mainly acidic, with high organic content in which cesium remained chemically mobile and available for uptake into the roots of vegetation. Because scientists failed to take into account the special geological and vegetal conditions in Cumbria, their flawed advice continued to oppose the farmers' personal experience of continuing high levels of radiocesium and their cultural intuition of cyclical processes.

Moreover, in advising the farmers to hang on to their lambs a little longer, the experts appeared not to understand the consequences for the lambs' physical condition, which is critical to their market price. Pinpointing the optimum moment for marketing lambs forms the centerpiece of sheep farming expertise. The critical elements of the decision are flexibility and adaptability to the unexpected. Following variable winter conditions, several hundred lambs born over a period of six weeks from mid-April until the end of May will fatten to market readiness at different times from August to October. Usually, therefore, the farmer selects a few ready lambs the day before market and takes them for sale. The timing of the sales is critical because lambs rapidly go out of condition and lose market value if allowed to become overfat or underfed. The decision process requires highly flexible judgments: whether to take any lambs at all; if lambs are taken, how many and which ones; and to which of several nearby markets to take them. Complex craft judgments regarding trends in prices, rates of finishing of other lambs, pasture conditions, the buildup of disease, the condition of breeding ewes for mating for next year's lamb crop, the need for money, and many other dynamic factors partly or fully beyond the control of the farmer enter into these decisions. The process is one of informal but highly refined expert judgment. It runs completely counter to the rigidity of the bureaucratic method for dealing with the crisis: Sell the lambs later, and formalize the process into an inflexible, fully documented activity accountable to distant bureaucrats.

In response to the desperate overgrazing problem, on August 13, 1986, the government permitted farmers to sell and move contaminated sheep from restricted areas if they were marked with blue paint.[21] All sheep in the restricted regions had to be tested for contamination. Sheep testing below the action level of 1,000 becquerels per kilogram could be sold without restriction; sheep testing above the action level could be painted and sold at a loss. Slaughtering the marked sheep for market was forbidden until the original area was rendered nonrestricted.

Although it was possible to lower contamination levels beneath the action level by grazing sheep in the less contaminated valleys instead of the highly contaminated fells, the sparse valley grass was needed for valuable winter hay and silage crops; once grazed on, the grass grows back only slowly. When the technical experts realized that heavy contamination affected mainly the high fells, they advised the farmers to keep the sheep in the valleys, a grossly unrealistic suggestion, as the hill farmers pithily pointed out.[22] Experts responded with, among other things, the statement that when the sheep were given imported feed "such as straw," they would soon register clean.[23] A typical reaction was:

> [The experts] don't understand our way of life. They think you stand at the fell bottom and wave a handkerchief, and all the sheep come running.... I've never heard of a sheep that would even look at straw as fodder. When you hear things like that, it makes your hair stand on end. You just wonder, what the hell are these blokes talking about?[24]

Furthermore, gathering sheep beforehand from the fell requires an arduous day's work on foot simply to get them back to the farm. A full gather on some of the larger farms takes 10 separate days. If low clouds on the morning of a gather affect visibility, as is common, the gather must be postponed until visibility improves. All this is coordinated with neighbors in a mutual aid system. In these circumstances, flexible decision making is essential, and a deep natural skepticism is induced toward decision-making systems (such as those of science and technology) that are based on a belief in control and certainty.

Inevitably, the Chernobyl-related restrictions destroyed much of this flexibility and undermined the farmers' autonomy and sense of identity in managing familiar uncertainties by the complex dynamics of forecasting and adaptation. The restrictions required farmers to notify the local MAFF office in Carlisle at least five days in advance of their intention to sell a certain number of sheep, and to identify the market. The farmer had to give notice in order to schedule the monitoring session and had to wait with the sheep on the appointed day. Gathering, sorting, and managing sheep for the many tests required by MAFF and others took more time and interruption than officials recognized. The lambs sometimes needed to be gathered and returned to the fells two or three times before they passed a monitoring session, a source of further frustration.

Although the farmers accepted the need for restrictions, they could not accept the experts' apparent ignorance of the effects of their approach on the normally flexible and informal system of hill farm management. This experience, of expert knowledge being out of touch with practical reality and thus being of no validity, was often recounted with diverse concrete illustrations in interviews with the sheep farmers. Many local practices and judgments important to hill farming were unknown to the experts, who assumed that scientific knowledge could be applied without adjusting it to local circumstances.

Compensation Conflicts

Three particular points of conflict over compensation illustrate the cultural divide separating farmers and officials. First, when farmers began to assess their losses and make claims during the winter of 1986-87, MAFF told them to produce full, quantified documentation. They were told they should have kept a detailed diary of such costs ever since the crisis first erupted. Many farmers angrily replied that during those early weeks, the very same ministry experts had been reassuring them that the restrictions would not last long enough to affect anybody.

Second, the initial compensation offered was to make up the market loss suffered on blue-marked, radiation-blighted sheep. However, in September 1986, the government had announced that compensation would be discontinued. Sales after September 28 would be assumed not to have been forced by grazing shortage, and therefore, losses on sales after that date would not be eligible for the compensation. Quite apart from the fact that many farmers did not hear of this deadline until it was too late, the officially claimed notice period did not consider the time needed to gather, sort, and get sheep to market and the farmers' total lack of control over scheduling the various efforts. Furthermore, the effect on prices of the rush to sell created by the deadline was not officially acknowledged. Also unrecognized was the effect of the whole crisis on the price of unmarked sheep, and so no compensation was offered. Moreover, the lowered price for unmarked sheep was the yardstick for compensation. The government was now contradicting its previous advice to hang on to sheep in the confident scientific expectation of imminent removal of restrictions. To bewildered farmers, this switch was easy to read as a deliberate trap, and many did indeed see it that way, as a conspiracy to defraud them of compensation, using allegedly secret knowledge that the high contamination levels were going to last much longer than anyone was admitting.

When market losses were estimated for compensation, payments for marked sheep were calculated into the average for that market. This kind of averaging incensed farmers, who felt that their sheep should be judged for the price they would have gained as healthy sheep in a normal market. A judgment of this sort epitomizes the kind of individual, expert decisions that are central to the farmers' daily practice. To farmers, such a judgment was reliable as a decision rule. To administrators, however, the criteria had to be standardized and "objective." This amounted to saying that government did not trust the farmers.

Third, many of the farmers' costs were intrinsically very difficult to document and quantify. Extra time was spent waiting for monitors to come to the farms and laboriously gathering and handling sheep to comply with the restrictions. Extra handling and unsettlement also worsened the animals' condition and thus affected their value; these effects were very obvious to farmers but invisible to inexperienced bureaucrats. Eventually, the farmers were awarded a payment for each head of sheep handled, but not before the experts had solidly established themselves as unrealistic and arrogant.

Thus came the typical farmers' lament. They complained that the experts "can't understand. They think a farm is a farm and a ewe is a ewe. They think we stamp them off a production line or something."[25] These comments were often elaborated with detailed explanations of variations in conditions and of resultant optimal husbandry practices even between neighboring farms—variations and decision factors that were obvious to the specialist farmer but invisible to the outside expert.

The very nature of the documentation task contradicted the farmers' experience. Restricted hill farmers filled out administrative forms for each movement and sale of sheep and provided auctioneers with copies. As the restrictions developed and the rules altered, the forms and procedures also changed, and government agencies showered farmers with instructions and advice. The barrage of written advice was intended to help, but it was alien to people accustomed to dealing with everything personally and informally. Farmers depended heavily on practical help from their local farmers' union official, local MAFF officials, and local auctioneers, all of whom they knew and trusted individually. Indeed, filling out forms was often totally entrusted to these officials, the explanatory documents being consigned to the kitchen fire. In effect and completely without prior design, these informally defined local mediators rescued the official information process from disaster.

The Sellafield Factor

The Sellafield nuclear reprocessing plant in Cumbria complicates public perceptions of hazards and expert credibility. The plant was established as a military plutonium factory called Windscale (the name was later changed to Sellafield) in 1951, only a few miles from the hill farms now beset by radioactive contamination.[26] Its military nuclear reactors were supplemented with electricity-producing nuclear reactors in 1956. Sellafield's own radioactive emissions have been a source of controversy since the mid-1970s and have provoked repeated allegations of damage to local public health and the environment.[27] In particular, in 1983, a consistently rising incidence of childhood cancers over the past 25 years was identified within a 15-mile radius of Sellafield, although no causal link to the plant could be definitely established. Thus, well before 1986, considerable anxiety about the plant's discharges and management already existed. In addition, in 1957, the site suffered the world's worst nuclear reactor accident prior to Chernobyl, when a military reactor caught fire and burned for three days, emitting an estimated 70,000 curies of radioactivity. (A curie is the radioactive decay rate of one gram of radium.) Milk from 200 square miles of farmland had to be thrown away for several weeks afterwards because of iodine 131 fallout, but full monitoring data in the environment were never released and may never have been collected.

Because of the remarkable coincidence of large depositions from Chernobyl around such a huge nuclear site, the suspicion arose that contamination on the fells had always been high from Sellafield's routine discharges or the 1957 fire, but had simply not been monitored or admitted before the Chernobyl emergency. Such concerns were widely expressed by residents after the Chernobyl incident but were denied by the experts, who stated unequivocally that the isotope ratio of cesium-137 to cesium-134 in Sellafield discharges could be distinguished from the fresher Chernobyl discharge.[28] Because the half-life of cesium-137 is about 30 times that of cesium-134, the ratio of cesium-137 to cesium-134 increases with time. The Chernobyl fallout ratio was about 2 or 3 to 1, whereas the ratio of the remaining radiocesium isotopes from the Sellafield fire was about 12 to 1.

To the farmers, this distinction was highly theoretical. Interviews with the farmers revealed a widespread belief that contamination from Sellafield had existed unrecognized since well before 1986. Farmers believed for several reasons that Sellafield radiation contributed to their high levels of contamination. First, the isotope ratio distinction could not be demonstrated to them. They were simply asked to believe the same experts who had shown themselves to be equally confident but wrong about the rate of decline of the contamination. The false certainty of the scientists was frequently cited as a sign of their lack of credibility. Second, the farmers were well aware of the fantastic variability of contamination over very small distances on their own farms; yet they saw these variations processed in public scientific statements into average figures with no variability or uncertainty. If these measurements could be so misrepresented, perhaps the isotope ratios could also be more variable than what the experts would publicly acknowledge.

When on September 30, 1986, the initial ban over nearly the whole county was reduced to apply to a much smaller crescent around the Sellafield plant (Figure 5.2), farmers felt confirmed in their judgment that background radiation from Sellafield was raising their levels of contamination. One farmer close to Sellafield, relating the distribution of post-Chernobyl monitoring data on his own farm to his own experience, noted that the highest readings of contamination regularly came from just that place where vapor clouds from the plant usually hit the fell side.[29] Another farmer remembered walking on ash deposited on the same mountains in the wake of the 1957 fire, whereas the scientists said there was no contamination of the fells from that fire.

The farmers' skepticism about Sellafield's claimed innocence was consolidated when requests for radioactive monitoring data from the fell tops and from hill sheep before Chernobyl were diverted to avoid the embarrassing official admission that little or no such data had actually been gathered before Chernobyl.[30] The farmers thus drew their own conclusions about expert credibility from the official maneuvering to cover up this important gap. Government technical officials appeared doubly incompetent, since the scientific ignorance about radioactive cesium in the local environment could have been dispelled by proper research in the area after the 1957 fire. Whether such research had been overlooked or was being covered up, neither explanation benefited the experts' credibility. Moreover, in March 1988, a survey reported that half the contamination on the fells was from Chernobyl and half was from Sellafield and nuclear weapons' testing fallout combined.[31]

The Cumbrians' reactions to Sellafield and Chernobyl strikingly substantiate the point that lay people define and judge a risk according to their experience of those institutions that are supposedly in control of hazardous processes, not just according to the physical parameters of the processes alone.[32] Furthermore, this institutional basis of judgment has a dauntingly long reach through time and across social issues. Entirely separate issues to experts—the 1957 Windscale fire, the control and justification of Sellafield's routine discharges, and the Chernobyl accident—became the same issue to members of the public, who experienced the same social structures and relationships of dependency, perceived scientific arrogance and unrealism, secrecy, and official unwillingness to admit uncertainty or error.

Communication and Decisions

Fieldwork has revealed a cultural chasm underlying the failure of expert communication about radioactivity and sheep restrictions. Eventually, farmers adapted to the restrictions, and experts overcame some of their ignorance of hill farming and its local environment. This pragmatic adaptation provides no basis for transferring the benefits of experience to other situations, however. Moreover, a deep mistrust of scientists and central government officials persists among the hill farmers. In some respects, this distrust has been exacerbated as farmers' experiences increase. For example, the complications and untidiness of the scientific methods practiced in post-Chernobyl field research on the farmers' farms contrast sharply with the professed certainty of official scientific knowledge and the implied tidiness of the scientific method.[33]

Communication is not just an appendage to decision making, intended to provide post hoc explanation and justification. The allocations of authority and power inherent in routine decision making communicate built-in assumptions about which kinds of experience and social groups are worth something and which are marginal. If a communication program ignores this social and historical context, it is likely to be self-contradictory, unrelated to rooted experiences and concerns, and thus ineffective. Effective communication between technical experts and lay people, therefore, requires both groups to reconsider their regular social relationships.

In the sheep farmers' case, for example, critical to the scientific experts' lack of credibility was their inability to recognize that the farmers held extensive informal but expert knowledge about the habits of sheep, the local physical environment, and farming practices and decision making, all of which needed to be integrated with more abstract and formal scientific knowledge to create an effective framework for response to the Chernobyl fallout. Nor did the experts recognize the cultural and practical incompatibility of hill farming with a bureaucratic model in which everything is assumed to be subject to standard rules, control, deterministic planning, and formal evidence.

In addition, a deeply embedded scientific assumption—amounting to a general stereotype—about lay people is that they cannot handle uncertainty and risk and thus need to have technical information "simplified."[34] In the United Kingdom, this stereotype is amplified by the strongly paternalistic political culture, in which the government's role is to reassure people. In Cumbria, the scientists' tendency to understate uncertainty (supposedly for public benefit) backfired and damaged the credibility of scientific information because the idiom of certainty and standardization did not accord with the normal experience of the lay public.

Although hill farmers may be more accustomed to uncertainty and risk than are other communities, evidence suggests that scientists misconstrue the lay population's fear of hazards. For example, technical experts in the European chemical industry were horrified at the requirement in the 1982 Seveso Directive to inform the surrounding public, many of whom were long-time residents, that they lived near a major hazardous chemical plant.[35] However, contrary to the industry's fearful expectation of public disquiet on being informed of such hazards, the universal experience was that people had already understood that a hazard existed and therefore did not react. The experts' assumption that, in blissful ignorance of the risks, lay people expected a risk-free environment was shown to be a fiction.

Although the degree of uncertainty and variability expressed in scientific information communicated to the public should not be limited automatically because of some untested assumption as to the public's needs and capabilities, the automatic adoption of an alternative model of a public thirsting for uncertainty and variability could be equally false and ineffectual. The social relations pertaining to routine decision making and communication should allow negotiation between experts and the public to determine the appropriate levels of uncertainty and disaggregation in each particular case. This negotiation would result in an intercultural understanding about the expectations of knowledge or information—for example, how conclusive or how universal such knowledge or information is.[36] In Cumbria, some hill farmers eventually managed to communicate with scientists who visited their farms repeatedly to do research and who often stayed for several days as guests. During these visits, the parties engaged in informal conversation about the scientific research process. This serendipitous and limited interaction improved the credibility of these scientists and of associated institutions, even though such encounters revealed scientific uncertainty. The Institute for Terrestrial Ecology was most fortunate in this respect because, as a locally based institution, it had the closest such practical contact. Through the farmers' informal grapevine, the institute subsequently gained a reputation as being plainspoken, open about uncertainty, independent, and trustworthy.

The scientific expertise administered by MAFF was more centralized, hierarchically structured, and geographically and culturally remote. Although the farmers treated all scientists and experts with skepticism, they quickly learned to distinguish and evaluate the different institutional affiliations; special contempt was reserved for MAFF.

The situation was rescued only by the mediation of local MAFF officials who were personally known and trusted by the farmers. However, these officials were not scientists, so the negotiation of an effective communications framework—with the expression of accurate scientific knowledge in socially appropriate terms and the assimilation of local knowledge with the existing scientific knowledge—was crippled. The dominant MAFF view assumed a deficit model of communication and public understanding of science, in which a universally valid body of scientific knowledge is diluted, distorted, and often undermined by the lay public and media. MAFF officials did not appreciate the fact that science may also be parochial (the assumption about cesium immobilization by clay soils, for example) and that it may need to be supplemented by special situational knowledge, perhaps expressed in a nonscientific idiom.

A less centralized organization of scientific expertise in the ministry would have aided the two-way information exchange, as well as the intercultural negotiation, of what was expected (for example, the appropriate degree of uncertainty) from science. The necessity of reorganizing the routine social structure of decision making is ignored in current conceptions of risk communication.[37] Of course, it may be argued in any particular case that the reorganization of routine decision making—that is, of power and social control—is an unacceptable price to pay for better communication of technical hazard information. However, if the aim is genuinely to develop effective and authentic communication, rather than to achieve the short-term goal of public quiescence, that reorganization is probably the going price. Furthermore, the achievement of short-term goals is increasingly attended by long-term disorientation and instability in public reactions to expertise.[38] Such a price may therefore be worth paying.

Appendix

Timetable of Official Reactions to Radiation Contamination in Cumbria

DATE	EVENT
1951	Windscale (later Sellafield) reprocessing plant and nuclear reactors begin operation.
1957	Windscale reactor fire emits radioactivity, resulting in a ban on the sale of milk in a 200-square-mile milk area.
1983	Raised incidence of childhood leukemias is reported near Sellafield.
1984	Sellafield operators are prosecuted for illegally exceeding authorized levels of discharge and polluting a local beach.
April 26, 1986	Chernobyl accident.
May 2–3, 1986	Radioactive cloud crosses the United Kingdom. Heavy rain falls over Cumbria and North Wales.
May 6, 1986	Secretary of State for the Environment Kenneth Baker states that there is no risk to health in Cumbria from the Chernobyl accident.
May 11, 1986	National Radiological Protection Board (NRPB) head John Dunster claims that the effects of Chernobyl will be over in a week or two.
May 13, 1986	Cumbrian lamb samples tested for cesium show levels in excess of 1,500 becquerels per kilogram of tissue.
May 30, 1986	Ministry of Agriculture, Fisheries and Food (MAFF) notes "higher readings" of cesium, but assures the public that no action is warranted.
June 20, 1986	Three-week ban on movement and slaughter of sheep in Cumbria and North Wales is established.
July 24, 1986	Three-week ban is extended indefinitely. Compensation is announced for overfat sheep (i.e., lambs kept too long from being sold).
August 13, 1986	Marked sheep could be sold and moved, but not slaughtered. Compensation is announced for marked sheep.
September 1986	MAFF announces deadline of September 28 for compensation for marked sheep.
September 30, 1986	The restricted region is whittled down.
April 28, 1987	British government announces that restrictions may continue through a second lambing and marketing season.

June 1987	Previously unrecognized radiation hot spot is discovered in Yorkshire. Opposition Labor spokesman David Clark alleges contamination of food chain by lambs prior to ban of June 20, 1986.
January 1988	Government papers reveal extent of cover-up of 1957 Windscale fire. House of Commons announces inquiry into government response to Chernobyl emergency.
July 1988	House of Commons Select Committee report's main criticism is of government communications.
Fall 1988	Scottish Universities' Reactor Research Centre's aerial grid survey by helicopter for radiocesium shows some areas of Scotland with up to 40 times the official MAFF figures. Levels around Sellafield register about 300,000 becquerels per square meter, roughly 10 times the highest recorded level of Chernobyl deposits.

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NOTES

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5. See, for example, Ministry of Agriculture, Fisheries and Food (MAFF), evidence to the U.K. House of Commons Select Committee Report, *Chernobyl:The Government's Response, Minutes of Evidence, Vol. II* (London: H. M. Stationery Office, July 1988); and MAFF letters to farmers, March 21, 1988, and December 12, 1988. When a report from the Welsh Country Landowners' Association suggesting a ban of at least 30 years was widely publicized, MAFF's criticism of it was notable for its lack of specific commitment to a shorter duration (MAFF press release, London, February 8, 1988). MAFF press releases and circulars may be obtained from Food Science Division, MAFF, Great Westminster House, Horseferry Road, London SW1P 2AE, United Kingdom.

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Agriculture, Fisheries and Food (MAFF) in 1988 confirms suspicions of higher, previously unmeasured levels of radiocesium in the soil of the fell areas; readings of up to 100,000 becquerels per square meter were recorded, levels an order of magnitude higher than Smith's findings. The aerial survey recorded radiocesium signals to a depth of 30 centimeters and so includes a record of the combined contamination from Chernobyl fallout, weapons testing fallout, and Sellafield/Windscale emissions. The survey also found even higher radiocesium levels at certain points along the coast known to be contaminated by Sellafield's marine discharges. The new radiation figures are published in MAFF, *Aerial Radiometric Survey in West Cumbria 1988*, available from MAFF Publications, Lion House, Willowburn Trading Estate, Alnwick, Northumberland, NE66 2PF, United Kingdom.

9. F. B. Smith and M. Clar, "Deposition of Radionuclides from the Chernobyl Cloud," *Nature*, 1986, 322:690–91; and Smith, "Environmental Consequences." The latter paper exposed a high-deposition area in Yorkshire that had not been communicated to MAFF and that had thus escaped close monitoring. This fueled allegations that sheep above the contamination limits had gotten into the food chain.
10. Martin Oliver, editor of *Farming News*, House of Commons Select Committee Report, Vol. II, May 25, 1988, 227.
11. U.K. *Hansard Parliamentary Debates* (Commons), 6th ser., vol. 97 (1986), col. 20.
12. *Ibid.*
13. U.K. National Radiological Protection Board press release, May 11, 1986, available from NRPB, Chilton, Didcot, OXON, OX11 ORQ, United Kingdom.
14. *Parliamentary Debates*, col. 182.
15. MAFF press release, London, May 30, 1986.
16. MAFF press release and circular letter accompanying ministerial statement to Parliament, London, June 20, 1986.
17. In spring 1988, the restrictions covered 69 farms and 640,000 sheep in Scotland, 416 farms and 300,000 sheep in Wales, 123 farms and 27,335 sheep in Northern Ireland, and 150 farms and 90,000 sheep in Cumbria. These data are available from the U.K. House of Commons Select Committee Report, Minutes of Evidence.
18. MAFF press release.
19. For example, MAFF advisory letters of August 13 and 18, 1986, told farmers that since "levels were continuing to fall" they "should consider very carefully" whether they wished to mark and release their sheep, rather than wait a little more.
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29. Hill farm interview, November 1987.
30. For example, demands for such pre-Chernobyl data by farmers to MAFF scientists at the public meeting in Broughton, a local market town, in February 1987 were met by references to a very thick MAFF document, which contained only post-Chernobyl monitoring data.
31. "Chernobyl II," *Farmer's Weekly*, March 11, 1988, 76. See also "Chernobyl I," *Farmer's Weekly*, March 4, 1988.
32. See, for example, Brian Wynne, "Technology, Risk and Participation: The Social Treatment of Uncertainty," in Jobst Conrad, ed., *Society, Technology and Risk* (London: Academic Press, 1980)
33. Brian Wynne, "Public Understanding of Science: From Content to Process," *Newsletter of the European Association for Studies of Science and Technology (EASST)*, February 1987, 3–8; and Robin Millar and Brian Wynne, "Public Understanding of Science: From Contents to Processes," *International Journal of Science Education*, 1988, 10:172–184.
34. For example, Royal Society of London, *The Public Understanding of Science* (London: Royal Society, 1985).
35. Brian Wynne, *Implementation of Article 8 of the Directive EEC/501/82: A Study of Public Information* (Brussels: Commission of the European Communities, Directorate-General XI, 1987); and Alison Jupp, "Public Information about Major Hazards" (master's thesis, University of Manchester, 1987).
36. Robert Paine, "Making the Invisible 'Visible': Coming to Terms with Chernobyl and Its Experts" (unpublished draft, Memorial University of Newfoundland, 1988).
37. The conventional approach that does not adequately recognize the social context of perception and communication is illustrated in the literature

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38. See, for example, Royal Society, *Public Understanding*. Also see Brian Wynne, ed., *Risk Management and Hazardous Wastes: Implementation and the Dialectics of Credibility* (London/Berlin/New York: Springer Verlag, 1987), especially Chapter 11, "Risk Perception, Decision Analysis and the Public Acceptance Problem"; and Brian Wynne, "Frameworks of Rationality in Risk Management: Towards the Testing of Naive Sociology," in Jennifer Brown, ed., *Enivronmental Threats: Social Sciences Approaches to Public Risk Perceptions* (London: Belhaven Press, 1989).

Chapter 6

Evaluating the "America Responds to AIDS" Campaign

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The Centers for Disease Control (CDC), a U.S. Public Health Service agency, has the primary responsibility for educating the public about the human immunodeficiency virus (HIV) and inhibiting the HIV epidemic through prevention activities. CDC has approached this task through three routes: a multiphase national AIDS media campaign, projects involving community-based organizations that focus on small groups or specific populations, and a network of counseling and testing projects targeted to individual clients.[1] This chapter examines the first of these routes, the "America Responds to AIDS" or "ARTA" social marketing campaign.

Social marketing is "the design, implementation, and control of programs seeking to increase the acceptability of a social idea or practice in a target group."[2] It has existed in the United States for over a century and at various times has focused on such health-related behaviors as tobacco use, alcohol and drug use, control of hypertension, cancer screening, seat belt use, and—recently—behaviors placing a person at risk for HIV infection or a sexually transmitted disease. A "social change campaign," which is a component of social marketing, is "an organized effort conducted by one group (the change agent), which intends to persuade others (the target adopters) to accept, modify, or abandon certain ideas, attitudes, practices, and behaviors."[3] A change in or maintenance of behavior is the goal of many social change campaigns.

In 1987, CDC established the National AIDS Information and Education Program (NAIEP) to direct the Public Health Service's general AIDS media campaigns and social marketing activities. NAIEP is responsible for assuring a comprehensive, consistent federal effort to inform the public about HIV infection and AIDS and for supporting social norms consistent with low-risk behaviors.[4] Its goals include educating and informing the general public about behaviors that would place any individual at risk of being infected with the HIV virus (primary prevention) and also educating and motivating infected individuals to avoid transmitting HIV to non-infected individuals (secondary prevention).

NAIEP accomplishes its goals through an ongoing media campaign distributed under the ARTA logo or under localized, state logos (e.g., "Tennessee Responds to AIDS"). ARTA has one or two phases, or production and distribution cycles, each year. NAIEP's social marketing program also includes a National AIDS Clearinghouse and a National AIDS Hotline. Whenever possible, these activities are coordinated with state and local health departments' AIDS prevention activities and with the media campaigns of other organizations.

The ARTA campaign must deal with a number of impediments. First, it must address several issues—including illicit drug use, sexual activity, and death—that are considered taboo or that create highly charged reactions in our society. For example, it is not generally acceptable in our society to recommend open discussion of one's past sexual partners and their experiences. Further, some members of the general public do not condone even covert reference to any sexual behaviors, let alone homosexual or bisexual behaviors. The lethal danger of HIV infection is also problematic. Many of us have difficulty confronting our own mortality and do not welcome a reminder of it by reference to a fatal disease.

A second difficulty faced by ARTA's designers is that the nature and status of HIV research have changed rapidly over the last decade. The ARTA campaigns must reflect the most current status of the epidemic and the medical knowledge, legislation, research, and therapy issues surrounding it. This often forces NAIEP to develop, evaluate, and produce materials quickly.

A third problem is that most HIV-related behaviors are either addictive (intravenous drug use) or, at the very least, very emotion driven (sexual intercourse). People become very comfortable with their sexual practices and tend to find them generally rewarding. To suggest suddenly the idea that everyone should practice abstinence or use condoms strikes some individuals as irrational, inappropriate, or too high a price to pay for safety.

A fourth impediment to the ARTA campaign is its rigorous clearance process. Draft materials are developed and reviewed by NAIEP and its contractors. In addition, cross-cultural panels and representatives of national organizations, health departments, community-based organizations, and the national television networks all review the materials at various stages of development. Various officials within CDC, the Public Health Service, and the Department of Health and Human Services must review and—in some cases—approve the materials. The approval process can take four to eight weeks between the production of early drafts and final materials.

A last constraint on the ARTA campaign is the expectations of the state health departments. Many health departments rely on the ARTA campaign for the media component of their HIV prevention efforts. Other prevention activities are coordinated with the scheduled release of each campaign phase. Delays in that release therefore have wide-sweeping implications.

The National Academy of Sciences Recommendations and Overview of NAIEP's Response

In 1987, CDC commissioned the National Academy of Sciences (NAS) to recommend evaluation approaches for all CDC HIV prevention activities, including counseling and testing programs, health education and risk reduction projects, and the ARTA media campaign. For the ARTA public service announcement (PSA) campaign, NAS recommended that NAIEP conduct formative, efficacy, process, and outcome or effectiveness evaluations.

NAIEP had already been conducting process evaluations. But, in May of 1989, NAIEP formed the Applied Communications Research, Epidemiology, and Evaluation (ACREE) unit to respond more fully to the NAS recommendations. This chapter examines some practical issues about evaluation that ACREE has identified.

Formative Evaluation

Formative evaluation identifies problems that exist before the implementation of the solutions occurs. The goal is to answer the question, "What works better?"[5] NAS recommended that concept testing and copy testing occur during formative evaluation of new ARTA material. Concept testing, the first step of formative research, uses qualitative and quantitative research methods to determine why individuals are or are not performing the behavior in question. The goal of concept testing is to produce messages that will persuade the target audience.[6] Within concept testing, focus groups can be used to find out what messages would be most appropriate for specific populations. For the ARTA campaign, focus groups can provide insights as to how various persons currently view the HIV/AIDS epidemic and their own behavior (e.g., sexual behavior) in relation to it. Focus groups do not necessarily represent any particular population, but they can be used to clarify the reasons for misperceptions or noncompliance with recommendations concerning HIV-related behaviors. A better understanding of these issues can help in developing materials that the target population will understand and find appealing and to which they will respond as intended.

The second step of formative evaluation involves testing actual materials under development. In copy testing, "alternative message appeals are compared in terms of their success in achieving specific cognitive, affective, or behavioral outcomes."[7] Because of ARTA's broad reach, NAIEP has added the additional goal of ensuring the absence of unintended, negative effects on the nontarget audience that will also see the material. For example, if a specific PSA is targeting at-risk persons, we do not want those not at risk to think that HIV has no effect on their own lives or that infected people in any way have "earned" their infection because they could have avoided at-risk behaviors. Thus NAIEP's copy testing must address three issues: (1) Can each item have a measurable impact on its stated objective? (2) Does any item have an undesired effect on either the target or the nontarget audience? and (3) Which materials under development are clearest, most appealing, most memorable, and most effective?

ACREE currently performs three stages of copy testing: early, late, and ad hoc. In early copy testing of television broadcast materials, for example, storyboards (simplified cartoonlike displays of proposed materials) and animatics (films of storyboards with a soundtrack) are used.[8] Late copy testing is done using material produced prior to editing or material under final production. Ad hoc copy testing is actually an ongoing process involving a variety of studies designed to address issues that have relevance beyond a single piece of material as they arise. For example, currently all ARTA PSAs include a tag line encouraging viewers to call the National AIDS Hotline or a local hot line. A series of projects is under way to determine what elements of a PSA might influence the viewer's willingness or intent to call the hot line.

In accordance with NAS recommendations, for much of our formative research, ACREE recruits convenience samples of study participants who are randomly assigned either to view a single item or to serve as a "nonexposed control." The "exposed" subject views the material and provides open-ended feedback, using one or more commercially developed response instruments. In addition, all subjects complete a short questionnaire consisting of scaled items related to the communication objectives of the current campaign phase. For late copy testing and some ad hoc testing, individuals respond to materials using hand-held data entry equipment that monitors reactions on a "moment-by-moment" basis. Results are analyzed while the participants are still in the viewing room, allowing discussion of the reasons behind findings that are of note for various audience segments, very much as in a focus group.

Efficacy Evaluation

Efficacy evaluation examines whether a specific campaign could be successful under "optimal conditions," using quasi-experimental designs in a field setting.[9] NAS recommended that this type of evaluation be carried out before the campaign is launched, continue for at least six months, and use a randomized experimental design in test and control markets.[10] However, meeting these recommendations is difficult for the ARTA campaign for two reasons. First, NAIEP has little control over the airing of ARTA PSAs. The campaign relies on donated time, and this precludes optimal targeting or exposure over a short period. Even if NAIEP could afford to pay for short-term, research-related PSA placement, the program could not afford the higher talent fees provided to actors in paid-for-placement advertisements. Second, and more critical, all the states expect to receive new ARTA material at the same time; indeed, state representatives have been extremely negative about the idea of some areas receiving materials a full six months ahead of other locations. ACREE therefore does not at this time plan to do efficacy testing prior to launching a campaign. Instead, this research will be done postlaunch, in selected study sites, to provide guidance to the program, states, and the media on various issues relating to marketing and distribution.

Process Evaluation

Process evaluation answers the question "What is actually delivered?" Process evaluation is concerned with "whether the campaign was actually aired at all, how often it was aired, and to whom?"[11] Process evaluation of some sort is done by most Public Health Service agencies doing media campaigns because it is relatively inexpensive and feasible with a limited staff. Since NAIEP's inception, the program has paid for the monitoring of all its television PSAs through the commercial Arbitron system. For a fee, Arbitron monitors the appearances of material on network television and in 75 media markets.[12] ACREE analyzes Arbitron data and is obtaining clearance from the Office of Management and Budget to examine the relations between PSA airings and National AIDS Hotline calls. Arbitron data, in combination with advertising "reach" information available for purchase through commercial channels, enable the program to characterize the ARTA PSA audience. Additional data sources—including NAIEP's own surveys, the National Health Interview Survey, and the National AIDS Hotline—are used by the program to define its audience and redirect placement as much as possible for a campaign dependent upon donated time and space.

Outcome or Effectiveness Evaluations

The most difficult—and arguably the most important—evaluation recommended by NAS is outcome or effectiveness evaluation, intended to determine whether or not the campaign actually has made a difference in the real world. This type of evaluation answers the question: "Does the campaign work?"[13] As with formative and efficacy evaluations, NAS recommended the use of randomized experiments for evaluating the effectiveness of an AIDS media campaign. ACREE is currently using cross-sectional surveys at sentinel locations and secondary data analyses for its outcome evaluations.

Lessons from Pilot Evaluations Done for ARTA

To illustrate how ACREE applies the NAS recommendations, we will use examples from the formative and efficacy evaluations of the fifth phase of the ARTA campaign, developed between August 1989 and June 1990 and released on July 26, 1990. The campaign theme was "Preventing HIV Infection and AIDS: Taking the Next Steps," and its goals were to improve the public's understanding of the term "HIV" and to encourage Americans to take the necessary steps in preventing HIV infection and AIDS. "HIV is the virus that causes AIDS" was constantly reiterated throughout the campaign's radio, television, and print material. Nine television PSAs (7 English, 2 Spanish), 11 radio PSAs (8 English, 3 Spanish), and 7 print PSAs (6 English, 1 Spanish) were used in this campaign. Messages to the general population in these materials included (1) "You cannot tell by looking if someone is infected with the HIV virus," and (2) "Many individuals who did not think that they could get HIV are infected." Individuals engaged in high risk behaviors were targeted for the messages, "If HIV infection is diagnosed and treated early, some infected individuals can prolong their lives" and "There are benefits to the early detection of HIV."[14]

Formative Evaluation

For the early copy testing stage of formative evaluation, we had two main goals. First, we wanted to know whether viewers of a given PSA had differences in knowledge and beliefs (compared to those who did not view the PSA). Second, we wanted to assess the reactions to the PSAs, for purposes of refining and selecting subsequent copy. Early copy testing was done on storyboards and animatics, audiotapes, and rough copies of print materials. From 32 shopping malls throughout the United States, over 5,000 participants were recruited. Each site tested four different PSAs (two television, one radio, and one print). Participants completed an open-ended "cognitive response form" and a questionnaire related to the objectives of the PSAs.[15]

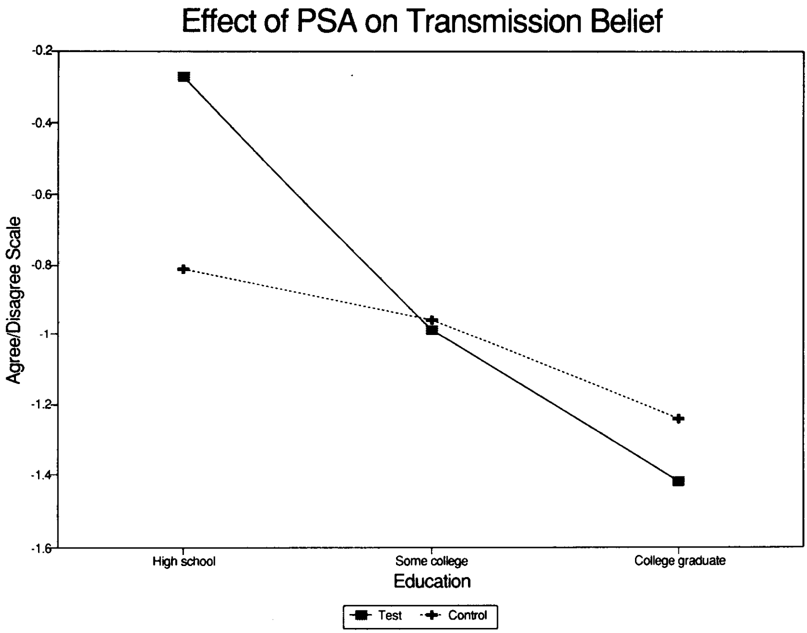
The majority of items in the questionnaire were belief items. For example, each PSA included the statement that "HIV is the virus that causes AIDS." Study participants were asked if they agreed or disagreed with this statement. The responses of participants exposed to each PSA were compared with those of a control group using various statistical methods.

An excellent example of the importance of testing materials against both target and nontarget audiences is provided by the early copy test of a television PSA entitled "Father/Baby." This PSA showed an HIV-infected father talking to his baby about his hope that now, with treatment, he could live to see his child walk and talk. This PSA was targeted toward high-risk individuals and was to be used in areas where there was a high incidence of HIV infection and AIDS. The intended message was that early detection and treatment of HIV infection are beneficial. Although this PSA targeted high-risk individuals, it was also tested against members of the general public, because a PSA aired on television would be seen by the general public as well as at-risk persons.

When this piece was presented to NAIEP and CDC management, public health professionals found it extremely moving. Similarly, in copy testing, when it was tested with members of the general public, quantitative results were statistically significant and in the expected direction. But when the copy test results were stratified by the participants' levels of education, a more complex pattern was seen: The higher the educational level of the participant, the more positive was the effect. More important, for two test questions not expected to have been affected by this PSA, the responses of individuals with a high school education or less were statistically significant but in the undesired direction. Figure 6.1 shows the results for one of these items, responses on an "agree-disagree" scale to "Only gays, intravenous drug users (IVDU's) and people who have sex with a lot of strangers need to worry about getting infected with HIV, the virus that causes AIDS." Although participants with some college education disagreed with this item more strongly than those in the control group, those with a high school degree or less disagreed less strongly than those in the control group. A content analysis of the open-ended feedback suggested that all study participants viewing this particular piece were reacting to its visual elements—the infected father having a baby in his arms—and not to the verbal content.

Because the PSA had received high approval within CDC, NAIEP officials debated whether it might be salvaged. Perhaps changing the relationship between the characters might resolve the unintended effect—e.g., using an older child rather than an infant, or a brother and a sister rather than a father and a baby. But we decided that any changes that might resolve the negative effect would also weaken the PSA's strength. Therefore, the PSA was not produced.

Figure 6.1. Effect of PSA on transmission belief.



1. Data shown represent means of responses elicited on an "agree-disagree" scale (-2 = "strongly disagree," -1 = "disagree," 0 = neutral, 1 = "agree," 2 = "strongly agree"). Responses elicited to the statement, "Only gays, intravenous drug users (IVDU's), and people who have sex with a lot of strangers need to worry about getting infected with HIV, the virus that causes AIDS."
2. Data provided by S. Middlestadt, "Quantitative Formative Evaluation of the 'America Responds to AIDS' Campaign," in preparation.

This example helped reinforce several lessons: (1) We, as PSA developers and reviewers, must not assume that our own reactions represent those of the general public. (2) Material for mass media must be tested against both the target and nontarget viewing audience, and these audiences must be segmented by at least basic demographics. (3) Both qualitative and quantitative copy testing are invaluable. (4) Testing for unintended negative effects is as important as testing for intended positive effects.

Efficacy Testing

For the fifth phase of the ARTA campaign, efficacy tests were performed on two different television PSAs. Each PSA was tested at one site. The goals of the efficacy test were quite basic: (1) to examine whether NAS's recommendation of performing the testing prior to release of the campaign could be carried out, given the one-month time constraint between production of phase V and its delivery to states; and (2) to see whether either PSA had any measurable impact—either positive or negative—on the viewers. The efficacy tests were done by the states of Illinois and Tennessee, in collaboration with ACREE.

The two television PSAs that were tested were called "Wonderful World" (tested in Springfield, Illinois) and "Sofa" (tested in Memphis, Tennessee). The "Wonderful World" PSA showed children playing in an open field with one girl stating her desire to grow up in a better world. The voice-over concerned HIV and AIDS, and the PSA targeted the general public. The "Sofa" PSA showed a heterosexual couple passionately kissing in front of a television. The man would turn off the television with a remote control, but it would repeatedly come back on, with the announcer talking about how HIV is transmitted. The PSA targeted young unmarried people, and its intent was to encourage conversations about HIV and AIDS.

These two PSAs were chosen for several reasons. Representatives of health departments in some states, including Tennessee, had expressed concern about the sexually suggestive content of "Sofa" when they had reviewed it in its storyboard form. Some CDC personnel had expressed concern about the following text in the "Wonderful World" PSA: "Many people have joined in the fight against HIV, the virus that causes AIDS. But the disease is still spreading, and only you can stop it. Only you have the power to prevent it from happening to you." Their concern was that some viewers would interpret this message as supporting discrimination against HIV-infected people.

For the efficacy test, participants were recruited by telephone. They were asked to watch a particular news program for a study involving an important national issue. In each city, the state health department paid one television station to air one PSA twice during the local news program for three sequential nights. A second station was asked not to air any AIDS PSAs. After the last PSA airing, participants were contacted by phone to answer a questionnaire.[16]

Three key issues were addressed in the efficacy test: (1) Did the viewers recall the PSAs? (2) Did the PSAs increase the salience of AIDS as an important national issue? and (3) Did the PSAs have any adverse effects?

Three measures were used to determine whether viewers recalled the PSAs: unprompted recall of an AIDS message, prompted recall of an AIDS message, and correct playback of the specific PSA.[17] Recall of both of the PSAs was quite good. The total recall level for "an AIDS message" was noticeably higher in Memphis than in Springfield (Table 6.1).[18] The correct playback level of 59 percent for the "Sofa" PSA was also noticeably higher than the correct playback level of 21 percent for the "Wonderful World" PSA.[19]

Table 6.1. Proportion of Exposed Participants Recalling "an AIDS message," by Study Site.*

	Study Site	
Recall	Springfield (*n* = 230)	Memphis (*n* = 211)
Unprompted	66 (28.7)	90 (42.7)
Prompted	47 (20.4)	63 (29.9)
Total recalling	**113 (49.1)**	**153 (72.6)**

*Data provided by M. Siska, J. Jason, P. Murdoch, W. S. Yang, and R. Donovan, "Recall of AIDS Public Service Announcements and Their Impact on the Ranking of AIDS as a National Problem" (submitted, *American Journal of Public Health*).

The salience of AIDS as a national issue was based on the participants' responses when they were asked to "list the most important problems facing the nation today." They were asked this question both pre- and posttesting.[20] The mention of AIDS as an important national issue increased between pre- and posttesting only for the exposed group.

To examine whether the PSAs had any negative effects, verbatim responses to open-ended questions were analyzed. The broadcasting stations were also asked if they had received any negative responses or complaints from the general public. Only "Sofa" produced negative comments on open-ended questions (a total of two comments). Neither produced a greater than "average" number of telephone calls to the stations by nonparticipants viewing the PSAs.

The execution of this pilot efficacy test convinced ACREE personnel that, if ARTA's time frame continues to leave available only three to six weeks between message production and distribution for efficacy testing and analysis, the role and design of efficacy testing must differ radically from that recommended by NAS. As recommended by NAS, ARTA's efficacy tests will include multiple markets and involve control and intervention markets. Testing will continue for three to six months. But our current plan is for efficacy testing to occur after the campaign is launched. Intervention sites will receive heavy marketing of materials to local media, using varying mixes of media channels (television, radio, print, out-of-home posters, etc.) to assess the efficacy of the channels in reaching various audience segments. Media in control sites will be asked to withhold material during the period of study. The results will be provided to state health departments and media personnel and will offer guidance as to the optimal combination of media channels to reach various subgroups of the general public with the specific ARTA messages used.

Conclusion

In this chapter, we have outlined ACREE's approach to the NAS evaluation recommendations, given the practical realities and constraints faced by the Federal government's ARTA campaign. Our conclusions fall into two categories. First, as the examples from the fifth phase of ARTA show, evaluation of how the audience—both target and nontarget—perceives PSAs is critical if we are to use our resources effectively. Creating messages for the public cannot rely on internal evaluations guided by those of us inside the production process. Our second conclusion is more general and applies to the evaluation process itself. We must continue to explore new evaluation techniques and investigate essential communication issues, while at the same time fulfilling NAS's recommendations. In addition, we must allow our approach to evaluation to evolve. Each evaluation study will teach us and guide us toward the best approach to take on the next campaign phase's evaluations.

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NOTES

Kara L. Marchman received a B.A. degree in sociology and psychology from Emory University. She is pursuing a master's degree in public health, with an emphasis in behavioral sciences and health education, at Emory University. Janine Jason is a pediatric immunologist and epidemiologist with extensive publications in immunology, child health, violence, and HIV/AIDS, as well as the book *Parenting Your Premature Baby* (New York: Henry Holt, 1989; paperback edition, Garden City, NY: Doubleday, 1990). She is currently chief of applied communications research, epidemiology, and evaluation for the National AIDS Information and Education Program in the Office of the Deputy Director (HIV), United States Centers for Disease Control.

1. S. L. Coyle, R. F. Boruch, and C. F. Turner, *Evaluating AIDS Prevention Programs* (Washington, DC: National Academy Press, 1989).
2. Coyle et al., *Evaluating AIDS Prevention Programs.*
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6. C. T. Salmon and J. Jason, "Evaluation of the 'America Responds to AIDS' Social Marketing Campaign," *Public Health Reports* (in clearance).
7. Salmon and Jason, "Evaluation of 'America Responds to AIDS.'"
8. *Ibid.*
9. Kotler and Roberto, *Social Marketing Strategies*; and Salmon and Jason, "Evaluation of 'America Responds to AIDS.'"
10. Kotler and Roberto, *Social Marketing Campaigns.*
11. *Ibid.*
12. *Ibid.*
13. *Ibid.*
14. S. Middlestadt, "Quantitative Formative Evaluation of the 'America Responds to AIDS' Campaign" (in preparation).
15. Participants were randomly assigned to view a single item or serve as a control. Thirty test respondents were recruited for each PSA. The close-ended questionnaire was given to both PSA viewers and, at each site, 42 control participants; the close-ended questionnaire consisted of standardized items on a five-point scale.
16. Participants 18–54 years of age were recruited by random-digit dialing techniques. They were not told that the study involved AIDS or television commercials. They were randomly assigned to watch one of the two stations at appropriate times. They were contacted three times: for initial recruitment, to remind them to view the programs, and to answer a posttest questionnaire one to three days after the last PSA airing. Payment for commercial placement by a nonfederal group permitted later unpaid placement at a lower talent fee rate.
17. Recall was classified as unprompted if the viewer answered "yes" to having seen a public health message when asked about having seen any commercials in five different categories, one of which was "public health message." Prompted recall was classified when the participant was prompted with the question: "Did you see any commercial messages or public health messages that dealt with AIDS?" and the participant answered "yes." Correct playback of an AIDS message was defined as occurring if the participant described at least one of two predetermined elements of the PSA.
18. $p < .001$.
19. $p < .001$.
20. The first five responses of the participants were recorded.

Chapter 7

Effects of *Square One TV* on Children's Problem-Solving Behavior

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The current period in mathematics education can be characterized as one of reform. There is widespread dissatisfaction of professionals and lay people alike with the present state of mathematics learning among children in the United States; indeed, much of the literature refers to the deficiencies that currently exist as a "crisis" in mathematics education.[1] Many feel that children in the United States are not learning enough of the mathematics that will be appropriate for the coming decades and that children's conceptions of the nature and uses of mathematics are inaccurate and misinformed.

At the forefront of the movement for reform are two professional organizations: the National Council of Teachers of Mathematics (NCTM) and the Mathematical Sciences Education Board (MSEB) of the National Research Council. The MSEB reports *Everybody Counts* and *Reshaping School Mathematics: A Philosophy and Framework for Change* detail the problems affecting U.S. mathematics education and provide an overall conceptualization of what needs to be done about them.[2] At the same time, in its *Curriculum and Evaluation Standards for School Mathematics*, NCTM has identified goals for elementary students studying mathematics.[3] Among these goals are that students learn to value mathematics, that they become confident in their mathematical abilities, that they become mathematical problem solvers, and that they learn to communicate and reason mathematically.

In an attempt to contribute to this reform movement, Children's Television Workshop (CTW) has created *Square One TV*, a television series about mathematics, aimed at an audience of 8- to 12-year-old children, primarily watching at home (although some stations carry the series during school hours). Each program is one-half hour in length and employs what is called a magazine format, in which a variety of discrete segments constitute an entire program. The series is humorous, and the majority of segments parody television styles and conventions familiar to children. Several types of segments are used: studio sketches (featuring a seven-player repertory company), game shows, short films, music videos, and animation. Each program of *Square One TV* ends with an installment of "Mathnet" (a serialized parody of the detective series "Dragnet"), in which two mathematicians use mathematical problem solving to solve crimes. At the time of this writing, three seasons of *Square One TV* have been produced, resulting in a total of 155 programs. A fourth season (consisting of 40 programs) is currently in production.

The series has three main goals:

1. To promote positive attitudes toward, and enthusiasm for, mathematics;
2. To encourage the use and application of problem-solving processes; and
3. To present sound mathematical content in an interesting, accessible, and meaningful manner.

Each of these goals is refined into a range of subgoals; the complete breakdown is shown in Appendix A. In emphasizing the importance of encouraging problem solving and positive attitudes toward mathematics, the goals of *Square One TV* are consonant with those of NCTM, thus indicating an underlying philosophy that is in keeping with the ongoing reform movement in mathematics education. As a result, a natural question that arises—not only for the producers of the series, but also for anyone interested in educational reform—is the degree to which regular viewers are affected by material directed toward these goals.

An earlier CTW study found that children in the target age group could recall and comprehend the mathematical content presented in a sample of segments from the first season and that in many cases they could extend that information to new, related problem situations.[4] The study also probed for the children's interpretations of the characters' feelings or attitudes toward the mathematical situations in which they found themselves. However, that study was not designed to provide a thorough investigation of the children's own attitudes toward mathematics or their abilities to apply the problem-solving processes shown on *Square One TV* to novel kinds of problems.

The present study was a natural outgrowth of that CTW study. Its purpose was to address goals 1 and 2 directly by examining in great detail the changes that might occur in children's problem-solving behavior and attitudes toward mathematics as a result of viewing *Square One TV*. In this chapter, we will present a brief description of the portion of the study concerned with problem solving.[5]

Method

Subjects and Procedure

Fifth graders in four public elementary schools in Corpus Christi, Texas, participated in the study. This site was selected because *Square One TV* had not been part of the local after-school broadcast schedule prior to the completion of data collection, and it had not been shown in school. Each of the schools provided a standard, districtwide mathematics program using a popular mathematics textbook.

Over an eight-week period, the children in two of the schools (the viewer group) were shown 30 episodes of *Square One TV*. Although these episodes were shown in school, teachers did not incorporate them into their lessons and did not comment upon them in any way; thus, the children's exposure to the series consisted of sustained, unaided viewing in a group setting. The two control schools (the nonviewer group) did not see *Square One TV* at all; their schedule did not change from what it normally was.

Forty-eight children (24 from each group), matched for sex, socioeconomic status (SES), ethnicity, and performance on a standardized mathematics test, were tested before and after the eight-week viewing period in an experimental pretest-posttest design. One-half of the children were boys and one-half were girls; 67 percent were Latino, 4 percent were African-American, and 29 percent were white, percentages that mirrored those of the school system as a whole.

Problem solving was tested via three sets of hands-on, nonroutine mathematical problem-solving activities, each of which could be solved through a number of approaches. The three activities represented a range of complexity, from combinatorics problems through mathematical games.[6] For the purposes of this chapter, we refer to the pair of problem-solving activities A and A', for example, as problem-solving activity A*.

Both at the pretest and at the posttest, each child was tested individually in two 55-minute sessions, the first consisting of two problem-solving activities and the second containing the third activity and an approximately 40-minute attitude interview. The CTW interviewers and coders were blind to the children's viewer or nonviewer status; that is, they did not know which children were viewers and which were not. Similarly, the children did not know of the interviewers' connection with *Square One TV*.

Overview of Results

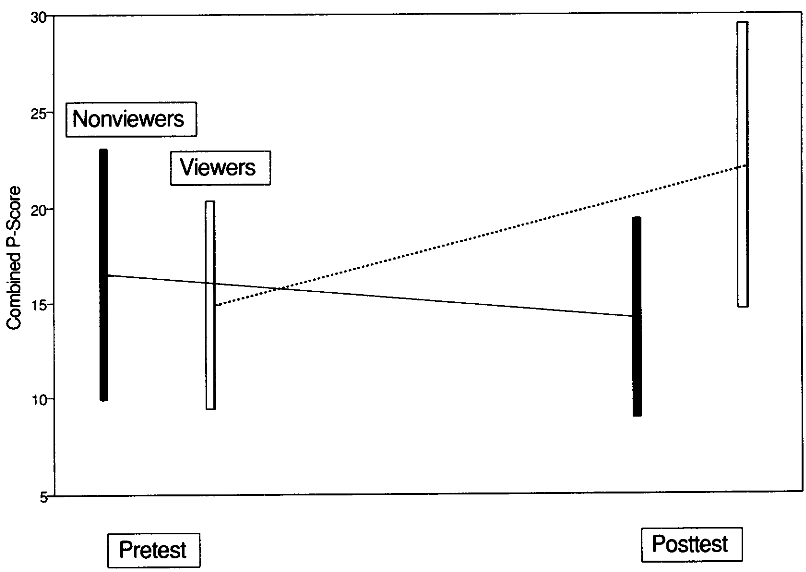
For each of the three activities, each child was scored on two measures: (1) the number and variety of problem-solving actions and heuristics used (the P-score),[7] and (2) the mathematical completeness and sophistication of the solution reached (the M-score). These two scores are conceptually independent in the sense that a child's use of a large number of problem-solving actions or heuristics would not necessarily lead to a sophisticated or complete solution; and, conversely, a sophisticated and complete solution might be obtained despite a child's use of a very limited problem-solving repertoire.

P-scores

From pretesting to posttesting, children in the viewing group made greater gains in their P-scores on each of the three problem-solving activities than the nonviewers did.[8] The viewers' pretest to posttest gains were statistically significant;[9] the nonviewers did not make statistically significant gains. Further, in each activity, there was a statistically significant difference in P-scores at the posttest between the viewers and the nonviewers.[10]

Figure 7.1 shows the mean combined P-scores that viewers and nonviewers obtained in the pretest and posttest.[11] As the figure shows, there is substantial overlap between the viewers' and nonviewers' P-scores at the pretest. At the posttest, however, the viewers' P-scores increased noticeably, while the nonviewers' did not.[12] At the posttest, then, there was much less overlap between the two groups.

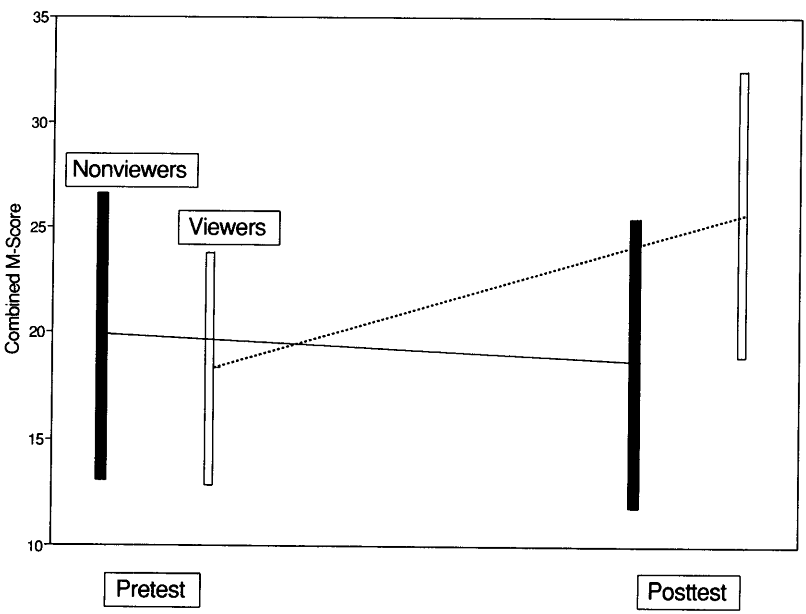
Figure 7.1. Mean P-scores (all PSA combined) for viewers and nonviewers in pretest and posttest, with one standard deviation above and below the mean.



M-scores

From pretesting to posttesting, children in the viewing group made significantly greater gains in their M-scores than did nonviewers on two of the three problem-solving activities.[13] Figure 7.2 shows the mean total M-scores that viewers and nonviewers obtained in the pretest and posttest.[14] The same pattern observed for P-scores is apparent here: At the pretest there was substantial overlap between the two groups. However, at the posttest, the viewing group's M-scores were noticeably higher, resulting in much less overlap. The nonviewers' M-scores did not change in a statistically significant way from pretesting to posttesting on any of the activities.

Figure 7.2. Mean M-scores (all problem-solving activities combined) for viewers and nonviewers in pretest and posttest with one standard deviation above and below the mean.



Relationship Between P-scores and M-scores

Even though the P- and M-scores are conceptually independent, in this sample they were significantly correlated: Higher P-scores tended to be associated with higher M-scores.[15] A model-fitting analysis indicated that while the television series exerted direct effects on both P-scores and M-scores, its effect on the children's M-scores was also, in part, mediated by its effect on P-scores.[16] That is, exposure to *Square One TV* resulted in the children's using an increased number and variety of problem-solving behaviors, which in turn led them to reach more complete and sophisticated solutions.

Effects of Sex, Socioeconomic Status (SES), and Ethnicity

There were no statistically significant sex-related differences in children's M-scores at either the pretest or the posttest. Further, the changes in the children's M-scores from pretest to posttest did not interact significantly with their sex.

Similarly, the children's sex did not have an important main effect on their P-scores. Both boys and girls who watched *Square One TV* improved from pretesting to posttesting,[17] and there was no difference between boys and girls in the viewing group at either the pretest or the posttest.[18] Thus, it appears that *Square One TV* had a similar effect on the boys and girls in the viewing group.

Children of middle SES received higher P-scores than did children of low SES,[19] and higher M-scores on two of the three activities.[20] But, as with sex, the changes in children's P-scores and M-scores did not interact in a statistically significant way with SES, indicating that *Square One TV* exerted a similar effect on the low- and middle-SES children in the sample.

In the study, minority children were largely of lower SES, and nonminority children were of middle SES. Thus, a pattern similar to the one found for SES emerged when the data were analyzed by ethnicity. That is, nonminority children received higher P-scores than did minority children[21] and marginally higher M-scores in problem-solving activity C*,[22] but there was no statistically significant interaction between ethnicity and the effects of *Square One TV* on either P-scores or M-scores. This result indicates that *Square One TV* affected minority and nonminority children similarly.

Relationship to Standardized Test Scores

Ten months before the study started, school district personnel administered an annual standardized mathematics achievement test to all fifth graders in the district. The children's scores on this achievement test were not correlated with their P-scores or M-scores on any of the problem-solving activities.[23]

Discussion

The results of the study are quite striking when one considers that (a) the viewers and nonviewers were carefully matched in the pretest and (b) the viewers' exposure to *Square One TV* took place without any further enhancement in the curriculum. Viewers showed noticeably greater improvement than nonviewers did, both in their use of problem-solving actions and heuristics and in the solutions they reached, despite the fact that the only difference in the experimental treatment of the two groups was that viewers were shown 30 programs of *Square One TV*. Moreover, the series exerted similar effects on boys and girls and on children of different ethnic and socioeconomic backgrounds.

There are several ways in which the foregoing results are very encouraging for the reform movement in mathematics education. First, they provide a clear indication that material produced in response to the goals of the reform movement can have the desired impact on children's problem-solving behavior. Second, they illustrate the types of measures that can be used to assess children's performance on nonroutine problem-solving tasks, an issue that is of great concern if one is to implement mathematics curricula that are based on this type of problem solving. Finally, they demonstrate that *Square One TV* can play a significant role in the effort toward reform.

Appendix A
Elaboration of goals of *Square One TV*

GOAL I. To promote positive attitudes toward, and enthusiasm for, mathematics by showing that:

A. Mathematics is a powerful and widely applicable tool that is useful to solve problems, to illustrate concepts, and to increase efficiency.

B. Mathematics is beautiful and aesthetically pleasing.

C. Mathematics can be understood, used, and even invented by nonspecialists.

GOAL II. To encourage the use and application of problem-solving processes by modeling:

A. Problem formulation

1. Recognize and state a problem.
2. Assess the value of solving a problem.
3. Assess the possibility of solving a problem.

B. Problem treatment

1. Recall information.
2. Estimate or approximate.
3. Measure, gather data, or check resources.
4. Calculate or manipulate (mentally or physically).
5. Consider probabilities.
6. Use trial-and-error or guess-and-check.

C. Problem-solving heuristics

1. Represent the problem: scale model, drawing, map; picture; diagram, gadget; table, chart; graph; use object, act out.
2. Transform problem: reword, clarify; simplify; find subgoals, subproblems, work backwards.
3. Look for: patterns; missing information; distinctions in kind of information (pertinent or extraneous).
4. Reapproach problem: change point of view, reevaluate assumptions; generate new hypotheses.

D. Problem follow-up

1. Discuss reasonableness and precision of results.
2. Look for alternative solutions.
3. Look for alternative ways to solve problem.
4. Look for, or extend to, related problems.

GOAL III. To present sound mathematical content in an interesting, accessible, and meaningful manner by exploring:

A. Numbers and counting

1. Whole numbers.
2. Numeration: role and meaning of digits in whole numbers (place value); Roman numerals; palindromes; other bases.
3. Rational numbers: interpretations of fractions as numbers, ratios, parts of a whole or of a set.
4. Decimal notation: role and meaning of digits in decimal numeration.
5. Percents: uses; link to decimals and fractions.
6. Negative numbers: uses; relation to subtraction.

B. Arithmetic of rational numbers

1. Basic operations: addition, subtraction, division, multiplication, exponentiation; when and how to use operations.
2. Structure: primes, factors, and multiples.
3. Number theory: modular arithmetic (including parity); Diophantine equations; Fibonacci sequence; Pascal's triangle.
4. Approximation: rounding; bounds; approximate calculation; interpolation and extrapolation; estimation.
5. Ratios: use of ratios, rates, and proportions; relation to division; golden section.

C. Measurement

1. Units: systems (English, metric, nonstandard); importance of standard units.
2. Spatial: length, area, volume, perimeter, and surface area.
3. Approximate nature: exact versus approximate, i.e., counting versus measuring; calculation with approximations; margin of error; propagation of error; estimation.
4. Additivity.

D. Numerical functions and relations

1. Relations: order, inequalities, subset relations, additivity, infinite sets.
2. Functions: linear, quadratic, exponential; rules, patterns.
3. Equations: techniques for solving (e.g., manipulation, guess-and-test); missing addend and factor; relation to construction of numbers.
4. Formulas: interpretation and evaluation; algebra as generalized arithmetic.

E. Combinatorics and counting techniques

1. Multiplication principle and decomposition.
2. Pigeonhole principle.
3. Systematic enumeration of cases.

F. Statistics and probability

1. Basic quantification: counting; representation by rational numbers.
2. Derived measures: average, median, range.
3. Concepts: independence, correlation; "Law of Averages."
4. Prediction: relation to probability.
5. Data processing: collection and analysis.
6. Data presentation: graphs, charts, tables; construction and interpretation.

G. Geometry

1. Dimensionality: one, two, three, and four dimensions.
2. Rigid transformations: transformations in two and three dimensions; rotations, reflections, and translations; symmetry.
3. Tessellations: covering the plane and bounded regions; kaleidoscopes; role of symmetry; other surfaces.
4. Maps and models in scale: application of ratios.
5. Perspective: rudiments of drawing in perspective; representation of three-dimensional objects in two dimensions.
6. Geometrical objects: recognition; relations among; constructions; patterns.
7. Topological mappings and properties: invariants.

Appendix B

This appendix gives a description of problem-solving activity C', which was used in Children's Television Workshop's summative evaluation of *Square One TV*.

In this activity, the child is told about a person named Dr. Game, who owns a game factory. Dr. Game was recently dismayed to find that his factory had been broken into and that some of his games had been changed in some way. The child has been hired by Dr. Game to find out what is wrong with one of these games.

The experimenter shows the child the equipment for the game, which consists of the following: two spinners, one numbered 3, 4, and 5, and the other numbered 2 and 6; a coin marked "+" on one side and "x" on the other; a number board with two elasticized loops—one orange and the other green—arranged so that the loops surround two sets of numbers; two stand-up, cutout players, one of whom wears a sign around its neck saying "Orange" and the other with a sign saying "Green"; and nine plastic chips. The spinners, number board, and players are pictured in Figure 7.3.

The experimenter explains the rules of the game to the child. To play the game, a person called the spinner, but not identified further, spins both spinners, getting two numbers, and flips the coin, getting addition or multiplication. Then he or she does the addition or multiplication, and finds the answer on the board. If the answer is inside the green loop, then the green player gets one chip; if the answer is inside the orange loop, then the orange player gets one chip. Whoever has more chips at the end of nine spins wins the game.

After the child is reminded that something is wrong with the game and that the task is to find out what is wrong, the experimenter leaves the child to work alone. A kit of materials (paper, pencils, pens, a calculator, a ruler, a protractor, and some circular stickers) is available for the child to use if he or she wants to.

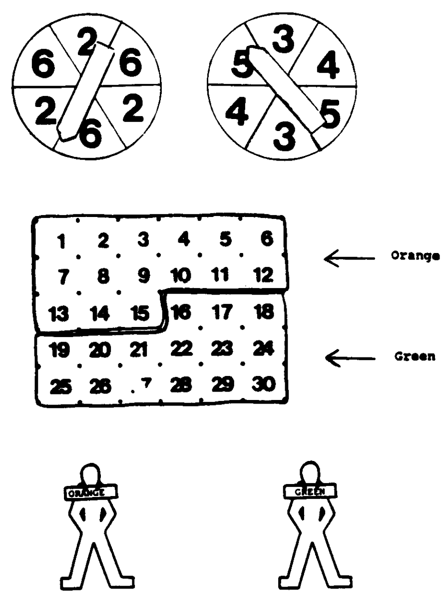
[What is wrong with the game is that it is unfair to the green player. The probability of awarding each chip to the orange player is .75, and the probability of the orange player's winning more chips than the green player by the end of the game is more than .95.]

When the child has told the experimenter what he or she thinks is wrong with the game, the experimenter asks several standardized questions that encourage the child to describe his or her actions, thoughts, and strategies. Then the next task is posed: to change the game so that it is fair.

[The game can be made fairer than it is in a variety of ways: by moving the orange and green loops appropriately; by changing some or all of the numbers on the spinners; by changing the operations on the coin; by awarding more than one chip to the green player if the answer is in the green loop; or by some combination of these.]

Again, the child is left alone, to work on changing the game. The experimenter returns to the table when summoned or if the child seems not to be working productively any longer. As before, the experimenter uses a set of carefully structured probe questions to get at what the child was doing and thinking during the period he or she was working on the problem.

Figure 7.3. Spinners, number board, and players used in problem-solving activity C'.



ACKNOWLEDGMENTS

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NOTES

Eve R. Hall is the former director of research for *Square One TV*. She now serves as director of research for *Ghostwriter*, a television series produced by CTW that is aimed at promoting literacy among 7- to 10-year-olds. Shalom M. Fisch is director of research for *Square One TV*. In addition, he is an adjunct instructor at New York University, where he is finishing a dissertation in experimental and developmental psychology. Edward T. Esty is the principal mathematics consultant for *Square One TV*. At the Mathematical Sciences Education Board, he is codirector of a project focusing on the assessment of attitudes and beliefs about problem solving.

1. S. A. Hill, "National Need: Mathematics Education Must Undergo Basic Changes," *National Research Council News Report*, 1987, 37:6, 17–18; C. C. McKnight, F. J. Crosswhite, J. A. Dossey, E. Kifer, J. O. Swafford, K. J. Travers, and T. J. Cooney, *The Underachieving Curriculum: Assessing U. S. School Mathematics from an International Perspective* (Champaign, IL: Stipes Publishing Co., 1987); National Assessment of Educational Progress, *The Mathematics Report Card: Are We Measuring Up?* (Princeton:

Educational Testing Service, 1988); National Council of Teachers of Mathematics, *Curriculum and Evaluation Standards for School Mathematics* (Reston, VA: National Council of Teachers of Mathematics, 1989); National Research Council, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (Washington, DC: National Academy Press, 1989); National Research Council, *Reshaping School Mathematics: A Philosophy and Framework for Change* (Washington, D C: National Academy Press, 1990); and T. A. Romberg, *School Mathematics: Options for the 1990s. Vol. 1: Chairman's Report of a Conference* (Washington, DC: Office of the Assistant Secretary for Educational Research and Improvement, 1984).
2. National Research Council, *Everybody Counts*; and National Research Council, *Reshaping School Mathematics.*
3. National Council of Teachers of Mathematics, *Curriculum and Evaluation Standards.*
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5. Further details on this portion of the study can be found in E. T. Esty, E. R. Hall, and S. M. Fisch, *Children's Problem-Solving Behavior and Their Attitudes towards Mathematics: A Study of the Effects of Square One TV. Vol .2: The Effects of Square One TV on Children's Problem Solving* (New York: Children's Television Workshop, 1990). For a detailed account of the portion of the study concerning attitudes, see E. Debold, E. R. Hall, S. M. Fisch, D. T. Bennett, and S. V. Solan, *Children's Problem-Solving Behavior and Their Attitudes towards Mathematics: A Study of the Effect of Square One TV. Vol. 3: Children's Attitudes Toward Mathematics and the Effects of Square One TV* (New York: Children's Television Workshop, 1990).
6. The least complex problems (problem-solving activities A and A') were combinatorial problems involving orders of stripes on a shirt or of circus performers. Problem-solving activities B and B' (which were of medium complexity) asked children to sort cards representing party guests or price tags into groups meeting several conditions. Problem-solving activities C and C', the most complex problems, presented children with a mathematical game and asked them to figure out what was wrong with the game and how to fix it. (See Appendix B for an example of one of these problems.) Children received one set of problem-solving activities (either A, B, and C or A', B', and C') at the pretest and the other set at the posttest.
7. The P-score incorporates 17 problem-solving actions and heuristics that are derived from the subgoals of goals IIB, IIC, and IID (see Appendix A).
8. Two-way ANOVAs showed interactions of pretest/posttest with viewer/nonviewer to be significant at the $p < .001$ level for problem-solving activities A*, B*, and C*.

9. *p* <.001 for problem-solving activity A* and C*, *p* <.01 for problem-solving activity B*.
10. *p* <.001 in each case.
11. Because the correlations among the P-scores for problem-solving activity A*, B*, and C* were positive and statistically significant (*p* <.01), a principal components analysis was used to combine them into a weighted sum.
12. The decline in the nonviewers' mean combined P-score is marginal (*p* <.10). The nonviewers' P-scores declined significantly in problem-solving activities A* and B* (*p* <.01), but not in C*.
13. Two-way ANOVAs showed interactions of pretest/posttest with viewer/nonviewer on problem-solving activity A* (*p* <.01) and problem-solving activity C* (*p* <.001). From pretest to posttest, the viewers' M-scores increased significantly on problem-solving activities A* and C* (*p* <.001). Further, the difference between the two groups at the posttest was significant in problem-solving activity C* (*p* <.001) and marginal in problem-solving activity A* (*p* <.10). Changes in M-score in problem-solving activity B* were not significant for either group. Something akin to a ceiling effect appeared to be operating in the sophistication and completeness of children's solutions in this activity at both the pretest and the posttest. Thus, there was little change from the one to the other.
14. For summary purposes only, the M-scores from problem-solving activities A*, B*, and C* were combined simply by adding them. The correlations among the three M-scores were not all significant, so any combination of M-scores across the problem-solving activities should be interpreted with caution.
15. $r = .52$; $p < .001$.
16. For further details on this analysis, see Esty et al., *Children's Problem-Solving Behavior.*
17. *p* <.01.
18. There was, however, a marginal (*p* <.10) three-way interaction among sex, condition, and pretest/posttest; this was attributable to a drop (*p* <.05) from pretest to posttest in the nonviewing girls' P-scores.
19. *p* <.01.
20. *p* <.01 for problem-solving activity A*; *p* <.05 for problem-solving activity C*.
21. *p* <.05.
22. *p* <.10.
23. The correlations between P-scores and standardized test scores range from -.18 to .11: the correlations between M-scores and standardized test scores range from -.07 to .02.

IV. The Applications

The Art of Explaining for Public Understanding

Chapter 8

Comparative Strategies for Making the Complex Clear

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The chapters in this section deal with explanations—with how people explain things for audiences made up of individuals who don't know much about the topics at hand. Most of us concerned about public understanding of science are in the business of explaining things to other people, and yet most of us know very little about how we do that. I want to describe how I think journalists come to some understanding of how to explain. I encourage you to think that explanation is not some sort of desiccated topic fit only for scholars or for boring textbooks, but is in fact a very important component of storytelling, particularly when you are trying to tell stories about science and technology.

Journalists are in the business of explaining things, and they know that they are in the explanation business. Yet journalists themselves are rarely trained in any formal way to explain anything; instead, they come to some understanding of explanation almost viscerally.

Journalists have always known that they have a collective audience for whom they have to design messages. Historically, the first way of thinking about explanation was the issue of readability, which became very prominent in journalism in the 1930s, 1940s, and into the 1950s. The assumption was that you could make things clear by keeping the language simple. Use simple words, and people will understand what you say. Use short sentences, and people will understand what you say. In the 1930s and 1940s, a number of people interested in journalism came up with readability formulas; the things are still floating around today, letting you determine that a writer is writing at a 5th-grade level, a 12th-grade level, etc. Even today, when asked to articulate what it means to explain something, many journalists will respond, "Well, I aim at a 7th-grade [or 5th-grade, or whatever] level reader."

Clearly, this way of thinking about explanation was not sufficient. In the 1960s and 1970s, the notion of explanation became more sophisticated. Instead of just simple words, you began to hear noises about "tools," about drawing "word pictures" for readers, using things like analogies, metaphors, and definitions. This was a gigantic step beyond monosyllabic sentences and into the domain of how to draw word pictures for people who have to read them.

Still, the whole notion of explanation attends little to audience and instead focuses on how to package the message. To this day in the world of journalism, there is very little attention paid to what people actually get out of the stuff that they read. There are still a lot of assumptions being made. Today, however, slowly but surely, individuals are beginning to think of not only how you frame a message so that it's clear, but also what that message needs to be about. In other words, not only is this whole notion of explanation a task of manipulating a piece of information, but also it requires deciding what it is you have to manipulate, what piece of information has to be given to a particular audience, what people know, and what they need to know in a particular context.

In the shorter presentations that follow, and in the longer chapter by Katherine Rowan, you will get some insight into the strategies for explanation that are in use today—and that could be drawn on for tomorrow.

NOTES

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9

Television

Jonathan Ward

The Universe Group
Washington, DC

I am a television producer in private practice, after 17 years of working on evening news shows and doing science and medicine and technology and ecology and things like that. I worked for CBS back in the days when there was a CBS News. Now I work for practically everybody, especially cable channels that believe that having a fraction of the audience, instead of the entire audience, is a reasonable possibility.

How does "explanation" fit in with television? If you assume that organized scientific inquiry began with Sir Francis Bacon, then television is about one-seventh the age of science; it's about as old as I am, which may or may not be a good thing. Where Francis Bacon built on Aristotelian science and attacked it, we in television build on the works of Edgar Bergen and Charlie McCarthy, which has led to certain problems in explaining things on TV, some mechanical and some conceptual.

For example, consider time constraints. There are only 24 hours in a day, so the time is chopped into little bits and sold. Thirty seconds is a long time; a minute is enough to change people's minds. In the news business, 6 seconds is how long someone is allowed to speak on the average these days; a sound bite is 6 seconds long, unless it's a film piece within the "MacNeil-Lehrer News Hour" on PBS, where you can get almost 15–17 seconds. But some stories just don't fit in a minute and 15. The death of literacy in America does not lend itself to "Film at eleven!" so that story is not generally done. Television is a visual medium, and people who consider themselves experts in the visual medium take their text from MTV; they feel that the more images you cram in, the better.

(There are new studies which show that that's not true: The MTV-type commercials actually do a worse job of selling than something that's more stately and doesn't have such loud music; music interferes with the message. It's very interesting.)

The other problem with TV is that the gatekeepers are not necessarily literate in science. They are most likely trained in—it's almost too painful to say—journalism or something like "The Arts." When you go to them with "another step on the road toward a cure for cancer," they don't want to hear about it; they want the cure. Conceptually, in television, you have to get them—first the gatekeepers and then the real audience—into the tent, which means you need a news peg: "Why are you telling me this today?" You need to personalize the story: "Show me somebody who has got the disease." This often distorts the message; if you don't have somebody who has the disease, then you have a harder sell getting your story on the air.

I'm working currently on a piece on the history of muscular dystrophy—how the gene was found, how the protein the gene encodes was found and what happened after that, and what happens in a world where you have diagnostics but no treatments yet. It's a very interesting subject, so I'll use it as an example.

We needed personalization. A little kid named Bruce Briar out in Spokane, Washington, was born with multiple birth defects. The doctors knew where some of them were on the X chromosome; then Bruce came down with muscular dystrophy. They said, "Wow! It must be in the same place!" An observant doctor passed blood samples on to an investigator from the Howard Hughes Medical Institute. The researchers then decoded the gene. To tell this to people, I've got computer animations of things like zippers; I've got things that look like pop beads coming in four colors; I've got double helixes; I talk about spiral staircases, and I talk about....Well, it goes on and on. You know all the ways to tell about DNA as well as I do. All these explanations may have a tendency to confuse more than illuminate, but I have video to go with it, so maybe that will help...confuse. If science is a rapier, then television science is a Scud missile.

I drive scientists crazy because I like to have something happen in front of the camera. To a gentleman who spends most of his time coordinating the work of his postdocs, I say, "Can you get in there and actually run a gel?" He says, "No, I don't know how to do that. I haven't done that since I was a postdoc for somebody else." So we try to get them doing something, and that is sometimes very difficult. I say, "What did you think when you first heard about Bruce Briar?" He says, "I wanted to get the tissue samples away from Howard Hughes Medical Institute investigators, and I had to wait a year to do it. It really made me angry." I say, "Okay, you finally got these tissue samples. How did they arrive here?" He looks at me as if I'm a little strange. I say, "Was it Federal Express?" and he says, "Why do you want to know that?" I'm just trying to find some hooks into people's experience—you know, a video of the guy saying "Oh great, the tissue samples have arrived. They came by Federal Express this morning!" I need, on camera, some sense of the excitement of science in process. We don't get along too well sometimes, these scientists and I.

Take another example: Cold fusion became very popular simply because the diagrams were simple. Everybody could draw a palladium rod. If that had not been possible, Pons and Fleischmann would be even more obscure than they are now. Computer simulations are available to us. If you have seen the Jet Propulsion Laboratory's looks at the surface of Mars and the surface of Venus, where you have whizzed along in some sort of little sky car across the surfaces of these planets, you have an idea of what power a computer simulation can have. But notice that JPL distorts the vertical dimension a hundred times, so you get a sense of a very craggy planet. That is totally for visual effect; they are playing a TV game, and they're inventing a little.

Casting is another important thing. A scientist that you put on the air has to be personable; he has to be voluble. If not, you take pictures of him and do a voice-over; don't let him talk. As for victims, it would be nice if they would have a tear dripping down their cheeks.

All of these are tools designed to hold people through something more complicated than they usually get. After all, the level of television is really pretty low—we are talking to people who sometimes still believe in the laws of contagion. These are people who would pay money for a sheet that Elvis slept on. So it's a little hard when you start explaining things. But once you start, once you give them a chance to come up to speed, these are people who can handle complex information. These are people who know about the Phalange militias in Beirut. Right now, during the 1991 Gulf War, they know more about flying things that are designed to kill people than you would ever have thought possible. They like acquiring a little more knowledge; they like it if you don't talk down to them; they like it if you give them a chance to come up to speed in some graceful way without saying, "You poor benighted fool, let me explain this to you."

The corollary of all this is that if we do our science on TV badly, people don't blame the journalist. If we do our explanations badly, they blame themselves; they say, "Well, science is too hard. I knew I couldn't understand it." And in doing that, I think we've committed a major sin. So it is incumbent upon us all to do a better job of using these tools (some of them fairly trivial) to do something that could really be good.

NOTES

Jonathan Ward is president of the Universe Group, an independent television production company in Washington, DC. He was formerly executive producer of the *CBS Evening News* and *Walter Cronkite's Universe*.

Chapter 10

Girls' Clubs

Libby Palmer

Girls Incorporated
Port Townsend, Washington

I work for "Girls Incorporated," which is a new name for an old organization. It was "Girls' Clubs of America." We are a social service organization, working mostly in the inner city, although there are some suburban branches. We were set up during the industrial revolution to serve working-class mothers and daughters of working-class mothers. We serve about 200,000 girls of varying ages, from 5 to 18. We serve a lot of single moms' children, a lot of minority children, which means Latino, Black, or Asian, depending on the location of the community. We are the kind of place where you would expect girls to go for cooking class and basketball. In the olden days, we had charm rooms; we even have some rooms that still have hair dryers in them. But most of them have been converted to computer centers.

About 1985, the organization and a lot of its members got the radical idea that one reason that girls may not be going into science is because they simply didn't have a chance to mess around, to take things apart, to play with the toys that the boys played with. That is true for a collection of reasons, especially societal attitudes that are promulgated not just by teachers, but by parents, through consumption habits, and through purchase habits. In any case, it seemed that if the girls were coming to us in the afternoons and on Saturdays and during the summer, they could be doing science and at least starting to remedy the lack of experience they had at school and at home.

It was a very simple hypothesis, and it has been wildly successful. We've implemented it in an environment where there are no pressures from boys (who do tend to grab things away from girls), where there is no pressure from an adult who may have preconceived ideas about what's right for boys and what's right for girls, and where there is the support of a female adult, usually a scientist or somebody who likes science. Imagine—girls grab things; they build things with Legos; they do experiments with Bunsen burners and test tubes; they are not afraid of playing with pulleys and gears. We call it "Operation SMART." We started with some girls around 6 to 10 years old and gradually were funded to extend it to other ages; mostly I have been working with teens. Our approach to young people is that they are never lost, at any age. Whether you want kids to know science to fulfill the "pipeline prophecy" or to promote science literacy, it's never too late for science; it is going to be important for all of their lives.

How do explanations fit into this? We offer a nontraditional model of science education, of explanation. For example, you would very seldom find me, as an Operation SMART leader, doing what I am doing now. You, in an Operation SMART group, would never be sitting in straight rows with me here behind the table. We would have tables set up all around; we would have things going on; I would be walking around; I would be asking you a question or suggesting that you talk to the person next to you. That is the basis of our nontraditional model.

What else is nontraditional about it? We encourage the girls actually to participate in formulating explanations, rather than letting them get explanations from the teacher. That, we feel, is key. Some people call it inquiry-based science education; there are lots of terms for it. But it's very important, because one of the things that many studies have found is that girls and minorities have too often seen a white male authority figure as a scientist. That person may be a very good scientist; this is not encouraging disrespect of the science that the person is doing. But there is certainly a lack of identification. There is a lack of invitation: "I'd like you to be a scientist, do you want to come do science with me?" You don't see that very often. And hence, for the girls, there has been a feeling of "That science is very interesting, but it just is not my cup of tea; I'll let someone else do it."

So instead, we focus on making explanations. Now, how do we make explanations? We have to have something to make them with. [At this point, Palmer invited a four-year-old girl in the audience to help.] Elizabeth, do you think you and your Mom could help me? Okay; it's really easy. Could you just hold up a fist? You know how you usually count; you go 1, 2, 3 ... [holding up her fingers]. Could you show them how to do that?

[Elizabeth demonstrates.]

Now, everybody do what Elizabeth did, except we are going to count in kind of a funny way. You usually start with what? That's right—"one."

Okay, this is going to be weird. [Palmer started with one hand:] 10, 9, 8, 7, 6... [then Palmer held up the fingers of her other hand] and 5 make 11! Now, how did that happen? How did we get eleven fingers? [Elizabeth looks puzzled, and sits down. Most of the audience looks puzzled too.]

Well, when you do this in a group of kids, or a group of adults, some of you are going to walk out of here counting your fingers. And that's the point. There's something about events like that—discrepant events, oddball things that capture your interest. It doesn't matter whether you have gone to graduate school and gotten a doctorate, and it doesn't matter whether you know the right language—you've got 11 fingers now, and that's weird!

So we would use an event like that as a basis for examination. An explanation is an attempt to come to terms with "Why did that happen?" If you give an explanation of ordinal and cardinal numeration to four-year-olds, they should turn their backs and walk out of the room, except they are usually too polite. So we think about what is relevant and what's right for the young people we are working with.

Since I am also responsible for training the leaders, I have to think about the adults too. Our leaders are sometimes science literate. Sometimes they are people who have gotten master's degrees in various forms of science, but for one reason or another have not become professional scientists. Sometimes they are science phobic, but they have a great desire to overcome their phobia to be able to share science with young people. I have to look for explanations that are right for them.

Even more important, I have to find ways to inspire the search for an explanation. How do you instill that desire to figure out why something is happening, rather than the desire to have an explanation provided? When do I not want to give an explanation? That's a crucial point. All of our work assumes that you, the teacher, may not be the best person to produce the explanation. If you are a scientist or you are in communications, you want to give explanations. But when is an explanation downright harmful? I have had lots of science education, and I've had a lot of bad explanations at the wrong time. I think many of you will recognize this phenomenon. If you are in the middle of figuring something out, if your mind is still thinking about "10, 9... where did she get that extra finger from?" and I interrupt your conceptual processing and give you a good, accurate, verbal description, I question whether that explanation serves a useful purpose. So one of the things we have to teach our leaders and our adults is to restrain themselves from offering explanations.

What other functions do explanations serve besides clarifying? Very often they seem to say, "I am the authority, and that's why I am giving you the explanation." But if one of our goals is to enable science to reach more people, then a little bit less of this authoritarian recognition is needed. So here is another instance when you could withhold an explanation.

Another point: Young people do not have the same need for verbal explanation as adults. They want to experience a little bit more; they need to find their own frames of reference. They want to make the connections to some previous world—"Oh, when I was on the plane the other day, I noticed that such and such happened." An explanation in general terms is a valuable abstraction, but it robs the young person of the chance to formulate the connection—and I submit that when they do that, they are doing science. How do we as adults enter into the young person's thinking process so that we recognize that they are indeed formulating explanations?

There is a really simple clue: listening and watching. I once knew a teacher who suggested that her students put a piece of Scotch tape on her mouth every once in a while because, as teachers and as communicators, we are used to hearing ourselves speak. If we can remember that one of the values of science is skill and observation; and if we set up a rich situation for young people or for the adults who are being trained; and if we simply observe and encourage them to communicate with each other and eavesdrop (politely); then you will see them attempting to formulate an explanation. Then you will be a researcher in the science of education, if there ever is to be such a thing, and you also will see science at work. That is where we get the hint of how to use explanations as part of science communication.

NOTES

Libby Palmer has bachelor's and master's degrees in mathematics and has taught both mathematics and science at all levels, from preschool through college. As director of Operation SMART, a national program of Girls Incorporated, she oversees 88 after-school science clubs for girls. She is also co-founder of the Port Townsend Marine Science Center, a hands-on interpretive center in Port Townsend, Washington.

Chapter 11

Newspapers

Tom Siegfried

Dallas Morning News
Dallas, Texas

For journalists, trying to explain science is difficult. They go to scientific meetings, and generally what they see is incomprehensible. So they have to simplify it, and scientists aren't always happy with the results. When the situation works a little better, the scientist makes the statement, and the journalist who knows the subject matter is able to translate it and explain it in an effective way.

When you talk to scientists about public understanding, what you hear mostly is, "We've got to get science on TV because everybody gets all their news about science from TV." The truth is that people don't get all or even most of their news about science or anything else from TV; they get it from other people. And those other people they get science information from are people who read science sections in the newspapers. So, I'm going to talk about explaining science in the newspapers. I am going to talk about practical considerations for science editors and writers.

The truth is that in daily newspaper journalism there is very little room or space for any real explanation. Cancer is cured, fewer people will die—that's the end of the story in the daily newspaper. Despite the supposed advantage over television, you really don't have space to go into much more detail than that. The only way you can get into any kind of substantial explanation is if you have a dedicated science section where stories can go into some depth. Science sections have a lot of stuff in there. We don't have enough space, we don't have enough pages, but there are opportunities to do more things in a special section than you can do in a daily paper.

So what are the elements of explanation? First, as I mentioned earlier, knowing the subject is more important than a lot of journalists think, and to write good explanations, you have to make an extra effort to know the subject thoroughly. There are some prominent newspapers in this country that have science journalists who don't apparently believe that. Nevertheless, I think that knowing the subject should be at the foundation of trying to explain science. You can't succeed by thinking that any good reporter can go out and do it. You have to know what you're doing to do it well.

Second, a lot of science journalists, or at least people, seem to have a general misconception that when you do explanations in science journalism, you have to define your terms carefully so that people know what you are talking about. Then you can go and write the story. That's a very bad idea, because (1) definitions are boring and (2) people won't remember the definitions by the time they get to the next paragraph. The key to explaining science in newspapers is to use the language people already have, which is another way of saying that you need to relate it to things they already know. You need to integrate it into the framework of knowledge they already have. My rule of thumb is to try to limit any given story to one new term, which you don't define, but describe and explain to make the reader familiar with it. Sometimes other technical terms will creep in, but you don't use more than one technical term to try to tell the story. You try to convey one term and use that; others may show up incidentally, but you don't define and use those as if they were well-known terms. Explain things that are new to readers in terms of things they already understand.

I write about quantum physics a lot just because it's fun to do, and it's also very important and nobody else does it, so somebody ought to. It's one thing, though, to decide to do that and another thing to carry it off in a way that anybody can read it and get anything out of it. I first tried to write a story about the Einstein box (Appendix A) by talking about electrons being waves sometimes and particles other times and how that all leads to extremely important and incredible implications about the nature of reality. It helped a lot to start this out by writing about dogs and cats, instead of waves and particles; the beginning of this story presented no barrier to understanding the concept because the reader had to do only one thing: read about dogs and cats and see the relationship between dogs and cats. The reader did not at the same time have to try to find out the relationship between electrons and protons and waves and particles, things that couldn't be readily visualized. That would have been a double job for the reader.

The whole point of trying to do this is to make it easier for the reader to read the story. If you are trying to explain something, step number one is to get the reader to read it; part of that is using things they already understand and then gradually introducing the implications they don't understand.

Another issue related to explanation is to make the writing as visual as you can. You should use analogies and metaphors and descriptions to help explain; sometimes metaphor isn't really necessary for the explanation of the idea, but it will help create images in the readers' minds that will help them to read the story more easily. A couple of examples illustrate the point:

> If the radio waves are properly tuned, the charged particles can gain energy from the moving radio waves, just as a surfboard gains energy from a water wave.

> You would think that the task of capturing the rapidly moving antiprotons from the cloud of debris emanating from the tungsten target would be as impossible as trying to catch the queen bee in the swarm of bees emanating from a kicked-over hive.[1]

It is impossible to read that first sentence without visualizing somebody surfing; it's not so much that somebody on a surfboard helps explain the concept as that the image keeps the reader going, keeps the reader reading, keeps pictures in the reader's head. The same is true of the queen bee example. The images keep people reading, as well as aiding the explanation in some cases.

Since I always criticize scientists at meetings for not bringing any new results, I have brought a preprint (Appendix B). It will not appear in publication until tomorrow in *The Dallas Morning News.* This example is similar to what I've been saying, but it leads to a different point: You have to limit what you are trying to explain. In this case, there is an interesting paper in a recent issue of *Physical Review Letters* about the possibility of sending messages between parallel universes. I think most of our readers are pretty interested in knowing that—really!

You do have to consider the readers' specific needs for information in dealing with their lives. But I find vast amounts of interest in things that haven't the slightest thing to do with daily life. That's an important thing in conveying the whole essence of science; if you're going to limit yourself to writing about hemorrhoids, you aren't going to give people the sort of picture of science that really communicates the essence of it all, and you're not going to give them a lot of things that they really are interested in. I find this all the time—vast amounts of interest in things that are far removed from, say, what they are going to eat for breakfast tomorrow.

The point of this preprint is that I'm writing about a modification of Steven Weinberg's non-linear formulation of quantum mechanics and how the nonlinearities lead to different predictions of experimental results. The temptation is to sit and think, "How am I going to explain nonlinearity in quantum mechanics?" The answer is, "I don't want to explain nonlinearity in quantum mechanics; that's not the point."

The author was looking at the slightly different math that Weinberg used for this quantum theory stuff, which gave slightly different answers to certain questions, and changing that around and seeing what the implications are. The word "nonlinear" never has to appear in this. It is beside the point, it's not something that needs to be explained, and the temptation we sometimes run into in doing some of these stories is to explain things that don't need to be explained.

This leads to an issue that sometimes comes up on "informing versus educating." I've heard a lot of scientists in meetings say, "Newspapers need to do a better job educating people about science." Well, you know, we can't do that; we are not capable of that. The whole education system gets people for 10, 12, 16 years and can't educate them about science. Now I have a 750-word article here, and I'm not going to educate anybody about anything. I'm not there to introduce new vocabulary or to educate people about science; I'm there to provide them with some interesting and useful information. If I'm lucky, my story can have a secondary effect of generating more interest. This is why I think science sections are extremely valuable in the schools, because the teachers all force the kids to read these sections. They are not a substitute for an education, but they inspire interest and can bring certain things out that can help get kids excited.

Finally, these points are all related. It's hard to separate them out. But the key is making the story interesting, making it easy, not putting barriers in the way of people reading your explanation. The most important part of the story, therefore, is the first sentence; the first sentence should not present any barrier to reading. It should be inviting. Sometimes I have written first sentences that get criticism from people who say

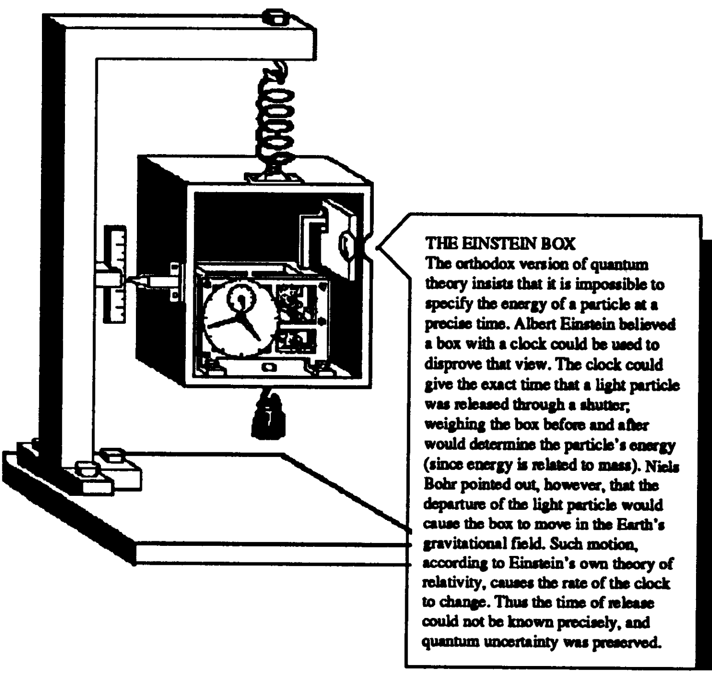
I'm too breezy; but I think that attitude is destructive of good explanation and understanding. You have to give the reader the feeling, coming in, that this is something that isn't going to be drudgery, like a science textbook; this is something that can be read.

For example, the first sentence should not start out with "The mechanism of a supernova explosion has been elucidated by a new study"; it should do something that presents no barrier at all, such as "For nearly four centuries, astronomers wishing upon a star have wished that it would explode." I have some other examples here of some of the ways that I have attempted to accomplish this in the past.

- The pulse of the planet Earth, unlike the heartbeat of America, does not yet have a corporate sponsor.
- Its name is bond. Hydrogen bond.
- To create artificial intelligence, it takes the real thing.
- When space probes a year ago showed pictures of a peanut or potato-shaped object at the heart of Halley's comet, scientists said it would take a year to analyze all the new data and draw firm conclusions. Their year is up, and some scientists now say Halley is perhaps shaped more like an avocado.
- Like Jack Benny, the universe is reluctant to reveal its true age.

These have all actually been in print. [Audience member: How long does it take you to think of them?] Some of them come fast, and some of them come slowly, but the other secret to accomplishing this is that I'm the editor of the section. I write the stuff, and I am also the editor of the section, so I let these things in where some other people might fail at getting them in.

Appendix A
The Einstein Box



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Experiments refute Einstein

Imagine that a mysterious animal enters through your front door every day at noon. By 1 p.m. it has found its way to the kitchen, where you observe that it is either a dog or a cat.

After some experimenting, you find that if you put out cat food in the kitchen in the morning, a cat will show up later; if you use dog food instead, the animal will be a dog. So far, no problem.

But suppose you wait until 12:30 to put out the food, after the animal has entered but before you have seen it. At 1 p.m. you will still find a cat if you used cat food, a dog if dog food, even though the choice was made after the animal had come into the house.

It seems quite absurd, but it's exactly what happens in the bizarre world of subatomic physics.

Such paradoxes led Albert Einstein to wage a losing debate against the prevailing theory of atoms and subatomic particles-called quantum mechanics-for the last three decades of his life.

He proposed numerous imaginary "thought experiments" in an unsuccessful attempt to expose flaws in that theory.

In the three decades since Einstein's death, many physicists have clung to the hope that his views would eventually prevail. But in recent years advanced electronic equipment has made it possible to carry out many of the experiments that Einstein could only imagine. The findings suggest that Einstein was wrong, confirming that modern physics is bizarre beyond belief.

"No one even after years of experience ceases to feel that quantum mechanics is weird," says Princeton University physicist Ed Witten.

The weirdness that governs the subatomic work raises a more sophisticated version of the old question about whether there is sound if a tree falls in a forest when nobody is around. The modern question is more fundamental: What is a subatomic particle doing when nobody is looking at it?

Most physicists hold the view that nobody can say what a subatomic particle is doing unless somebody is looking at it. Furthermore, the particle may at times behave like a wave, depending on the type of observation made. And light, ordinarily thought of as a wave, can appear to be made of particles if viewed in a certain way.

Resolving this dilemma is not as simple as explaining why water is sometimes found in the form of waves and at other times is packaged as ice cubes. It is as if anytime you poured from a pitcher, liquid water flowed smoothly into the cup. But if you then stuck your hand into the same pitcher, you would find only ice cubes-no liquid.

In a similar way, experiments designed to find out if an electron, for example, is a wave produce proof that the electron is a wave. Experiments designed to see if it is a particle produce equally convincing proof that it is a particle.

For Einstein, such results were cause for despair; there must be an underlying reality, he believed, that the quantum theory did not describe. But others, led by the Danish physicist Niels Bohr, argued that quantum theory was as complete a theory as nature would allow. A subatomic object not being watched simply has no precise position or velocity, no physical form that can be described apart from an experiment designed to observe it.

One of the lessons of quantum theory, says physicist John Wheeler of the University of Texas at Austin, is the need to abandon traditional views of particles moving in smooth unbroken paths through space.

"We have to accept a picture of the world different from what we've been accustomed to in the past, where we thought of something as chugging along and that every step of the way you could put your finger on it," Wheeler says. "We realize now that it's a wrong way of speaking."

Bohr, who died in 1962, debated the matter with Einstein until his death in 1955. Whenever Einstein proposed a thought experiment to undermine quantum theory, Bohr countered with an explanation that rescued the theory.

Once, Einstein devised an elaborate imaginary box with a clock shutter and gears to illustrate a supposed error of the theory. After a sleepless night, Bohr showed that Einstein had neglected his own theory of relativity. Quantum theory was upheld.

Most physicists considered Bohr the winner in the debate. But Einstein's objections were not forgotten, and recent advances in optics and electronics have taken the debate from the blackboard to the laboratory. Earlier this year, investigators met in New York to discuss some of the new experiments testing quantum theory's implications.

One such experiment, conducted last year at the Institute of Theoretical and Applied Optics in Orsay, France, tested the suggestion that subatomic particles might have hidden properties that would remove the seeming lack of knowledge about their nature. The experiment's results confirmed Bohr's view that such hidden properties could not exist. Some critics say, however, that different mathematical assumptions would render the finding inconclusive.

To Wheeler, the critics' protests are not convincing

"They go around making a big noise," he said in an interview. "They want a world that never was and never could be.

"All that can be said, I think, is that some people get more and more uncomfortable as they discover what quantum theory really is and what it says."

Such discomfort certainly grew after experiments based on a thought experiment devised by Wheeler. In the late 1970s, Wheeler pointed out that the choice of whether light would behave as wave or particle at a given point could be made after the light had passed that point-like choosing to observe a dog or a cat after the animal had entered the house.

In Wheeler's thought experiment, a half-silvered mirror is put in front of a light ray. If light is a wave, half the wave intensity would pass through the mirror and the other half would be reflected elsewhere. Suitably positioned receptors would detect the light as waves.

On the other hand, a particle of light would either pass through the half-mirror or it wouldn't. Detectors would record a different distribution of light in that case.

A movable mirror can be positioned so that the choice of observing wave or particle can be made after the light had passed the first mirror. The decision of where to put the other mirror thus seems to tell the light what to do when it reaches the first mirror, even though the choice is made after the light has passed the mirror.

As bizarre as it sounds, one version of Wheeler's experiment was actually conducted by a team of physicists at the University of Maryland in 1984. A second version was done later by a group in West Germany. Both found that nature behaved as Wheeler had expected.

"It couldn't have come out differently," he said.

Wheeler's "delayed choice" experiment is a direct descendant of one of the original Einstein-Bohr thought experiments of the 1920s and '30s. In the original "double-slit" experiment, proposed in 1927, Einstein envisioned passing an electron through a slit onto a photographic plate to detect an electron's impact.

With one slit, the electron acts like any particle. But if two slits are present, an interference pattern of alternating light and dark ridges will form, evidence that the electron has acted like a wave.

Einstein argued that the electron could pass only through one slit or the other. How could a second slit influence the electron if the electron didn't pass through it?

Experiments at Orsay have shown, however, that the interference effects would exist as Bohr predicted.

A philosophy professor questioned Bohr about the double-slit experiment, asking "Where can the electron be said to be?" Bohr replied, "To be? To be? What does it mean to be?"

"We've learned, I think," said Wheeler, "that we have to say that that is the kind of question we shouldn't be asking."

There are still physicists who, like Einstein, believe that we will someday be permitted to ask such questions. Witten notes that the latest efforts to resolve the differences between general relativity and quantum theory conceivably could require changes in the Bohr view, although "the evidence so far does not suggest that."

"My thought," Witten says, "is the theory will only get weirder."

Appendix B
Slight change in laws of science might permit parallel universes

Isaac Asimov, the master of science fiction, once wrote a novel (The Gods Themselves) based on the existence of a supposedly impossible form of the element plutonium. From that beginning, Asimov created a tale of strange beings in a parallel universe trying to communicate with Earth.

It is common in science fiction to generate a plot from an apparent scientific impossibility. In fact, science fiction writers would be in serious trouble if they were not permitted to use spaceships that travel faster than light, a violation of current laws.

Yet studying the ramifications of impossible things is not limited to science fiction. Serious scientists from time to time try to figure out what the consequences would be if standard theories and laws were someday found to be wrong. Two intriguing examples appear in recent issues of the scientific journal Physical Review Letters.

One paper examines the implications of varying values for an important numerical quantity in physics. That quantity, known as Planck's constant, is presumed to be the same throughout nature. But Ephraim Fischbach of Purdue University, Geoffrey Greene of the National Institute of Standards and Technology and Richard Hughes of Los Alamos National Laboratory say there is no logical reason why Planck's constant has to be constant. It is conceivable, they say in the Jan. 21 Physical Review Letters, that Planck's constant differs for different subatomic particles. If so, the well-known laws of conservation of energy and momentum may actually be wrong.

The other paper analyzes the impact of slightly changing quantum mechanics, the rules governing atoms and everything smaller. In this case, a possible consequence could be—really—the ability to send messages between parallel universes.

That paper, by physicist Joseph Polchinski of the University of Texas at Austin, modifies a proposal by another UT Austin physicist, Nobel laureate Steven Weinberg. In 1989, Dr. Weinberg developed some new math for quantum physics that produced slightly different answers than the standard quantum equations. Dr. Weinberg didn't really think that standard quantum mechanics was wrong; his formulas were meant as guides for testing how accurate the standard quantum theory really is.

Since then, tests using Dr. Weinberg's math have seemed to confirm standard quantum theory. But Dr. Polchinski says that those tests might be contaminated by the existence of parallel universes.

Actually, the idea of parallel universes has been considered seriously by many theorists for decades. In 1957, the late Hugh Everett proposed that quantum math could be interpreted as meaning that a new universe is created every time an observation is made of a fundamental physical process. In other words, each observation creates a new and separate branch of the original universe, ultimately leading to uncountably many branches.

Many scientists dismiss altogether the idea that these parallel universes really exist. Other scientists say it wouldn't matter anyway, because we would never know about those other universes—there would be no way to communicate with them.

Dr. Polchinski, though, demonstrates in the Jan. 29 Physical Review Letters that an "Everett phone" might be possible if standard quantum math is slightly wrong. A system of signaling could be devised that would in principle permit observers in different universes to transmit messages of any length from one universe to another.

Now, AT&T does not have to worry about a new form of competition anytime soon. In practice, Dr. Polchinski says, the Everett phone might not work at all. All the previous universe branches may be communicating with the one we happen to be in, and that quantum static might wreck the Everett phone idea.

"Practical communication between branches may be drowned out by the coupling to all the other branches," Dr. Polchinski writes.

Furthermore, there is still no evidence that Dr. Weinberg's new math should be preferred to standard quantum math. But Dr. Polchinski notes that experiments confirming the standard math may be misleading, since they have ignored the possible influences from parallel universes.

If the non-standard math is right, there is only one way to avoid parallel universes, Dr. Polchinski says: allowing signals faster than the speed of light, a violation of Einstein's theory of relativity. As hard as it is to swallow the idea of parallel universes, faster-than-light communication is probably even more difficult for most modern physicists to contemplate.

It may turn out that standard quantum physics is right and there is no need to worry about the long-distance charges for accidentally dialing another universe. But these new studies show that science is full of possibilities for surprising new ideas with astounding implications. The future that science has in store may in fact turn out to be stranger than any thing so far imagined in science fiction.

NOTES

Tom Siegfried, science editor of *The Dallas Morning News*, edits a weekly science section for the paper and writes a column that appears in the section each week. He taught journalism at Texas Christian University before joining *The Dallas Morning News* in 1983. In 1989, he won the AAAS-Westinghouse Science Journalism Award for large daily newspapers.

1. Both quotes are from Robert L. Forward, *Future Magic* (New York: Avon, 1988).

Chapter 12

Museums

Robert Sullivan

National Museum of Natural History
Washington, DC

I represent not only museums, but science centers, zoos, arboretums, botanical gardens, planetariums, aquaria—any of the ritual places that we dot around the landscape where we locate scientific authority for a broad public. More people attend these kinds of institutions than attend baseball, football, and basketball combined; we are a significant place for people to come and engage or participate in science. But I don't think that we are a comprehensive or serious place of learning about science if you mean that we present scientific information in any kind of didactic or sequential or linear or structured way.

Why? Because we have an audience, and the audience brings their whole bodies with them, not just their eyes or their heads. We are automatically an open-ended place of learning; I can't determine for that audience whether they will see the first thing I wanted them to see or the last. In all likelihood, they won't see the first; they are highly mobile in our physical location. So we can't even try to be comprehensive places of scientific learning. Rather, we are a beginning point for the learner; we never consider ourselves an end point. We never finish an experience; we hope we begin one. In that sense, we are provocative places of encountering science.

We are sensual places. People come to us with their whole body of senses, and we have to pay a lot of attention to that. We shouldn't attempt to suppress one sense at the expense of the others, as would be the case, say, if I'm trying to read a book, and I'm tapping my foot and moving my body, but mostly I'm trying to get my eyes to do the work. In a museum, my whole body is there doing the work, and, as often as not, the state of people's feet is as important as the state of their minds in what they receive from my exhibits.

We have the average visitor's attention for an hour and 15 minutes. Actually, we probably only have their attention for a half hour, but we have them for an hour and 15 minutes. The first 30 minutes or so are spent seeing the ritual icons, fulfilling some of the pilgrimage aspects of the visit to the institution. That is, "I've got to see the Hope Diamond. I've got to see the dinosaurs. I've got to see the Native American Hall." Only after that do we have that wonderful and important 20 minutes of discretionary time with the visitors when they are actually going to try and find something they didn't intend to come and see. Suddenly they are engaged by it, and they will pay attention to it for those 15 or 20 minutes. That's a key slot of time that museum people try to keep in mind. We are not a transmittal institution; we do not transmit information to a passive visitor. We are the place for a transaction that occurs between a visitor and his whole set of prejudices, attitudes, assumptions, and beliefs and an object, an exhibit, an experience. That transaction takes place. The order in which we would like it to take place is this: First, the visitors are engaged; then, they are enriched by this experience somehow; and one step later, if we're lucky, we have a chance to do some educating. But if the first two happen, we are happy and we feel successful.

We are a place that can change people's attitudes toward science; we may not be able to change their comprehensive knowledge of any field of science or any fragment of science, but we can get to their feelings about science because we are emotive places. We are places where they can meet real working scientists, where they can find out a little science for themselves, where they can engage with an object, a tangible thing of science, and touch it, hold it, smell it, manipulate it, turn it around, and ask questions about it. We have the opportunity to take younger visitors and let them feel some mastery over science, some sense of competence. What they walked in feeling unattracted to or frightened of, they walk out feeling as though it may be something they want to look for further, that they want to go get a book on at the gift shop, or that they want to buy. My daughter, for example, at five years old, goes and buys a collection of gems and minerals at the shop, to continue that inquiry after she has had the experience in the museum. That is success.

I want to take away from you the idea that, as institutions, we have to teach some curriculum of science. I want to focus on what we have the ability to affect: public attitudes toward science.

A burden we bear as a ritual set of institutions is that people trust us, probably more than they would trust a government "scientist" or a scientist associated with industry. Because we have been so marginal in the culture for the past hundred years, museums have been spared some of the mud that other institutions have received; we are still kind of innocent in the public eye. The public sees us as a place where they can get trustworthy information. But in fact, we are far behind the times. In most museums, including my own, the science that is happening within the institution is at least 20 years ahead of the exhibitions. If you look at the National Museum of Natural History, simple things like plate tectonics and ecology are not mentioned. We haven't caught up with it yet. Science changes a lot faster than museums, especially collection-based museums; science centers have a little easier time of it, but even they have problems. The Franklin Institute in Philadelphia just opened a major new addition, and the science is already dated.

Before we put too much pressure on them, it is good for us to remember some other things about museums. We are in the heart of the two-step process of getting people's attention and then communicating with them. Almost everybody visits a museum as a social event, usually in a group, and that group is usually characterized by social inequity. There is one person who is the acknowledged folk bearer and one who is the follower—whether a parent and child, a student and teacher, or someone who is in town bringing out-of-towners to the museum. Normally, our visitors are coming with someone who is a mediator between themselves and the exhibit. One of the problems that we're working on is that we don't empower those mediators very much; they feel as much left out of the loop and as unable to decode what we have there on the walls and in the exhibit, as the stranger to the institution. So, as institutions, we have to work to acknowledge those mentors who come in with the group and to give them a special kind of authority and confidence in the institution. We have to strive not to make them feel diminished in the institution, but rather to make them feel empowered in the institution.

Let me give you one specific example. We just opened an exhibition called "From Crystal Gardens." The exhibition really starts from a very simple observation. When you walk into it, in the Gem and Mineral Section of the museum, you are surrounded by these crystals that your eyes immediately tell you grew. Now, you have a whole series of intellectual denial systems that say, "They're stone; they can't grow." Nonetheless, your eyes have told you part of the truth; these things did grow. You picked up some sort of visual clues that said, "They grew."

Now, normally, in a museum setting, even if you were to acknowledge the folk observation that the crystals grew, the first paragraph of the label would tend to deny it. The label would make you feel that your observation that these things grew was essentially misinformed. Actually, crystals do grow through precise mathematical formulas that you could not possibly recognize with your eye. So, rather than deny the folk observation, we start the sentence with "Crystals do grow, yes, you're right"; that is, we start by acknowledging the visitors and giving them a sense of confidence. We are saying, "You're right; now let's go with what you have observed correctly with your eyes and see where we can take that as a method of inquiry." We want the visitor to continue to ask questions.

Another technique that we are using a lot these days is anticipating visitors' questions. We don't want to deny a question's validity, but instead we want to respect and honor it. We say, "There it is, up in print, that question that you had on your mind; this will engage you because you don't feel so stupid for thinking it, and you do realize that it was not a misguided question and can eventually lead to some interesting conclusions." So trying to be more sensitive to and empowering that visitor is an important characteristic that is emerging in museums.

We are a political institution in our science, and that has to be acknowledged. There are a lot of things we don't talk about or put out on exhibit. In those choices of what to present or what not to present, we really do, unwittingly sometimes and consciously other times, frame a moral point of view for our visitors about science and about science topics. That is a huge obligation that we have to take more seriously as institutions, as we decide what to present and how to present it.

For example, we had a large debate with the anthropology division over whether or not to expose some of the uncertainties of science. We are putting in a system called the "dilemma labels," where we let the public in on the fact that there are multiple explanations, multiple points of view on some fact, and that scientists don't always agree. The argument is: Does that kind of label create vulnerability for science, especially in a public place like a museum, which is a ritual place of authority? Is that the place where you let the public in on the uncertainty of science or where you openly debate or show your own uncertainty or incongruity of explanation?

If we do present the arguments, how do we present them to the public? Do we give Creationism equal weight with evolution? Do we give mythical explanations of the origins of people as much weight as we give scientific explanations? If we ask the question, "Where did the native people of North America come from?" do we include both the archeological and the native mythical explanations and give them both validity in our labels? How do we handle political and moral, as well as scientific, issues? It's not as clean as a simple decision about what science is. For us, the question is: What is the impact on the public, and how will the public respond to us and interact with us?

But we hope that in the end they leave with more questions than answers, and they leave in the mood to go and frame questions in a new way or to frame some new questions. That is success to me as a museum person or a science center person. If, as institutions, we can explain science as a way of asking questions and a way of explaining the world and get people to believe that they should go out and ask some of those questions and explore further, then I think we have been successful.

NOTES

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Chapter 13

Strategies for Enhancing Comprehension of Science

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People who explain difficult science concepts frequently proceed on the basis of sophisticated explanatory instincts derived from a wealth of practical experience. They know that explaining, in the sense of anticipating and overcoming likely confusions (rather than demonstrating or proving), involves locating an audience's difficulties and offering examples, analogies, definitions, or sayings that may overcome those difficulties.

But explainers need resources beyond those of developed intuitions. Specifically, they will produce better explanations when their intuitions are supplemented by (a) firm belief in the value of good explanatory discourse, (b) large and easily accessed collections of explanations, and (c) a conceptual framework for determining why ideas are likely to be difficult for audiences and what strategies best overcome these obstacles. In this chapter, I will comment briefly on the importance of the first two resources and at greater length on the third. In particular, I will summarize a conceptual framework for identifying the basis of an idea's difficulty, describe empirically tested strategies for overcoming the problem identified, and discuss ways in which this framework allows explainers to extend and deepen their own knowledge of difficult ideas.[1]

The Value of Explanatory Discourse

Good explanations, like good storytelling or any other discursive art, intrigue. A story headlined "Why the stomach doesn't digest itself"[2] is likely to be read because it stimulates readers' interest. Although there is considerable evidence of science illiteracy, there is also evidence showing that people find science interesting and look forward to reading science news. According to both U.S. and British surveys, people report having greater interest in news about medical discoveries, new inventions, and new technologies than they have in sports, new films, or politics.[3] However, these surveys also show that despite interest in these topics, people on both sides of the Atlantic do not feel well informed about science.

This gap between interest in science and feeling well informed may indicate a continuing desire for engaging in explanatory discourse. Historian Jack Meadows reminds us that in the 19th century, people would flock to Michael Faraday's public lectures on the chemistry of the Christmas candle.[4] Today, that same explanation would more likely be presented in a children's science museum or as part of a news article reporting discoveries in superconductivity. But if it were offered in an interactive museum exhibit or through a newspaper article with clever headlines, engaging graphics, and good writing, Faraday's explanatory discourse might still be well received.

The Need for Accessible Collections of Explanations

Journalists, teachers, museum curators, and administrators are some of the people who typically explain science for a living. Often, they are asked to discuss topics about which they have no personal expertise. Journalists, for example, may file three stories daily on three diverse topics. Teachers and administrators frequently explain ideas they have just recently mastered. Thus, many people who explain need large and easily accessed depositories of well-explained information.

Electronic data bases — files of information accessed with computers and telephone lines — increasingly help journalists to meet their information needs. Hundreds of data bases are now available to many news organizations, so that the full text of articles from many newspapers, news magazines, and wire service stories may be located and read on computer screens. However, one limitation to current data bases is that the simplest explanations of science concepts are available only from news articles, dictionaries, and encyclopedias. Often, dictionary and news article explanations are overly brief, and encyclopedia entries are too technical or too focused on offering broad topical overviews, rather than explaining difficult-to-grasp ideas.

In an explainers' Utopia, data bases would include multiple accounts of scientific topics that are accessible to the lay person. For example, thorough, readable accounts of scientific subjects may be found today in introductory science texts, popular nonfiction, and children's science books. In the Utopia, topically indexed explanations from these sources could be appropriately credited and made electronically accessible to journalists. So, if these sources were available online, journalists writing about plastic surgery with pulsed tunable dye lasers could look up Ben Patrusky's *The Laser: Light That Never Was Before*, a children's book on how lasers work.[5] A simple sidebar story presenting this information would be useful to many readers. Only 42 percent of British adults in a 1989 survey were certain that lasers do not work by focusing sound waves; only 54 percent of the U.S. college students I recently surveyed were equally certain.[6]

The Utility of a Conceptual Framework

A third resource explainers need is a conceptual framework for identifying the key bases of an idea's difficulty and tested strategies for overcoming that difficulty.

Three obstacles

Research shows that people may fail to understand a difficult idea for any of three major reasons.[7] First, *they may not grasp the meaning and use of a concept or term.* For instance, in reading news stories about superconductivity, they may become confused about the difference between amps and volts. Perusing a story about the FDA's quandaries in regulating genetically engineered food, readers may wonder about the difference between a food additive and a food. Or, watching a television newscast, they may ask themselves what dioxin is.

Second, *readers may struggle to model or represent mentally some phenomenon, structure, or process.* They may wonder why they receive clear signals from faraway AM radio stations at night or why the sky looks blue during the day. While reading an advertisement for "low-cholesterol" margarine, they may realize that they do not understand how cholesterol comes to be in margarine or how cholesterol is produced.

Third, *readers may have a preexisting or tacit model that prevents them from believing (and therefore understanding) experts' representations of some phenomenon.* For example, it was difficult to believe (and thus to understand) how astronauts could, once out of the Earth's orbit, shut off their engines and "coast" for three days and 240,000 miles to the moon. Similarly, people may have difficulty understanding that men can get breast cancer, or that spacecraft make no sound when traveling through space.

Not infrequently, experts have trouble explaining difficult ideas to one another because new theories often violate deeply held beliefs or preexisting models. Galileo faced such responses from fellow experts. More recently, some experts found it difficult to believe that "doing nothing" would have been the best response to the Valdez oil spill (or so said certain other experts).

Overcoming these obstacles

Research shows that each of these difficulties must be addressed with a distinct type of explanation. *Elucidating explanations* are designed to clarify the meaning and use of a term. For instance, in stories about superconductivity, journalists may need to refresh readers' memories about the definition of this term. They may also need to refresh memories about the distinction between amps and volts or the specific meaning intended by physicists with the concept of work.

The chief difficulty in mastering a concept and its use lies in distinguishing its critical (always present) from its variable (frequent but not necessary) features. Thus, good elucidating explanations focus audiences' attention on this distinction and encourage them to differentiate items that have these critical features from those that do not. Specifically, researchers in instructional design have found that good elucidating explanations contain (a) a definition that lists each of a concept's critical features, (b) an array of varied examples and nonexamples (nonexamples are instances likely to be mistaken for examples), and (c) opportunities to practice distinguishing examples from nonexamples by looking for critical features.[8]

Because good elucidating explanations include examples and nonexamples, as well as definitions, they are more effective at emphasizing a concept's critical features than are definitions alone.[9] For example, in a story on superconductivity, a reporter could define an amp as a measure of *the number of electrons* flowing through a surface at a given point in a unit of time and a volt as a measure of the *pressure* causing the electron flow. However, presented without examples and nonexamples, this definition may not be understood; readers may still be confused about the distinction between the terms.

To make the critical features of concepts clearer, reporters should illustrate them with examples and nonexamples. For instance, they could describe phenomena with different levels of amperage and voltage. One might write: "At a children's museum, you may have seen a Van de Graaff generator. You put your hands on it, and a charge of electricity causes your hair to stand on end. In this case, the number of amps you received is very low, but the voltage necessary to make your hair stand on end was comparatively high. In contrast, an electric chair works with higher amperage and high voltage."

The third feature of good elucidating explanations, that they offer opportunities to practice distinguishing examples from nonexamples, can occur in a one-on-one context but not in a textbook or news story. However, in interviews, journalists and administrators can test their comprehension of a difficult concept by generating several examples and nonexamples and asking an expert to check the accuracy of these sets.

Good elucidating explanations are sometimes found in popular media. A recent *Reader's Digest* article nicely illuminated the concept of "dietary fiber" when the author wrote: "The term 'dietary fiber' refers to the parts of plants that pass through the human stomach and small intestine undigested—ranging from the brittle husks of whole wheat to the stringy pods of green beans to the gummy flesh of barley grains."[10] In this passage, the author concisely lists the critical features of dietary fiber: "parts of plants" that "pass through the human stomach and small intestine undigested." She then goes on to offer a *range* of examples so that readers do not inadvertently think that fiber must be a grain, must be brittle, or must be gummy. For maximum clarity, she could also add a nonexample of an entity people might erroneously consider to be fiber (perhaps tough meat), and reassert that only plant materials count as dietary fiber.

Knowing that a concept is most fully understood when its critical features are identified and illustrated by examples and nonexamples helps refine and extend explainers' knowledge. In my science reporting classes, students are asked to develop elucidating explanations for the concept of science itself. The assignment seems easy at first, but students soon realize that there is less than full agreement over whether experimentation is a critical feature of all scientific activity and whether history and psychology are examples or nonexamples of science.

A second type of explanation, the *quasi-scientific*, is designed to help people mentally model or represent some aspect of reality. For example, journalists use quasi-scientific explanations when explaining how a microwave oven cooks food, why some people must eat less cholesterol-laden food than others, how a bicycle stays upright when in motion, or why our arms tingle after they have "fallen asleep."

Because the chief difficulties in adequately modeling such phenomena lie in locating their key components or processes, good quasi-scientific explanations have easily discernible main points and clear connections among them. Specifically, researchers in educational psychology have found that effective quasi-scientific explanations contain features that highlight the structure of the explanation, such as model-suggesting headlines, headings, topic sentences, organizing analogies, transitions, and signaling phrases ("the key point is..."). Quasi-scientific explanations may also feature diagrams.[11] Researchers have also shown that omitting transitional phrases to adhere rigidly to readability formulas, which mandate short sentences, may harm the understandability of a quasi-scientific explanation.[12] Transitions and longer sentences sometimes depict links within a process or structure. Readers may need this information to construct clear mental models of difficult-to-visualize phenomena.

People may be most instinctively adept at quasi-scientific explanation; asked to explain how a computer's central-processing unit works or how computer screens differ from television screens, explainers usually search for a pencil and paper to diagram their accounts. Further, graphics are increasingly used in popular media to explain complex mechanical and physiological processes. One of *Time* magazine's 1988 cover stories, "Searching for Life's Elixir," for example, describes the human body's cholesterol ingestion, production, and elimination processes. The story and accompanying graphics analogize these processes to that of a factory manufacturing, storing, and shipping cholesterol. However, while this story explains many ideas very well, it mixes analogies, comparing the body to a factory somehow beset with "heroes" and "villains" (i.e., high-density lipoproteins and low-density lipoproteins). Since good quasi-scientific explanations help people build mental models, an explanation that proposes two inconsistent models cannot be as effective as an explanation that sticks to one model.

A far simpler analogy-based account of the cholesterol management system was offered recently by a professor of foods and nutrition. Asked why some people must regulate their intake of fatty foods more carefully than others, Purdue Professor Jon Story suggested that the body's cholesterol regulation system could be likened to a washbasin with two spigots. One spigot lets in ingested cholesterol, the other cholesterol manufactured in the body by the liver. In some people, Story said, cholesterol is eliminated efficiently (when the liver turns it into bile acids); in others, the basin drains poorly, and cholesterol remains in their systems. Story's analogy helps people build a very simple and, therefore, vivid model of the cholesterol regulation system, one that may be easier to acquire by those lacking knowledge of physiology than the more complex analogies and information offered in *Time*.

Research has shown that highlighting structural devices in text not only helps people to envision complex processes, structures, or classification systems, but also enhances their problem-solving capabilities. In one study, college students were asked to read passages about the conditions necessary for "red tides," or carpets of microscopic dinoflagellates. When ocean air and water are calm and warm, dinoflagellates proliferate. Because they secrete poisons that kill fish, red tides can be quite harmful.

Two versions of this passage were created—one with structural highlighting, such as topic sentences and headings (e.g., "Dinoflagellates Bloom"; "Dinoflagellates Secrete Poison"), the other without these highlighting features. Students receiving the structurally highlighted text understood the passage more fully and were better able to answer problem-solving questions on reducing the likelihood of red tides, than were their counterparts who read the unhighlighted version.[13] Psychologist Richard Mayer and his associates have found similar associations between enhanced problem-solving capabilities and other types of structural highlighting, such as analogies and diagrams, across an array of scientific topics.[14]

The third type of explanation, *the transformative*, aims to purge an incorrect but intuitively compelling notion and help readers see why another idea, which may seem incredible, is more adequate — according to experts. For example, a transformative explanation should be used when demonstrating why, contrary to movie presentations, a spacecraft would not bank in space. A columnist explaining why irradiated food is healthful should probably employ this third form of explanation.

Because readers' chief difficulties in understanding counterintuitive science lie in seeing why their own, implicit theory is inadequate, good transformative explanations begin by discussing the implicit theory and demonstrating its limitations, rather than simply explaining the expert view.

Specifically, researchers in science education have found that the best transformative explanations are those that (a) state people's "implicit" or "lay" theory about the phenomenon, (b) acknowledge the apparent plausibility of this lay theory, (c) demonstrate its inadequacy,[15] (d) state the more accepted account, and (e) demonstrate its greater adequacy. Though many explanatory passages omit the first three of these steps, research shows that if the implausibility of a notion is *the* basis for an audience's difficulty with it, then the three steps are essential. Just as Galileo's associates could not easily give up the geocentric theory, so, too, do most people maintain lay views until they are presented with excellent reasons to do otherwise.

Isaac Asimov is especially adept at transformative explanation. For instance, to explain Newton's Third Law of Motion, Asimov writes:

> Perhaps . . . this [for every action there is an equal and opposite reaction] is not the best way of putting it. By speaking of action and reaction, we are still thinking of a living object exerting a force on some inanimate object that then responds automatically. One force (the "action") seems to be more important and to precede in time the other force (the "reaction"). It would be better, therefore, to state the law something like this:
>
> *Whenever one body exerts a force on a second body, the second body exerts a force on the first body. These forces are equal in magnitude and opposite in direction.*
>
> So phrased, the law can be called the "law of interaction".... [16]

Asimov further explains that the law of interaction involves equal and opposite forces exerted on *two separate bodies.* To illustrate, he asks readers to imagine throwing a rock. According to the law of interaction, he says, if the thrower exerts a force on the rock, an equal and opposite force is exerted by the rock on the thrower. However, normally rocks are thrown when throwers are standing on gravel or sand, so the friction between shoes and ground masks the rock's force on the thrower. But, as Asimov further notes, if the thrower were standing on ice, the rock would hurl one way and the thrower would slide back in the other direction.

Following Asimov's lead, we may recall having exactly this sensation when trying to push a stuck car while standing on slippery ice. Similarly, if astronauts floating in space try to fix a several-ton mechanical arm by exerting a force on that arm, they themselves will be propelled backward. Of course, in these cases, because it is "unmasked" by the absence of friction, the law of interaction has greater plausibility. Since the average person's lay theory says that inanimate objects do not exert forces, the notion that *every* action is in fact an interaction between two forces is highly counterintuitive. Asimov's explanation directly addresses this implausibility and tries to overcome it, whereas many other accounts, often in good introductory physics texts, present Newton's Third Law in ways that neither emphasize its profound implausibility nor attempt to demonstrate its reasonableness to shocked lay readers.

Asimov's account effectively employs each step necessary for an effective transformative explanation. He begins by stating the erroneous assumption that a force must be something exerted by an *animate* body on an inanimate body. He then shows, by offering the "law of interaction," that this is not what Newton's Third Law actually says. Next, he addresses a second lay theory, that if a person exerts a force on a rock by throwing it, absolutely no force is exerted by the rock on that individual. Once again, Asimov acknowledges the existence and the plausibility of this lay theory by noting that a person throwing a rock is typically standing on rough ground, so that friction between that person's shoes and the ground masks the effects of the law of interaction. He then demonstrates that the law does in fact operate on the rock-throwing individual by describing how rock throwing would affect the thrower if he were standing on smooth ice to do his throwing. Last, Asimov offers a second demonstration of the law of interaction's adequacy by describing how it operates to lift rockets off the ground.[17]

Although transformative explanations are not easy to produce, they have features of great interest. Good transformative explanations get attention by presenting surprising facts about the familiar. In addition, rather than simply dismissing erroneous notions, they treat lay people as thinkers who have plausible ideas, but who may not have had a chance to consider fully all the available information.

Science educators have found that students understand good transformative explanations better than those that fail to address widely held lay theories.[18] It is reasonable to assume that newspaper, magazine, and television audiences would respond in the same way.

Often, one can assert an accepted theory but be unable to demonstrate its greater adequacy. For instance, truly demonstrating the inadequacy of the geocentric theory and the greater adequacy of the heliocentric is substantially more challenging than simply asserting that the Earth travels around the Sun. Thus, knowing the features of good transformative explanations can serve as a goal in mastering counter-intuitive ideas just as it can in explaining them to others.

An Approach to Teaching Explanatory Strategy

When I teach student journalists about the foregoing three types of difficulties and the strategies for overcoming each, I sometimes receive an interesting objection to this framework. People quite reasonably say that the topic they must explain contains several difficulties: difficult concepts, difficulties envisioning them, and counterintuitive ideas. While there often are multiple challenges to learning complex material, I submit that it is useful to determine the *chief* obstacle and organize one's explanation to overcome that obstacle. Additional types of explanation can then be incorporated into this overall framework.

For instance, one might reasonably say that Asimov's explanation of Newton's Third Law was an elucidating, quasi-scientific, *and* transformative explanation: elucidating because he chose to re-name the law and explain the term "interaction"; quasi-scientific because he took steps to help us visualize the forces the law depicts; and transformative because he addressed the lay theory that inanimate objects exert no force. But while one can represent Asimov's explanatory strategy this way, doing so deemphasizes the overall objective of his explanatory efforts: to help people understand a profoundly implausible idea. Thus, in this case, and in many others, explainers are likely to find it most useful to identify the chief difficulty facing an audience and organize their explanations to address that difficulty, incorporating other types of explanations as substeps in their overall plan, rather than thinking of themselves as offering all three types of explanation in the hope that one will work.

Conclusion

To explain difficult science concepts, people need belief in the value of explanatory discourse, accessible sets of good explanations, and conceptual tools for diagnosing perceived difficulties and selecting strategies likely to overcome them. We would have very little faith in doctors who simply tried every cure they could think of, instead of first diagnosing their patients' ailments and selecting treatments that fit their diagnoses. Similarly, explaining is an art that should proceed with careful analysis and an informed strategy for selecting means of doing the job.

Just as there are physicians who vary in diagnostic skill, there will always be journalists, teachers, curators, and scientists themselves whose explanations for lay audiences are more illuminating, and more entertaining, than those that others produce. But with conceptual tools for determining why some notion is confusing and the knowledge of empirically tested strategies for overcoming that type of confusion, people who already explain scientific notions well will have resources for both analyzing their successes and generating even more of them.

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NOTES

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1986, 29:440–446; and J. A. Shymansky and W. C. Kyle, "A Summary of Research in Science Education—1986," special issue, *Science Education*, 1988, 72(3).

16. Isaac Asimov, *Understanding Physics: Motion, Sound, and Heat* (New York: Mentor Books, 1966), pp. 34–35.
17. Asimov, *Understanding Physics*, p. 35.
18. See, for example, C. W. Anderson and E. L. Smith, "Children's Preconceptions and Content-Area Textbooks," in G. Duffy, L. Roehler, and J. Mason, eds., *Comprehension Instruction* (New York: Longman, 1984), pp. 187–201; Hewson and Hewson, "Effect of Instruction Using Students' Prior Knowledge"; M. G. Hewson and P. W. Hewson, "The Role of Conceptual Conflict in Conceptual Change and the Design of Science Instruction," *Instructional Science*, 1984, 13:1–13; and Shymansky and Kyle, "A Summary of Research."

V. Summary

New Directions for Public Understanding of Science

Chapter 14

The Audiences to Listen To

Shirley M. Malcom

American Association for the Advancement of Science
Washington, DC

In a moment of madness, I agreed to share my perspectives on the audiences that activities relating to public understanding of science are and are not reaching. I preface this by saying that this is not my field of expertise. I've come to these conclusions by accumulating and synthesizing anecdotal information with some "real" research findings. My goal is to point us toward the actions that we must take in the future.

As several speakers during the workshop suggested, most activities pertaining to public understanding of science seem to be aimed at the same well-educated market of middle-to-higher socio-economic status. There are few hooks to "ordinary" people and, especially, to minorities within our population. How can we change this?

1. We must socialize all children to recreational science. Whether through scouting, Boys and Girls Clubs, museums, television, or library-based programs, we have to let children meet science in every aspect of their lives. School-based science education is necessary, but not sufficient.

2. We must make special efforts to get underrepresented groups to out-of-school science. We must target groups such as the Girl Scouts; Girls Incorporated; Jack and Jill; the YMCA; and the YWCA, as groups that are ripe for out-of-school science programming. We must target places with presence and legitimacy in communities (libraries, community centers, churches, malls, etc.) as the sites and sources of such programming.

3. We must work to increase people's incidental contact with science through radio and television spots, news coverage, newspapers, and magazines.
4. We must work to increase underrepresented groups' contact with science by targeting specialized media aimed at women and girls (e.g., *Seventeen, Good Housekeeping, Family Circle, Glamour,* and *Redbook* magazines), minorities (e.g., *Ebony* and *Jet* magazines, and Black and Hispanic newspapers, and radio and television shows, etc.), and seniors (*Modern Maturity* magazine).
5. We must work to increase the presence of science in widely read, popular publications such as *Parade* magazine.
6. We must target adults through print and video materials disseminated through the places where people go and, especially, where they go and *wait*, such as doctors' offices, hospitals, and health clinics.
7. We need to take better advantage of "captive audiences" by showing more science shorts on airplane videos (there are some now, but not enough), in airline magazines, on bus placards, etc.
8. We must use locations such as grocery stores to disseminate take-home information about science—just as take-home information on nutrition, recipes, and missing children are already distributed in these locations. This is a natural distribution point, since many activities rely on utilizing items you can find in the store. We can target parents, grandparents, older children, teachers, community youth leaders, and business leaders.
9. We must make science real by making it a part of the lives of people on television in a manner similar to that portrayed in *LA Law* and *Equal Justice. Good Morning, America,* the *Today Show,* and *Sunday Morning* need to provide regular science coverage, just as they provide regular coverage of music, the arts, and literature.

Each of these suggestions points to our need to identify specific locations and activities that provide opportunities for reaching people outside of the audiences that are already attending to information about science. Since people of different ages do different things, one way of categorizing opportunities is by age:

Ages: Where they are, what they do, and where they can be reached

INFANTS TO PRETEENS

Ages 0–4 Day care / church programs / pediatricians, health clinics / grocery stores and cereal boxes / family outings

Ages 5–8 Church programs / pediatricians, health clinics / grocery stores and cereal boxes / family outings

And, in addition

Before- and after-school care / field trips / malls / library programs / toy stores / Saturday cartoons and other children's television programs / youth-serving groups / day camp / home entertainment systems

Ages 9–12 Church programs / pediatricians, health clinics / family outings / before- and after-school care / field trips / malls / library programs / toy stores / Saturday cartoons and youth television programs / youth-serving groups / day camp / home entertainment systems

And, in addition

Theme parks / health centers / science songs (would you believe "rap"?) / children's magazines / sports-based science / TV sitcoms / Science-By-Mail program / Big Brothers and Big Sisters / hobby clubs / computers / comic books

TEENS TO ADULTS

Church programs / doctors' offices, health clinics / family outings / field trips / malls / library programs / television programs / home entertainment systems / theme parks / science songs / general magazines / sports-based science / Science-By-Mail program / Big Brothers and Big Sisters (on both sides of the program) / hobby clubs / computers / comic books

And, in addition

Science projects / Science-based community service / science-based employment / museum explainers

ADULTS

Political organizations / social and civic organizations (Kiwanis, League of Women Voters) / museums, zoos, nature centers, and other "places of science" / television (all programming)

Plus As parents, in many of the foregoing situations / as volunteers, in many of the foregoing situations / as lifelong learners

"Ordinary" people go to the movies, rent videos, participate in sports, and watch television. They also go to the mall, to the grocery store, to the doctor, and to church, and they play Nintendo. They may also read newspapers, magazines, and books. We must meet them on these terms. It seems to me that we have only begun to scrape the surface.

To date, the orientation of those in the field of public understanding of science has been heavily focused on products (a new exhibit, a new *Nova* show). We must now fund more "process-focused" activities; the AAAS Mass Media Science and Engineering Fellows program offers one model, but we must consider others. We must look at the kind of campaigns that have been taken on by other "interest groups" to better understand how to infuse our messages into television. If the Huxtables go to the art museum, why haven't we gotten them to the science museum? Why can't Vanessa decide to become a physicist? We spend money on museum exhibits; we need to factor in the process of thinking through the kind of exhibit that would attract groups different from those that already attend museums.

All too often, concerns about education and equity seem to be added onto other activities at the end. I urge us all to make them part of our initial thinking. Unless attention to audiences becomes part of the way we decide what we will do, we are just going around in circles.

NOTES

Dr. Shirley M. Malcom is the head of the Directorate for Education and Human Resources Programs at AAAS. Dr. Malcom is a nationally recognized expert in science and mathematics education policy. She currently serves on the Smithsonian Advisory Council, the board of the National Center on Education and the Economy, and the National Science Foundation Informal Science Education review panel.

VI. Appendices

For Further Action

Appendix A

AAAS Committee on Public Understanding of Science and Technology

Patricia S. Curlin

American Association for the Advancement of Science
Washington, DC

Increasing the public understanding and appreciation of the importance of the methods of science in human progress is a long-standing goal of the American Association for the Advancement of Science (AAAS). In 1959, the Association formed the Committee on Public Understanding of Science and Technology (COPUS&T) to help carry out this objective. Today, COPUS&T's major activities reflect the Association's emphasis on communicating science to the public through education and human resources, science policy, and international science.

The committee's strength comes from the talents and diversity of its members, who provide unique perspectives on the broad area of public understanding of science and technology. COPUS&T members include science and technology educators, advisers, researchers, and writers; science communicators from media production, broadcast and print journalism, and science and technology centers; and representatives from the public sector and government.

COPUS&T activities focus on linking science and the public. The committee's mandate is to advise AAAS on programs relating to public understanding of science, sponsor symposia and workshops, recognize outstanding achievements, encourage and sponsor research and other projects, communicate the results of these to the public, and work cooperatively with other organizations involved in similar activities. Recent COPUS&T activities include:

- *Advising the AAAS.* In 1987, COPUS&T examined future directions for the association in public communication, education, and understanding of science and technology. The committee's report to the AAAS board of directors recommended two target areas for action: encouraging science education at an early stage, in both formal and informal areas; and making better use of the AAAS annual meeting as a vehicle for enhancing public understanding of science and technology. Many of the committee's activities stem from this advice.

- *Sponsoring workshops and symposia.* Each year at the AAAS annual meeting, COPUS&T sponsors a broad array of workshops and symposia. These sessions have addressed international science museums, popular science, environmental reporting, writing and television strategies for communicating science to the public, nontraditional science communication in the developing world, science acculturation among young people, cross-national measurements of public understanding of science and technology, and science fiction.

  The 1991 COPUS&T-sponsored "Progress in Public Understanding of Science" workshop led to the present book. This was an attempt to bring together communicators, researchers, and practitioners to discuss what is being learned about science communication in society today. The book is a step toward bridging the gap in linking science and the public.

- *Recognizing achievements.* The AAAS Award for Public Understanding of Science and Technology was initiated by COPUS&T to recognize working scientists and engineers who popularize but are not members of the media. The award is intended to encourage popularization of science, recognize and support those who popularize, and signify that the scientific community regards popularization as a valued, prestigious activity. Administrated by COPUS&T, the award has been cosponsored by the Westinghouse Foundation since 1987. Four distinguished scientists have received the award and its $2,500 prize; a fifth will be presented with the award in 1992.

- *Initiating projects.* COPUS&T started another successful project in 1989—"Public Science Day." Organized as part of the AAAS annual meetings to bring a day-long exploration of science to grade school children and families in the host city, this event brings together the resources of the local community and the AAAS meeting. AAAS collaborates with local research agencies and both formal and informal education institutions to demonstrate that science and technology are part of daily life and are accessible to all. COPUS&T monitors and evaluates Public Science Day, providing guidelines for organizing the event.

- *Collaborating with others.* COPUS&T monitors and advises AAAS on projects such as the annual Benjamin Franklin Event, held in celebration of National Science and Technology Week. A series of lectures and hands-on demonstrations and activities, this event highlights the efforts of today's scientists, engineers, and educators. It is jointly sponsored by the National Science Foundation, the National Academy of Science, AAAS, and others.

  COPUS&T also monitors the Science and Technology Centers Project that links AAAS members with science centers and museums. Member scientists and engineers are encouraged to volunteer their services at their local science museums. Using AAAS volunteers and others, museums have initiated programs to enrich science education. One such program is Science-By-Mail, created by Boston's Museum of Science as a pen-pal project connecting scientists and students in grades 4-9 in challenging scientific partnerships. Another project, at the North Carolina Museum of Life and Science in Durham, prepares volunteers for visits to elementary schools with a handbook, *Sharing Science with Children: A Survival Guide for Scientists and Engineers.*

  COPUS&T advises the Mass Media Science and Engineering Fellows Program, which is designed to strengthen the relationship between science and technology and the media. The program places advanced students in science and engineering in mass media organizations nationwide for 10 weeks each summer. It is intended to enhance coverage of science-related issues in the media and, in so doing, improve the public's understanding of science.

• *Defining the audience.* In its 1987 report, COPUS&T describes the audiences for science as falling into three categories: (1) the 20 percent of the public that is well aware of and curious and informed about science; (2) another similarly sized group that is on a more passive, less motivated, but still "accidentally" interested level; and (3) the remainder of the public, for whom science remains an incomprehensible mystery. The report stresses that "One of the great challenges of public communication is to find the means to reach out to, and stimulate the potential interest of such persons." It is to help meet that challenge that COPUS&T has sponsored this book.

NOTES

Patricia S. Curlin is staff officer for the AAAS Committee on Public Understanding of Science and Technology and directs projects under COPUS&T's purview. She has a master's degree in energy policy from George Washington University, and her background is in communications and science policy.

AAAS Committee on Public Understanding of Science and Technology

1990 – 1991 Membership

Sheila Grinell (Chairman)
Consultant, Informal Science Education

Paula Apsell
Executive Producer, *Nova*
WGBH-Boston

Valerie Crane
President
Research Communications Limited

David L. Crippens
Senior Vice President
Educational Enterprises
KCET-TV

Ira Flatow
Independent Radio/Television Producer

Robert A. Frosch
Vice President
General Motors Corporation
(AAAS Board Representative)

Paul Hoffman
Editor-in-Chief
Discover

Fred Jerome
Executive Vice President
Scientists' Institute for Public Information

Marcel C. LaFollette
Associate Professor of Science and Technology Policy
The George Washington University

Talbert Spence
Chairman
Department of Education
American Museum of Natural History

Michael Templeton
Consultant in Science Learning

Joan Tucker
Executive Assistant to the President
Pace University

Gerald F. Wheeler
Professor of Physics and Director
Science/Math Resource Center
Montana State University

Patricia S. Curlin
AAAS Staff Officer

Appendix B
For Additional Information

Organizations

A great many organizations work on issues that affect public understanding of science. Many of these organizations publish newsletters, books, and other materials that address public understanding of science. Among the groups to which one can turn for information are:

American Association for the Advancement of Science
1333 H Street, NW
Washington, DC 20005
Telephone 202/326-6400

American Association of Museums
1225 Eye Street, NW
Washington, DC 20005
Telephone 202/289-1818

Association of Science-Technology Centers
1025 Vermont Avenue, NW
Suite 500
Washington, DC 20005
Telephone 202/783-7200

Committee on Public Understanding of Science
6 Carleton House Terrace
London SW1Y 5AG
United Kingdom
Telephone 071-839-5561

Council for the Advancement and Support of Education
11 Dupont Circle, Suite 400
Washington, DC 20036-1207
Telephone 202/328-5948

Council for the Advancement of Science Writing
PO Box 404
Greenlawn, NY 11740
Telephone 516/757-5664

International Science Writers Association
7310 Broxburn Court
Bethesda, MD 20817
Telephone 301/229-6770

National Association of Science Writers
PO Box 294
Greenlawn, NY 11740
Telephone 516/757-5664

Science Journalism Center
University of Missouri
School of Journalism
Box 838
Columbia, MO 65205
Telephone 314/882-4714

The Science Museum Library
Exhibition Road
South Kensington
London SW7 5NH
United Kingdom
Telephone 071-938-8201

Science Policy Support Group
22 Henrietta Street
London WC2E 8NA
United Kingdom
Telephone 071-836-6515

Scientists' Institute for Public Information
355 Lexington Avenue
New York, NY 10017
Telephone 202/661-9110

Society of Environmental Journalists
1090 Vermont Avenue, NW
Suite 1000
Washington, DC 20005
Telephone 202/408-2725

Selected Publications

Many books and articles address issues raised by the articles in this book. The following readings are intended only to provide starting points.

How to popularize

Warren Burkett, *News Writing: Science, Medicine, and High Technology* (Ames: Iowa State Univ. Press, 1986). A textbook on science journalism.

Victor Cohn, *News and Numbers* (Ames: Iowa State Univ. Press, 1989). A primer for journalists and others trying to understand the limitations of scientific studies and the questions to ask of any study.

Sharon Dunwoody and Jocelyn Steinke, eds., *Directory of Science Communication Courses and Programs in the United States* (Madison: University of Wisconsin Center for Environmental Communications and Education Studies, 1991). Just as the title says: a directory of courses and programs for those who want to learn more about how to popularize science.

Barbara Gastel, *Presenting Science to the Public* (Philadelphia: ISI Press, 1983). A basic how-to book directed towards scientists who want tips on dealing with the media or public audiences.

Beverly Serrell, ed., *What Research Says about Learning in Science Museums* (Washington, DC: Association of Science-Technology Centers, 1990). Short collection of brief articles by museum exhibit developers and educators. Focuses on how to engage effectively and teach visitors, especially children, with science museum exhibits.

Michael Shortland and Jane Gregory, *Communicating Science* (New York: John Wiley, 1991). A basic how-to book directed towards scientists who want tips on dealing with the media or public audiences. Written from a British perspective.

Issues in science popularization

John Burnham, *How Superstition Won and Science Lost: Popularizing Science and Health in the United States* (New Brunswick, NJ: Rutgers Univ. Press, 1987). History of science popularization in the United States. Argues that popularization has become fragmented and no longer provides the grand vision of scientific ideology that characterized it in the 19th century.

Marvin Druger, ed., *Science for the Fun of It* (Washington, DC: National Science Teachers Association, 1988). Collection of brief papers describing the various ways in which teachers, writers, and broadcasters attempt to meet the demand for informal science education.

Sharon Dunwoody and Marilee Long, comps., *Annotated Bibliography of Research on Mass Media Science Communication* (Madison, WI: University of Wisconsin Center for Environmental Communications and Education Studies, 1991). Thorough coverage of research on issues in science journalism.

David Evered & Maeve O'Connor, eds., *Communicating Science to the Public* (New York: John Wiley, 1987). Conference proceedings dedicated to defining basic issues regarding public understanding of science and science literacy. Somewhat critically evaluates the educational roles of schools, the mass media, museums, technology centers, and zoos.

Sharon M. Friedman, Sharon Dunwoody, and Carol L. Rogers, eds., *Scientists and Journalists: Reporting Science as News* (New York: Free Press, 1986). Both research and anecdotal reports about science journalism. Includes annotated bibliography of research materials on science journalism.

Hilde Hein, *The Exploratorium: The Museum as Laboratory* (Washington, DC: Smithsonian Institution Press, 1990). Details both the history and the philosophy propelling America's quintessential interactive science center. Describes the development, construction of, and teaching methods used with exhibits from the perspective of an enthusiast for hands-on methods.

Kenneth Hudson, *Museums of Influence* (New York: Cambridge Univ. Press, 1987). Profiles 37 historical and contemporary American and European museums deemed to have exemplified and shaped both the national mood of the time and the nature of the institutions that followed. Covers art, science, technology, natural history, and archaeological museums.

Marcel C. LaFollette, *Making Science Our Own: Public Images of Science, 1910–1955* (Chicago: Univ. Chicago Press, 1990). Survey of images of science in popular magazines throughout this century. Argues that science has consistently been presented in a better light than it should have been, leading to a conflict between science's image and the reality of science being unable to solve (and in some cases responsible for) social problems.

Dorothy Nelkin, *Selling Science: How the Press Covers Science and Technology* (New York: W. H. Freeman, 1987). Analysis of science journalism over the past 20 years. Argues that coverage of science is often manipulated by scientists and scientific institutions in order to serve their own needs.

Carol H. Weiss and Eleanor Singer, *Reporting of Social Science in the National Media* (New York: Russell Sage Foundation, 1988). General survey of social science coverage. Includes a thorough discussion of constraints that affect social science coverage.

Lee Wilkins and Philip Patterson, eds., *Risky Business: Communicating Issues of Science, Risk, and Public Policy* (New York: Greenwood Press, 1991). Series of papers on the links between public perceptions, public knowledge, and policy issues relating to science. Contains an extensive bibliography.

Journals

In addition to the foregoing books, many academic journals carry articles relevant to the themes addressed in this book. Among the more important are:

Communication Research
Journal of Communication
Journal of Environmental Education
Journal of Technical Writing and Communication
Journalism Quarterly
Knowledge: Creation, Diffusion, Utilization
Public Opinion Quarterly
Public Understanding of Science (new in 1992)
Science, Technology and Human Values
Social Studies of Science
Written Communication