SCIENCE, TECHNOLOGY, AND DEMOCRACY

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Is the "Citizen-Scientist" an Oxymoron?

STEPHEN H. SCHNEIDER

Is There a "Citizen-Scientist"?

Complex systems, like the earth's climate-ecosystem, will be characterized by a high degree of uncertainty and technical complexity for the foreseeable future. Climate is a good case study of the citizen-scientist question, and I will develop it here to make the arguments specific. Indeed, most everything that is interesting and controversial, like the behavior of complex systems that involve physical, biological, and social interactions, will never enjoy full understanding or full predictive capacity. Therefore these will always contain a high degree of subjectivity. Even for those systems that are objective, like a coin, people wanting to participate in policy making will have to learn to become comfortable dealing with probabilities. You cannot predict skillfully the sequence of faces of a multiply-flipped coin, but you can predict the odds of any sequence of faces—this is known as the "frequentist probability." The probabilities of each outcome are objective and you know what they are (at least for an unloaded coin). But estimating probabilities for interesting complex systems like climate and ecosystems or socioeconomic systems will involve a high degree of subjectivity—mixed in with elements of objectivity—this is often known as Bayesian or subjective probability. And even for the aspects of the climate problem for which we have lots of data and theory to make objective determinations, the way the data is applied often depends on assumptions which, in turn, are subjective.

Developing policy in an uncertain environment is a formidable task; a challenge made even more difficult by subjective assessments. What is the citizen, whether policy maker, journalist, or any nonspecialist in the lay public, to do in the face of this often bewildering complexity? To make effective policy, citizens need to ask scientists three fundamental questions. The first important question that a layperson can ask a scientist is What can happen?

The citizen tries to get experts—whether cancer specialists, military operations officers, environmental scientists, or economists—to agree on the range of possible outcomes. Honest experts will admit that surprises are possible—both happy and unhappy surprises—and that we have to anticipate those, too (but let's just leave our discussion here to the smaller universe of known outcomes). A typical outcome in the climate change debate could be three degrees warming if carbon dioxide in the atmosphere doubled.

But "what can happen" has little policy meaning by itself. What's more important is the *likelihood* of the event, so the second question is What are the odds? Consider three examples: (1) the probability of an asteroid hitting the earth, (2) the probability of correct identification using DNA fingerprinting, and (3) the probability of being killed for inner-city youth. The probability that the Earth will be hit by an asteroid that could wipe out 50 percent of the existing species and 99 percent of living things (other than bacteria), is exceedingly low, something like 1 in 10 million per year. This is comparable to the probability of being killed in a jet airplane crash. These odds are sufficiently low enough not to influence our actions very much. However, that is still a large number relative to some DNA fingerprinting introduced into evidence where 1 in 1 billion odds are claimed to represent a "reasonable doubt." In other words, citizens (jurors in this instance) have to learn to interpret what probability numbers mean. On the other hand, young men in the inner cities often face a probability of 1 in 100 of being killed. Yet too little is done, from a policy perspective, to address this situation. The point of these examples is to demonstrate that probability assessment is only one piece of information. The citizen must assign a value to these probabilities in order for the assessment to have meaning. The central, and critical, role of the citizen is to interpret these probabilities and determine an appropriate policy response. So, the citizen interested in science or thrust into a debate with scientific aspects has to learn to become comfortable with both objective and subjective probability conditions.

The final question is How do you know? When asking this question, the citizen is questioning the assumptions underlying debate. She is seeking an assessment of the key issues in the debate and an indication of the level of uncertainty surrounding any particular outcome.

The citizen-scientist is an important link between science and policy. The citizen-scientist is in a critical position to understand and use information from the scientific community to inform policy.

"Science" is not the Same as "Science for Policy"

In general, scientists strive in their scientific investigation to produce a large set of replicable experiments before probabilities (frequentist, in this case) can be attached to certain outcomes. Scientists are most comfortable when there is an empirical basis for those theories embodied in models used to project future outcomes like climate changes, population size, adaptive capacity, or endogenous growth of technology in response to climate policy. It is certainly true that "science" itself strives for objective empirical information to test theory and models. However, such objective or frequentist probabilities are not always available for policy makers to decide whether or how to respond to the implications of the state-of-the-art science (cf. Moss & Schneider, 1997).

An "objective" characterization of probability is the goal of most scientists, but often data is incomplete or other causes of uncertainty exist. Structural uncertainties, unobtainable data, or other impediments prevent the preferred situation in which all probability distributions can be "objective." Furthermore, even where there is a well-developed theoretical basis for believing certain outlier events of high consequence could occur (and perhaps even some empirical support for such a possibility), such outlier events often provide little basis for any objective assessment of probabilities. This causes many scientists to reject the notion of characterizing *any* likelihood estimates for such possible outcomes for which individual, corporate, local, and national decision makers have often chosen hedging strategies (e.g., purchase of personal insurance policies, corporate strategic investments, national vaccination programs or international security actions).

"Science for policy" must be recognized as a different enterprise than "science" itself, since science for policy involves being responsive to policy makers' needs for the best estimates of a wide range of plausible outcomes, even if those estimates involve a high degree of subjectivity. Most decision makers prefer to be informed about the wide range of possible events, and the levels of confidence the scientific community can assign to each event—as well as some estimates of how long it might take researchers to reduce those large uncertainties relative to how long it might take for such outcomes to actually unfold. For this reason, it is important to respond to the needs of policy makers and provide consistent and carefully labeled assessments of the wide range of outcomes.

Of course, uncertainty is not unique to the domain of climate change research. Even researchers in areas of science confined to the laboratory must confront uncertainties that arise from such factors as linguistic imprecision, statistical variation, measurement error, variability, approximation, subjective judgment, and disagreement. However, in climate research, as in other areas such as seismic hazard prediction, ozone depletion, and hazardous wastes, these problems are compounded by factors including their global scale, long lag times between cause and effect, low frequency variability with characteristic times greater than instrumental records and the impossibility of comprehensive experimental controls. Moreover, because climate change and other policy issues are not just scientific topics but also matters of public debate, it is important to recognize that even good data and thoughtful analysis may be insufficient to dispel some aspects of uncertainty associated with the different standards of evidence and degrees of risk aversion/acceptance that individuals participating in this debate may hold. Therefore, a "subjective" characterization of the probability will be the most appropriate. In this view, the probability of an event is the degree of belief that exists among leading experts that the event will occur given the information currently available.

Subjective Assessment: The "Climate Sensitivity" Example

Some experts do not like subjective assessment because they might be proved wrong. Consider the following scenario. Imagine a doctor who suspects that her patient may be suffering from a serious disease. She informs the patient of her subjective, preliminary opinion and suggests that diagnostic tests be performed to confirm or reject her opinion. These tests indicate a different diagnosis. It is well accepted that it would be dishonest and unethical for the physician to not inform the patient that the tests point to a new diagnosis. Yet, our political system seems to afford more credibility to people who predict the right answer (regardless of whether for correct reasoning) rather than those who got the answer wrong because of factors then unknown. How unknown factors turn out is luck, not skill. The "answer" is not really as important to a scientist as whether or not he or she gave the best judgment given what could have possibly been known at the time. Science does not assign credibility to people who got it "right for the wrong reasons"—the process is more important than the product. Science wants to know why we reach certain tentative conclusions. So should citizen-scientists.

Then, what is the reaction of a citizen (whether juror, judge, reporter, senator, or voter) when Scientist A says the probability of some catastrophic outcome is 25% and Scientist B says it is 2.5%. Citizens, even if statistically literate, can easily get confused, especially when each scientist uses long and complex technical arguments to back up their dissimilar intuitive, subjective judgments. This is typical of "dueling scientists." The resolution: *science-as-a-community* becomes important. Rarely can a few debaters be allowed to represent the credibility of a spectrum of views that characterizes the state-of-the-art knowledge base. A community of experts is needed to better accomplish that mission. Here is also where it gets tougher and tougher for the citizen to know how to participate. It is very difficult for an average citizen to listen to a technical debate among a few debating scientists, and really know whose subjective opinions about the likelihood of the various assumptions that

Table 1. Experts interviewed in the study

John Anderson, Harvard University	Michael MacCracken, U.S. Global Change Research Program
Robert Cess, State University of New York at Stony Brook	Ronald Prinn, Massachusetts Institute of Technology
Robert Dickson, University of Arizona	Stephen Schneider, Stanford University
Lawrence Gates, Lawrence Livermore National Laboratories	Peter Stone, Massachusetts Institute of Technology
William Holland, National Center for Atmospheric Research	Starley Thompson, National Center for Atmospheric Research
Thomas Karl, National Climatic Data Center	Warren Washington, National Center for Atmospheric Research
Richard Lindzen, Massachusetts Institute of Technology	Tom Wigley, University Center for Atmospheric Research/National Center for Atmospheric Research
Sykuro Manabe, Geophysical Fluid Dynamics Laboratory	Carl Wunsch, Massachusetts Institute of Technology

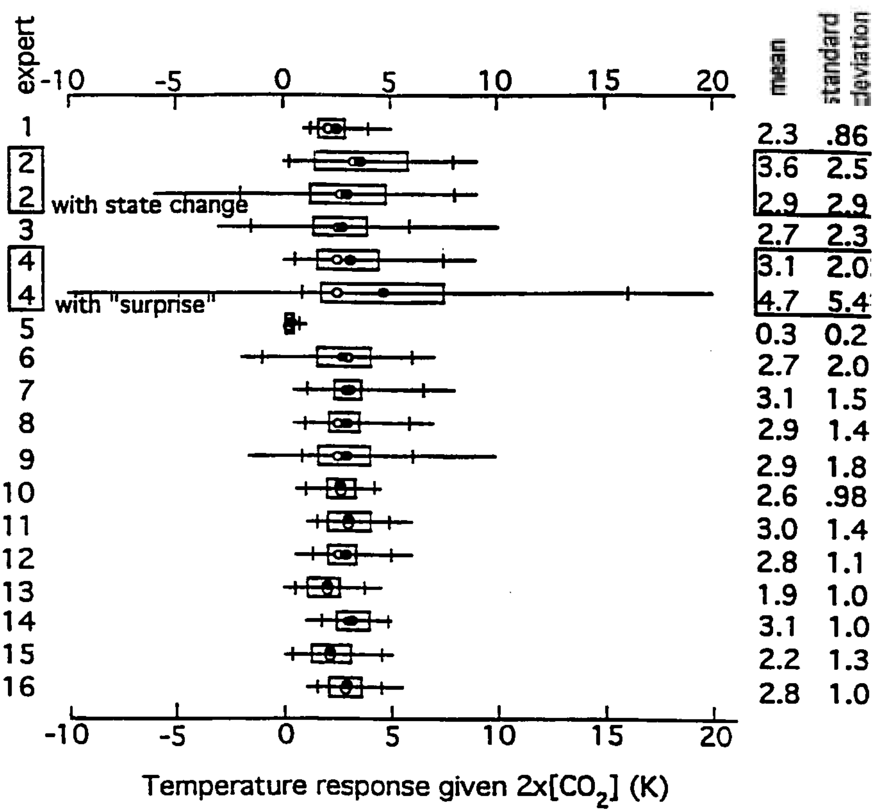
Expert numbers used in reporting results are randomized. They do not correspond with either alphabetical order or the order in which the interviews were conducted.

underlie disparate conclusions are more in the center of the knowledge spectrum than others. And even when there is a community assessment some will still claim that the process has neglected their contrarian evidence.

What does define a scientific consensus over the probabilities of possible events? Morgan and Keith (1995) and Nordhaus (1994) are two attempts by nonclimate scientists, who are interested in the policy implications of climate science, to tap the knowledgeable opinions of what they believe to be representative groups of scientists from physical, biological, and social sciences on two separate questions: first the climate science itself and second, impact assessment and policy. The first sample survey shows that although there is a wide divergence of opinion, nearly all scientists assign some probability of negligible outcomes and some probability of very highly serious outcomes, with one or two exceptions (e.g., scientist number 5 on Fig. 1 taken from Morgan and Keith (1995).

In the Morgan and Keith study, each of the 16 scientists listed in Table 1 was put through a several hour, formal decision-analytic elicitation of their subjective probability estimates for a number of factors. Figure 1 shows the elicitation results for the important climate sensitivity factor. Note that 15 out of 16 scientists surveyed (I am scientist 9) assigned something like a 10 percent subjective likelihood of small (less than 1°C) climatic change from doubling of CO_2. These scientists also typically assigned a 10 percent probability for

Figure 1. Box plots of elicited probability distributions of climate sensitivity, the change in globally averaged surface temperature for a doubling of CO_2 (2x[CO_2] forcing). Horizontal line denotes range from minimum (1%) to maximum (99%) assessed possible values. Vertical tick marks indicate locations of lower (5) and upper (95) percentiles. Box indicates interval spanned by 50% confidence interval. Solid dot is the mean and open dot is the median. The two columns of numbers on right-hand side of the figure report values of mean and standard deviation of the distributions. From Morgan and Keith (1995).



extremely large climatic changes—greater than 5°C, roughly equivalent to the temperature difference experienced between a glacial and interglacial age, but occurring some hundred times more rapidly. In addition to the lower probabilities assigned to the mild and catastrophic outcomes, the bulk of the scientists interviewed (with the one exception) assigned the bulk of their subjective cumulative probability distributions in the center of the often cited range for climate sensitivity by mainstream assessment groups (e.g., IPCC, 1996). What is most striking about the exception, scientist 5, is the lack of variance in his estimates—suggesting a very high confidence level in this scientist's mind that he understands how all the complex interactions within the earth-system described above will work. None of the other scientists displayed that confidence, nor did the lead authors of Intergovernmental Panel on Climatic Change (IPCC, 1996). However, several scientists interviewed by Morgan and Keith expressed concern for "surprise" scenarios—for example, scientists 2 and 4 explicitly display this possibility on Figure 1, whereas several other scientists implicitly allow for both positive and negative surprises since they assigned a considerable amount of their cumulative subjective probabilities for climate sensitivity outside of the standard (i.e., IPCC, 1996) 1.5 to 4.5°C range for surface warming if CO_2 were to double. This concern for surprises is consistent with the concluding paragraph of the IPCC Working Group I, Summary for Policymakers.

IPCC lead authors, who wrote the Working Group I Second Assessment Report, were fully aware of both the wide range of possible outcomes and the broad distributions of attendant subjective probabilities. After a number of sentences highlighting such uncertainties, the report concluded: "Nevertheless, the balance of evidence suggests that there is a discernible human influence on the climate." The reasons for this now-famous subjective judgment were many. These include a well-validated theoretical case for the greenhouse effect, validation tests of both model parameterizations and performance against present and paleoclimatic data, and the growing "fingerprint" evidence that connects observations of horizontal and vertical patterns of climate change to the patterns predicted to occur in coupled atmosphere-ocean models. Clearly, more research is needed, but enough is already known to warrant assessments of the possible impacts of such projected climatic changes and the relative merits of alternative actions to mitigate emissions, make adaptations less costly, or both. That is the ongoing task of integrated assessment analysts (e.g., Schneider, 1997b), a task that will become increasingly critical in the next century. To accomplish this task, it is important to recognize what is well established in climate theory and modeling and to separate this from aspects that are more speculative. That is precisely what IPCC (1996) has attempted to accomplish. What if we are left with dueling experts without the benefit of a fair representation of the spectrum of beliefs? For example, in the climate change debate, what if there were no IPCC report? The job of the citizen-scientist is facilitated when institutions like IPCC exist that promote "science as community." In the absence of such community assessment, the job of the citizen-scientist becomes more difficult.

Copernican Revolutions are Rare

Past episodes of basic changes in scientific thinking—*paradigm shifts*—are frequently invoked by contrarian scientists and supporting politicians to argue that the consensus view might turn out to be false. Indeed, many famous examples in the history of science demonstrate that new discoveries, or new theories reinterpreting well-known evidence, can displace apparently well-established knowledge. The two most cited examples are the overthrow of geocentrism or how Einsteinian relativity displaced Newtonian mechanics. Despite the fact that most basic theories (e.g., laws on conservation of mass, momentum, and energy) have stabilized in the latter half of this century, such paradigm shifts can still be expected to continue. History provides no reason to suppose that many more seemingly radical theories will not occur, even if we are forced to endure more "end of" popular books sporting polemical titles like the *End of History* or *The End of Science*.

At the same time, within the history of any given discipline the number of real paradigm shifts—truly fundamental changes in concepts, methods, and conclusions, sometimes called "scientific revolutions"—has generally been quite small. Thomas Kuhn (1962), originator of the concept, observed that "normal science," which consists of extending and analyzing the dominant paradigm's observations, experiments, and models, makes up the vast bulk of scientific activity. Just as in advertising, the all-too-frequent claims of "revolutionary" change are usually no more than rhetoric. Rarely are "Bargain Antiques" much cheaper or "Painless Dentistry" less uncomfortable than the mainstream competitors. Furthermore, the vast majority of paradigm challenges either fail or are really minor adjustments to normal science. (One recent case in point is the ill-fated claims of "cold fusion.")

It is true, however, that brilliant, revolutionary ideas have sometimes been ignored merely because they did not fit existing modes of thought, and it is virtually certain that this is happening now, somewhere, and will happen again in the future. Yet it is also true that most paradigm-challenging ideas fail because they are—to put it bluntly—simply wrong. Just as with battles, history tends to lionize successful scientific revolutionaries while fast forgetting the far larger number of failures.

Let me rephrase this in two points. First, being in the center of the current knowledge spectrum does not mean that you are right. Remember, Ptolemaic supporters with long beards and flowing robes, holding high positions in church and state, held sway for many centuries with the wrong theory and dissenters faced great personal peril—as the Galileo story exemplifies. However, most problems are not Copernican geocentrism. For most problems, the scientific mainstream is not a paradigm away from truth. And even though a few problems will turn out to be Copernican, for every real

Copernicus there are probably a thousand hopeful contenders. Only rarely does someone with great convictions and correct insights stand up to the scientific establishment and overthrow the dominant paradigm. This does not mean that alternative views or paradigms should be ignored, but should be treated with the same skepticism afforded all work (Schneider, Turner, & Morehouse-Garriga, 1998).

But how can the citizen figure out where the mainstream is and whose subjective probabilities to trust? The "citizen-scientist" becomes an oxymoron when facing this dilemma unless he or she is willing to put in a lot of effort: going to the library, reading National Research Council studies, Intergovernmental Panel on Climate Change assessments, and so on—in essence, trying to understand whether the subjective opinions of dueling experts represent marginal or mainstream views. And figuring out whether the marginal views are truly breakthrough (or in fact anything other than ideological blindness or special interest disinformation) is a tough nut to crack. I was once accused in debate of advocating "science by consensus rather than by experiment." After all, no Galileos would have emerged if only the consensus opinions were trusted, I was reminded. "But for decades I have believed in science by experiment" (e.g., Schneider & Mesirow 1976, p.10), I replied. All things in science are forever questioned and questionable. However, without inconsistency, I continued, "I also believe in science policy by consensus." Society is prudent to go with the best guesses of the majority, always keeping in mind the following three questions—and always challenging the dominant paradigm—while acting as if it were still likely to be true. This broader role for science in the context of social issues has been separated from the "normal science" of Kuhn and relabeled "postnormal" science by sociologists of scientific knowledge (cf. Funtowicz & Ravetz, 1992; Funtowicz & Ravitz, 1985; Jasanoff & Wynne, 1998).

The Three Questions for the Environmentally Literate

To recap, question 1 is What could happen? and question 2 is What are the odds? Question 3, then, is How do you know? In the process of a citizen asking an expert How do you know, one is asking to get deeply involved in the details of the debate. For example, I would be skeptical if a scientist presented me with a "certain truth" which ignored or dismissed underlying assumptions and their uncertainties. Cock-suredness about complex issues undermines credibility and is a telltale sign that it is time for a second opinion. But even that determination can be difficult for the citizen who is not very familiar with typical scientific debates. Sophisticated ability to discern who is more credible requires a citizen that is more than casually interested, but who is passionately involved. It requires one who watches Nova, or religiously reads *Scientific American* or the Tuesday Science section of the *New York Times* or researches issues in the library to ferret out credible views from marginal claims. Rarely is this distinction discernible in the popular media or by engaging a typical search engine on the internet with a few key words.

True scientist-citizens include good science journalists or the few senators and ministers who attend the bulk of their own hearings when scientists appear in detailed debates. I think U.S. Vice-president Gore is in that category, as is the former U.S. Senator from Colorado, Tim Wirth, or former prime minister of Great Britain, Margaret Thatcher. Such people have learned enough of the process of science over the years to become like a good science reporter: they have a nose for phonies or for people who are passionate without balance, and I do not mean "balance" in the traditional journalistic sense of pitting one extreme versus the mainstream (or sometimes versus the opposite extreme) without labeling where each claimant sits in the spectrum of knowledgeable opinions. Such inappropriate balance usually leaves nearly everybody not deeply familiar with the debate and the debaters confused.

A true citizen-scientist meets some pretty tough criteria that would exclude all but a small, dedicated minority. The group of people who can competently answer the three fundamental questions is limited. Ideally, a larger, broader group of people would have access to answers to the three questions.

Meta-Institution Building: A Science Assessment "Court"?

Being able to judge a scientist's credibility is a tall order for most members of Parliaments or Congress—or even their technical staffers. So what I think we need, at the risk of sounding somewhat elitist, is a "meta-institution." We need an institution in between laypeople and the expert community to help the citizen sort out conflicting claims. I am not implying that such a meta-institution is there to help citizens decide, for example, whether or not nuclear power is safe or whether we should have a carbon tax. Those are personal value judgments based on each person's political philosophy as to whether the risks and costs of one energy system justify turning to another, or whether investing current resources is worth the expenditure to reduce risks of performing the climate change experiment on "Laboratory Earth" (Schneider, 1997a). I believe that these are value judgments every citizen is already equipped to make—if only he or she knew what can happen and what the odds are.

To repeat, citizens need expert help with the "what can happen" and "what the odds are" parts of policy making. That is, laypeople need guidance in figuring out where the mainstream expertise lies and how confident it is of important outcomes—and that is where we may need some new institutions.

We actually have had institutions with the goal of performing such assessments of complex issues. One such was recently killed by the U.S. Congress: the Office of Technology Assessment. It was a nonpartisan congressional assessment office whose job it was to provide reports that could cut through the claims and counterclaims of the special interests, faxed by the thousands to the halls of power and the media—what I label the "one fax one vote syndrome." Too often, lobbying groups in the name of free speech buy bigger and bigger megaphones for nonmainstream experts whose "science" ostensibly supports their positions. If they get heard enough, these amplified experts might get equal status at the bargaining table with those espousing consensus views—that is, repeated exposure often buys equal credibility for what really is not a very credible scientific position by simply overwhelming the communications apparatus and scientific literacy of most citizens with complex technical counterexamples.

Often, such disinformation specialists are counting on citizens not being able to sort out the credibility of conflicting technical claims for themselves. This is common; every citizen is used to it. Nevertheless, it is very baffling. Staffers at the Office of Technology Assessment were not fooled by this strategy, nor have been National Research Council committees or Intergovernmental Panel of Climate Change experts. What these assessment groups do is evaluate the credibility of various conflicting claims. They do not decide policy. Policy determination involves personal value judgment about the response to a set of possible consequences, including assessment of priorities, risk, and costs. The expert assessment teams decide *whether the claims made about those probabilities are credible* or at least what the subjective probability estimates might look like—as the Nordhaus (1994) experts did. This task cannot be done easily by lay citizens—including journalists and decision makers.

That is where I separate out the role of the citizens from the experts. Typically, the experts assess the odds, but citizens make the choices about how to take risks of various kinds. If we set up a meta-institution, something in between the citizen and the scientist, it is absolutely essential that it have one characteristic—openness and transparency to all citizen groups, including special interests. For credibility, the assessors cannot meet behind closed doors where they would be in greater danger of scientific elitism or personal value biases creeping into their ostensibly balanced scientific judgments. Unfortunately, there are scientists who believe that it is inappropriate for scientists even to discuss in public issues in which there is a high degree of uncertainty. I think that is the truly elitist position, because what it says is that we scientists should be the judges of *when* we tell the public what is possible and at what odds. I think that openness is essential: reporters need to be there, special interests need to be there, ordinary citizens need to be there as *witnesses to the assessment process itself* (Edwards and Schneider 2000). Citizens' roles are not to determine what the probabilities of various claims are because that's not their competency, but to make sure that the assessment process is open and to ask the right questions.

A "FED for Science"?

The most difficult aspect is how we choose who sits on this "science assessment court." This is not a court that assesses guilt and innocence or makes policy recommendations, but a court (see also Kantrowitz, 1967) in a sense that it can evaluate the probability of claims. I propose the assessment team's members should primarily be chosen from the lists of the scientific societies (National Academy of Science, American Physical Society, Ecological Economics, etc.), perhaps with a few spots reserved for political appointees. The tenure of such appointees should survive the electoral terms of presidents and senators: perhaps a ten-year term. In a sense, I am proposing an institution like the Federal Reserve Board. However, my "FED for Science," would be *only* an information agency, unlike the FED, which actually makes economic policy. Its job is to label the exaggerators, the distorters, and the passionate who just cannot (or will not) see past their own denial of special interest. Perhaps the best metaphor is Consumers Union, a private watchdog and ratings service for products and services that independently assesses claims by producers or providers against objective and subjective tests.

As I suggested, citizens and interest groups should definitely be principal agenda setters and witnesses to the new institution, but not the assessors. This is my concrete proposal for getting the public more involved in debating technical issues. If the public is largely confused by a baffling technical brouhaha, then instead of participating in the value-laden, policy choice process, they are more likely to abdicate everything to the experts. That withdrawal of citizens from the decision-making process leaves the field wide open to the special interests to compete over who can shout louder, take out bigger ads, whose fax machines have a higher baud rate, or who can best finance which congressional representative's campaign—all in order to put the "spin" on scientific knowledge most favorable to their own interests. I would like to move the process of evaluating scientific credibility away from the political arena and into a meta-institution that has no responsibility for policy choice, has no decision-making authority, but can call anyone's statement, including one from the President or the Speaker of the House, "scientific nonsense."

It is an act of courage for an expert employed in the Executive branch to come out and say, "I'm sorry, the facts of my President are wrong." Such acts of courage are, almost by definition, discouraged by the hierarchical nature of the political chain of command; that is why we need an independent information agency. Information cannot be under the exclusive control of people with vested interests in the answer. All interests should be witnesses to the process, they should be able to ask questions of the assessors, should be able to have their favorite "new Copernicus" able to testify to the assessors, but they should not be able to vote on the credibility of the conclusions.

As I stated earlier, we already do have institutions that do scientific assessments. One problem for the National Research Council (NRC) is that it is under political attack from people who claim it is "elitist" because there are no citizens in the process—other than to fund their studies. A second problem is the NRC only operates when somebody gives them enough money to do an in depth examination of very specific questions. Moreover, the sessions are typically closed, with agendas set by the study members and the funding agency. The meta-institution I envision here is a new body that can take a letter from an ordinary citizen baffled by some conflicting Op-Ed essays, from a congressperson skeptical of a scientific witness, from an environmental group or an industrial lobby and provide a considered (say 6 weeks) reaction, not a two-year focused study. This "science assessment court" would partly rely on existing NRC studies for input, but not try to duplicate them. The assessors would basically be in the position of evaluating quickly the credibility of a whole series of claims and counterclaims about the validity of some scientific proposition or the probability that some outcome will occur. Moreover, they could commission an NRC study, or at least they could ask Congress to do that.

I do not envision a massive new bureaucracy, although some permanent staff are obviously needed. The design might stress a network of experts not all sitting in a formal edifice, but who are willing on short notice, to spend several days each week for a month to write a report on the credibility of specific issues, and their meetings would be available to be witnessed either in person or perhaps by closed circuit TV. I do not claim to know what the right institutional architecture is, nor the degree to which it should be internationalized to deal with global environment-development sustainability issues. I propose the concept of a meta-institution primarily because the current cacophony of claim and counterclaim contributes to the disenfranchisement of citizens from the scientific process. If my specific proposal is considered unworkable by some, then they should please propose a better one—the status quo simply is not working well.

In my first book, *The Genesis Strategy* (Schneider & Mesirow, 1976), I proposed a "Truth and Consequences Branch," a fourth branch of U.S. government, where people would be appointed for 20 years in staggered terms. Then, I envisioned a much higher visibility bureaucracy, whose job was to expose the phony scientific claims of the government. Now, I am more concerned about policy that is too often proposed on the basis of junk science (e.g., Ehrlich & Ehrlich, 1996).

Undoubtedly, some will attack this idea on the grounds that a new institution is an unnecessary federal expenditure to create yet another agency which will engage in inappropriate interference with the constitutional privileges of citizens to advertise their perceived brand of "truth" as loudly and effectively as they can. After all, such defenders of infomercials will claim, "both sides" are free to promote their elliptical views. I do not propose banning their faxes or their advertisements. However, this does not obviate the need for a balanced partisan-free presentation of the issues surrounding the debate. I do not think there is anything wrong with using public financing to evaluate the credibility of the scientific components of their various claims and counterclaims.

Advocacy Yes, Selective Inattention to Facts, No

I personally dislike the way the courtrooms often use expert witnesses. It is a very bad way to get toward the truth when each side picks elliptical experts who do not believe it is their job to make their opponent's case. Moreover, I think that is a scientifically unethical epistemology. I believe it is the job of an honest scientist to examine *all* plausible cases, and then to provide a subjective probability for each conceivable outcome that honestly reflects the range of information each expert believes to be most credible. Now, an expert could have a personal opinion on what to do with this probability assessment, which raises the question: "Is the scientist-advocate an oxymoron?" I believe this dual role is not an oxymoron, but requires great care. The scientist-advocate must work hard to separate out the factual from the value components of a debate. But an unconscious prejudice can be worse than a conscious one because if your prejudice is unconscious you cannot even fight to fix it. At least conscious prejudice creates the opportunity to change. With unconscious prejudice or ideological zeal, advocates can be captured by their perceived brand of "truth."

To me, the best safeguard for public participation in science-based policy issues is not to leave subjective probability assessment to a few charismatic individuals, but to the larger scientific community. Some will say it is impossible for an expert to be in a public debate with policy overtones and retain his or her objectivity in the science. I think that is not necessarily true. Just because some people cheat does not mean all do. No one is exempt from prejudices and values. The people who know it and make their biases explicit are more likely to separate them from their sober judgments about probabilities than those professing to be value neutral. If you *knowingly* distort what you believe to be the likelihood of certain outcomes for ends-justify-the-means reasoning, you are no scientist, you are just dishonest.

However, in the real world no one—expert or layperson—gets all the time needed to explain every nuance of complex issues. We are forced to be selective or be ignored. I have called this the "double ethical bind" (e.g., Schneider, 1989). To deal with the dilemma of trying to be heard but not to exaggerate, I focus on aspects of a debate which convey both the urgency and the uncertainty, typically by using metaphors. For example, in the climate change debate, I could use a metaphor of a low probability of getting cancer. But I think that metaphor exaggerates the risk. If the worst happens with cancer, you die, and I do not see global warming as killing all of us or Nature. Rather, I see it as a potentially serious stress that threatens selectively. A much better metaphor therefore, would be a parasite, or a debilitating condition. But this metaphor may seem inappropriate to some because it is not an exact match to climate change risks. So we are always stuck on this treacherous ethical ground between finding metaphors that simplify the complexity of the problem, yet accurately convey the risks and uncertainties of the case. If scientists do not find the metaphors to communicate, most citizens simply will not hear them. Instead, they will hear the infomercials, ads, and press releases faxed to journalists everywhere by those who do not think it is their job to make their opponent's case.

When an expert communicates with metaphors and is willing to play in the sound-bite world, even though, like me, you might be uncomfortable, there is one more step you can take to be as responsible as possible. Public scientists or scientific bodies that make public statements should also produce a hierarchy of backup products ranging from Op-Ed pieces (which are often a string of written sound bites), to *Scientific American*–length popular articles that provide more moderate depth, to full-length books coming out every five years or so. Such books should document in great detail the aspects of an issue that are well understood and separate these from those that are more speculative. Books also should provide a detailed account of how one's views have changed over time as the scientific evidence has changed. And even if only a decreasingly small segment of the public really wants to know what you think in detail about the whole range of questions, at least you retain an ethical stance because you have made available to anyone interested via articles and books in the popular and scientific literatures the closest one can come to full disclosure of what's known and uncertain—which is required of honest science. But full disclosure is simply not possible in time-constrained congressional or media debates—metaphors have to do the job, and the hierarchy of backups are crucial for full disclosure.

Rolling Reassessment

What happens when the current state of science has missed something really big that is potentially dangerous; or something we currently fear proves unfounded. That is why another element to this process must always be added: what I call "rolling reassessment" (Schneider, 1997a). It takes immediate actions to reverse long-term risks, but such actions are not without costs. Therefore, we should initiate flexible management schemes to deal with large-scale, potentially irreversible damages, and allow ourselves to revisit the issue every, say, five years. Credibility is not static—there are new outcomes to be discovered or other ones we can eventually rule out. With such new knowledge, whose credibility could be partially reassessed by the meta-institutions I proposed earlier, the political processes could decide we did not move fast enough in the first place (or maybe we moved too fast) and consequently make adjustments. The trouble is that once we have set up certain kinds of fixed political establishments to carry out policy, people can become vested and reluctant to make adjustments, either to the policies or the institutions.

Environmental Literacy

The long-term solutions to making competent citizen-scientists involves more than a meta-institution to evaluate the credibility of conflicting claims. We need competent consumers of the assessments generated by the scientific assessment meta-institutes. It involves education. It involves environmental and scientific literacy.

We rarely teach science literacy in school, even when we think we do via "science distribution requirements." Literacy is not just knowing the *content* of some scientific disciplines, as important as that is. It is not practical to teach detailed scientific content of a dozen relevant disciplines to all citizens—and it is not even necessary. What citizens need to know is the difference between a factual and a value statement; the difference between objective and subjective probabilities; the difference between a paradigm and a validated theory; the difference between a law and a system; the difference between a phenomenological model and a regression model (by that I mean the difference between associations of two data sets and a validated theory). Many people think that a correlation between two variables indicates causation or predictive power. A correlation is not a law. Just because the association predicted correctly a few times, does not mean it will always do so. Credible predictions come from having modeled the causal process correctly, not just from extrapolation of a few correlations. When the future conditions are different than the conditions in which some correlation was first observed, a process model will likely out perform a strict empirical model. Finally, environmental literacy means knowing the social process of knowledge transfer (i.e., media) and the political process through which decisions are made (cf. Schneider, 1997c), including an ability to sort out which claims and counterclaims by the one-fax-one-vote folks are more credible—that is where the meta-institutions like a "FED-for-science" come in.

Citizens need to have a high level of environmental and scientific literacy, but we rarely teach it in formal education. I would like to see elementary schools teaching these concepts, teaching by examples and via dialogues with students, how to separate facts and values, the difference between objective and subjective probability, efficiency versus equity considerations and conservation of nature versus economic development trade-offs. It could be done. I think what environmental literacy can do is empower citizens to begin to pick a scientific signal out of the political noise that all too often paralyzes the policy process.

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