Public Participation in Sustainability Science.

A Handbook

Edited by

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CHAPTER THREE

Models as metaphors

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CAMBRIDGE UNIVERSITY PRESS

Public participation in sustainability science.

This book discusses how citizens can participate more effectively in sustainability science and environmental policy debates. It discusses designs for participatory procedures, and experiences of their application to issues of global change. While the focus is on citizen participation, the involvement of specific stakeholders – including water managers and venture capitalists – is also addressed. The book describes how focus group methods were combined with the interactive use of computer models into new forms of participation, tested with six hundred citizens. The results are discussed in relation to important sustainability topics, including greenhouse gas and water management. By combining this with an examination of issues of interactive governance and developing country participation, the book provides state-of-the-art, practical insights for students, researchers and policy-makers alike.

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Introduction

This chapter discusses philosophical reflections on the intellectual adventure of conducting Integrated Assessment (IA) Focus Groups with citizens, as presented in this volume. The task of this exercise was ambitious: to bridge the gap between sustainability science and democratic debate in the climate domain. The science component was mainly represented by models, most (although not all) having the appearance of describing future states of the global climate and their consequences for human society. At first it could seem a daunting, indeed, overwhelming task: it was hard to see how lay participants could meaningfully relate to models whose construction required very special expertise in mathematics and software engineering; and whose comprehension required knowledge of climate science. But having witnessed the debates among the modelers themselves, the research team already knew that IA models are quite problematic products of science. It is freely accepted, even emphasized, among the experts that the models do not provide simple predictions; and so their epistemic status and policy relevance were already open to question. In addition, there was the knowledge that experts are usually "laypersons" outside their specialties, and that policy-makers are generally no more knowledgeable than ordinary citizens. And, in any event, the democratic process involves debate over issues where both expert and lay voices are heard. Hence the IA models were an appropriate vehicle for developing a many-sided dialogue on basic issues.

In the event, the involvement of this "extended peer community" proved far less difficult than anticipated. For, although the content of the IA models might be arcane, their conclusions were not. Indeed, as predictions of the future state of the planet, the outputs of the models lent themselves to discussion and criticism. This latter arose in two headings: the first, how much the general models could tell us that is relevant to our decisions; and the second, what sort of messages they are. In particular, once it was freely admitted that these are not ordinary predictions, categorical statements of what will and what will not be happening, then the lay participants found themselves engaged in an engrossing methodological debate. Given all the scientific talent and technological resources that had gone into the construction of the models, just what use are they if their outputs, whose form is that of categorical statements about the future, are just estimates or even guesses, shrouded in uncertainties?

The IA Focus Group procedures developed within our study could actually be an ideal forum in which such issues could be aired. It could well be that in the open setting of these focus groups, free of any of the commitments and prejudices that afflict any policy debate among vested institutional interests, such questions could be framed and expressed all the more clearly, and with greater force. We are not speaking of an "emperor's clothes" situation, since there has been a continuous and vigorous public debate within the specialist community about the meaning of IA models. But in the context of our research it was possible for plain people to speak plain words about their confusions and reservations about these scientific instruments. And so the learning experience became universal; they learned about the climate change problems in relation to urban lifestyles, and the experts learned about the different aspects of the usefulness of their tools in the general policy process. In these focus groups conducted with citizens, the IA models – which do not claim to make factual statements or reliable predictions – were seen as useful for enlarging the scope of people's imagination about climate change and the role of individuals in that problem. In that context models were discovered to be "poetic." Stimulated by this experience, this chapter explores the question of whether they could fruitfully be seen as "metaphors," expressing in an indirect form our presuppositions about the problem and its possible solutions.[1] Although this approach is very different from the traditional understanding of scientific knowledge, it may well be useful in helping science adapt to its new functions in an age of sustainability challenges and scientific uncertainty.

Models as scientific?

For nearly 400 years, our ideal of science has excluded metaphor; for science is supposed to be about exact reasoning, leading to certainty. In scientific discourse and inquiry the poetic faculty must be tightly constrained lest it lead us astray. The Royal Society of London expressed it

[1] This chapter is to some extent a sequel to earlier reflections on the problems of the proper use of IA models (Ravetz 1997a; 1999). I hope that it will contribute to the sense of a largely successful adventure, or voyage, that our study has been for all its participants.

simply (if somewhat obscurely) in its original motto of 1661: "nullius in verba." The facts and the power resulting from natural science now serve as the paradigm for all forms of practical knowledge. The "subjective" studies, or "gossip" in the words of one distinguished physicist (Ravetz 1971), are deemed inferior, existing only because of the present limits of scientific knowledge and the weaknesses of human intelligence.

It is possible that the triumphs of European science over the past four centuries have been due largely to this attitude, of excluding or downgrading the qualitative aspects of experience. Certainly, some confluence of external and internal factors made possible the unique rise of our science, to achieve a degree of knowledge and power that could scarcely have been dreamed of in previous civilizations. But now, at the start of the twenty-first century, we realize that the problems of "the environment" are becoming challenges to the "sustainability", or survival, of our civilization; and that our "urban lifestyles," made possible by our enveloping science-based technology, are largely responsible for this perilous situation. Our simplistic, myopic technology threatens to destroy our own habitat, and our reductionist science, by definition incapable of grasping systems thinking, is inadequate for managing the tasks of cleanup and survival. The quantitative social sciences that are designed around the imitation of Victorian physics become ever more clearly seen as caricatures. Instead of being genuinely scientific in the way that their practitioners so ardently desire, such disciplines are merely "scientistic," misconceived parodies of real knowledge. The modern program of scientists "teaching truth to power," deducing correct policies from incontrovertible facts, is, in the environmental field, in tatters. We now have an inversion of the classic distinction between the hard objective facts produced by science and the soft subjective values that influence policy. Now we have decisions to make that are hard in every sense, for which the scientific inputs are irremediably soft. The goal of the whole enterprise, "sustainability," is now recognized as something other than a simple, scientifically specifiable state. Rather, as pointed out by Kasemir *et al.* in Chapter 1, sustainability (especially when the social and moral elements are included) is something of an "essentially contested" concept in the sense of Gallie. In these circumstances the denial of rhetoric, as part of the traditional reduction of reality to quantitative attributes, can now be seen as a profound metaphysical prejudice, one of the patently counterproductive elements of our intellectual heritage.

All these problems are exposed most sharply in the use and interpretation of environmental models, particularly IA models that are cast in the form of describing future states of the global climate and their consequences for society. These "models" are themselves of an unusual sort.

They are not miniature globes with water and clouds swishing around; and in fact they cannot even be seen. Rather, they are sets of mathematical relationships, embodied in computer programs, which (it is intended and hoped) simulate some of the interactions in the bio-geosphere. To understand how any model works is indeed a task for experts; but to ask what it tells us, indeed why it has been constructed, is open to any interested citizen.

The outputs of the IA models are represented as assertions concerning quantitative indicators, expressed at some future time. But they are not simply "predictions" in the sense of the classical philosophy of science. In our traditional understanding, the statements of natural science are intended to be tested against experience, to determine the truth or falsity of the theory from which they are deduced. However, a computer model is not a "theory" in the sense of the achievements of Newton and Einstein. The models are not expected to be "true" or "false" in the classic scientific sense. Further, in the case of most IA models the outputs relate to times in the future which are too far away for any practicable "testing." And in any event, practitioners now agree that even if one were to wait for the requisite number of years or decades, the actual states of those indicators would most probably be quite different from those "predicted" back in our present. In the sense of the classical philosophy of science, all our models are trivially "false."

Those who develop and use these models must then become creative methodologists. The models are said to have a variety of heuristic functions. Prominent among these is clarifying our understanding of our assumptions. But it is not clear whether this relates to the assumptions made by society in general or by policy-makers about the environment, or merely to the assumptions made by the modelers about structure and inputs of their models. Models also might provide some indications of the way things will turn out in the real world; but then again they might not. All this endeavor with models is very important, as our assessment of the future is genuinely quite crucial in the setting of public policy. But IA models are clearly seen to be lacking in a methodological foundation in the successful practice of natural science. Therefore the justifications of this sort of modeling will not be able to succeed within the framework of the traditional conceptions of scientific knowledge and practice. They are based less on a successful practice of advancing knowledge, and increasingly on an embattled faith.

If these models are not fully "scientific," but to some significant extent merely "scientistic," how are they to be understood as objects of knowledge? Under the challenging conditions of our focus groups, fresh insights could be generated which would not be likely to emerge within the groves of academe. Thus, in one regional case study the discussions gave rise to the notion that climate change models are a form of "seduction" (Shackley and Darier 1998). The term is used in a non-sexual sense following the French philosopher Baudrillard, as "a game with its own rules," and refers rather more to the modelers than to the models themselves. Reviewing the variety and confusion among the explanations of the uncertainties, dependence on special assumptions, and value-loading of the models, they eventually arrive at the explanatory formula "truths/untruths." For the "IAMs [Integrated Assessment Models] are hybrids . . . : a mixture of conditionally valid uncertain and indeterminate knowledge – data, theory and insights – combined together in a fashion which generates further indeterminacy." Further, "several types of ignorance [are] involved, related to processes, phenomena and data."

The authors argue that the advocates of the models alternately use strong and weak claims for them, in order first to recruit possible supporters, and then to keep them on board when the inadequacy of the models becomes apparent. This is what is understood as "seduction"; but it should be observed that the process may well be directed even more to the modelers themselves, to maintain their own sense of worth in the face of disillusioning experience. Such an explanation was offered by Brian Wynne in his classic study of the IIASA (International Institute for Applied Systems Analysis) energy model, whose designers, aware at one level of its quite crippling flaws, had to practice a sort of Orwellian doublethink on themselves as well as their patrons (Wynne 1984).

In historical perspective, the dilemma of the modelers is really quite ancient. The policy-related sciences have been in such a bind for a very long time. The earliest mathematical social science, astrology, struggled constantly with suspicious clients and with methodological conundrums (as the "simultaneous births, diverging fates" paradox). The first applied natural science, medicine, faced harsh criticism and even derision until quite recently. It is a sobering thought that academic medicine, one of the mainstays of the university curriculum for well over half a millennium was, in retrospect, absolute nonsense. Those patients whose condition could be treated by an "empiric" had a chance of effective treatment; those who went to the learned doctors of physic needed to trust their luck, right through to Victorian times. It was only the triumphs of the applications of science in the present century that made success the natural and expected condition for science. Only recently has research science been accepted as the paradigmatic form of genuine and effective knowledge.

Now the sense of the power and limits of science is changing quite rapidly. We know that science can fail to produce a desired good in the form of safety and wellbeing; and we also know that science can produce evil, accidentally or intentionally. The authors of the seduction analysis suggest that we now go beyond "enlightenment rationality and instrumentalism, and to open up discussion to the messy processes of thinking, creating and imagining that we all engage in through everyday practice."

Metaphors and science

In that spirit, we feel justified in searching further afield, seeking other conceptions of knowing, with which we can explain and guide our actions in this still significant practice. Let us consider "metaphor," in spite of the long tradition within science of denying and deriding metaphor as an inferior form of expressing knowledge (for a note on the terms "model" and "metaphor," see Box 3.1). Surprisingly, we find metaphor embedded in the most apparently scientific sorts of discourse. Darwin's theory of

Box 3.1: Models and metaphors

"Model" is a word with many meanings. In this context it refers to computer programs designed to mimic the behavior of particular complex systems. Models are used in the cases where neither theoretical understanding, experimental verification, or statistical analysis are available in sufficient strength. The variables in the model represent observable properties of the system, and the structure of the model represents the relations among them that are known and also capable of simulation. Models normally require "adjustment" elements introduced *ad hoc* to make their outputs plausible; and validation of the models is always indirect.

"Metaphor" is a rhetorical device, meaning "carrying beyond." It refers to the denotation of an idea by a term which literally refers to something else. Its explicit rhetorical use, as in poetry, is to add dimensions of meaning beyond those available in prose. Although the practice of science is believed to be antithetical to poetry, any process of naming, particularly of new theoretical entities, relates them back to other ideas and in that sense is metaphorical. In computer models, the metaphors conveying extra dimensions of meaning tend to be hidden, both in the general assumptions about the world that make models relevant, and also in the particular assumptions about reality and value that shape the model and its outcomes.

evolution relied explicitly on metaphors, such as the "Tree of Life"; and what is "Natural Selection" but the greatest metaphor of them all? Even the concept of "species" so central to Darwinian theory, has functioned as a metaphor for discreteness, fixity, and indeed purity, so that biologists are only now discovering how much they have been biased against recognizing the importance of hybrids (Brooks 1999).

Even in physics, the very structure of basic theories, as thermodynamics, is conditioned by the metaphors embedded in it, as "ideal heat engine" and "efficiency"; and these reflect the perspectives and values of the society in which the theories were forged (Funtowicz and Ravetz 1997). In contemporary policy-relevant sciences, the importation of social values is clear in such titles as "the selfish gene." Overarching metaphors like "growth" are translated into particular sorts of social-scientific language, and are then given very particular sorts of policy implications. One may then legitimately inquire about the extent to which the practices in such fields, in their criteria of value and of adequacy, are themselves influenced by the same social values that provide their metaphors (Lakoff and Johnson 1980; Luks 1999).

Thus we find that in spite of our pretensions to manage so many aspects of our affairs scientifically, that practice is both described and informed by metaphors, themselves embodying societal and cultural values which doubtless shape the practice itself. Reflecting on this state of affairs, we can welcome the prevalence of metaphors, but we can also regret the absence, hitherto, of awareness of their prevalence. For without awareness of our driving metaphors, our supposedly scientific practice is afflicted by a sort of false consciousness of itself. Earlier theorists ascribed this particular defect to other sorts of knowing, assuming that science, by definition, is immune to it. But now we see that such confidence was misplaced. And a practice governed by self-delusion is vulnerable to every sort of distortion and perversion. Recall that we are not talking about the rock-solid experimental sciences of yesteryear, but about the sciences which are both intimately related to policy and also necessarily uncertain because of the complexity of their assigned tasks.

If we then propose to embrace metaphor as an explanation of a practice, in this case the mathematical methods used in environmental analysis, then our conceptions of its objects, methods, and social functions (three related aspects) must come up for review, along with the re-framing of the appropriate criteria of adequacy and value. This is a large task, to be conducted by a dialogue among all those concerned with the problem. The present remarks are intended only to show why such a dialogue is legitimate and indeed necessary, and to indicate the sorts of theoretical lines along which it should proceed.

We may start with Michael Thompson's insight (Thompson 1998) that, while the future is unknowable, this area of ignorance is to be viewed positively, as an opportunity for the growth of awareness through a dialectical process. The core of this awareness is that of our ignorance. In that way, studies of the future can induct us into Socrates' philosophical program, of becoming aware of our ignorance. Since the whole thrust of Western philosophy since Descartes has been to control, deny, and ultimately to conceal our ignorance, this is a radical program indeed (Ravetz 1997b).

We are thus confronted with two conceptions of the task of using models. One is based on the faith that scientific methods can be extended to knowing the future, and hence to bringing it under control. This conception is expressed in what I have called the "elite folk sciences" of reductionist quantification of the natural and human realms alike (Ravetz 1994/5). These include the so-called "decision sciences," along with mainstream economics and the predictive computer modeling fields. Their language is rich with metaphors, but they are all taken from the "possessive individualist" conception of humanity and nature. Their methodology is an imitation of the "hard" natural sciences, and they attempt to operate hegemonically in all the relevant fields. Needless to say, ignorance is a severe embarrassment to such sciences, as it presents itself as a simple refutation of their claims of total knowledge and complete control.

The other conception embraces uncertainty and ignorance, and welcomes the clash of distinct perspectives. Its style is dialectical, recognizing that the achievement of final truth is a false and misleading goal. This conception is permitted only at the very margins of the practice of "matured" science, as in discussions within small colleague communities at open research frontiers. Otherwise, in the pedagogy and popularization of research science, certainty rules. Up to now, that particular conception of science, inherited from a triumphant and triumphalist past, has been successful in that it has provided many more "goods" than "bads" for humanity (or at least its "fortunate fifth"). Hence it cannot be refuted in its own terms. But now that our science-based technology reveals its negative impacts on the natural environment and on ourselves as well, and in ways that cannot be controlled, predicted or even anticipated, the assurance of triumph is weakened. Uncertainty at the policy interface is now recognized, however reluctantly, as inescapable. Hence science as a whole, and especially the "predictive" fields, must now embrace real uncertainty, or sink into undeniable confusion and vacuity.

The dilemma can be seen creatively, if we understand these predictive sciences as telling us less about the natural world of the future, and more about our social and intellectual world of the present. In that sense, we see them as metaphors, providing knowledge not by mere straightforward assertion, but rather by suggestion, implicit as well as explicit. In that way the loss of the pretence of scientific certainty can be seen as a liberation, whereby our discourse about ourselves in nature is opened to the enhanced understandings of metaphor and poetry. This vision is amply borne out by the experience of our focus groups, where the confusion caused by the scientistic understanding of the models gave way to the creativity of discourse about their metaphorical meanings. Disagreement was thereby freed from its negative interpretation, and could then be appreciated as the expression of complementary visions of a complex reality.

Metaphors in environmental modeling

But how are we to find metaphors in the forbidding, frequently impenetrable, thicket of formulae and computer codes that constitute mathematical "models" of environmental processes? We can be sure that they will not be patent, announcing themselves as transferring meaning from some other term to the one under scrutiny. So we look for implicit features of the construct, concerning which perhaps even the modelers themselves may not have been aware. One place is in the assumptions, cast in mathematical form but expressing values as cogently as any *cri de coeur*. For example, whenever we put a numerical value on things at some future time, we are assuming a particular "social discount rate." This expresses the price that we, as individuals or a society, are willing to pay for deferring our use (or consumption) of resources. A high "social discount rate" means that future rewards have little value; it expresses the philosophy "What's posterity done for me?"; conversely a low social discount rate stands for "We are here as stewards of our inheritance." In between, the choice is driven by values and politics, as filtered by fashions in the relevant expert communities. Yet policy conclusions, apparently the outcome of rigorous theoretical logic realized in precise mathematical calculation, can depend quite critically on the size of this concealed quantified value commitment. In the design of permanent structures, either in the public and private sectors, the assumed working life (and hence the quality of construction) will depend quite critically on this assumed discount rate. And in the evaluation of environmental goods, the "present value" of an ongoing resource depends critically on the rate at which it is discounted into the future.

It can be quite instructive to witness an IA modeler displaying the predictions and recommendations of his model to three-digit precision, and then to learn that he has never tested it for sensitivity to the assumed social discount rate. There is a simple relation between decrease of value and discount rate; for example, we may define the "throwaway time" of an object as the length of time required for it to be reduced to a tenth of its present value. This is equal (in years) to 230 divided by the discount rate. So for a 10 per cent discount rate, we throw away before a "generation" of twenty-five years has elapsed; with 7 per cent, the throwaway time is thirty-three years. If we really value the wellbeing of our grandchildren, and have "throwaway time" of, say, sixty years, then our social discount rate is only 4 per cent. The future that we construct through the choice of discount rate, is (in this respect) a metaphor for our conception of the good life in the here and now, as revealed through our evaluation of the future.

Another implicit metaphor lies in the choice of the attribute of the future which is to be salient for our scenarios. There are too many complexities and uncertainties for anything like "the whole picture" to be conveyed at once. So modelers necessarily choose some aspect, which will involve a design compromise between what is scientifically reasonable, and what is humanly and politically meaningful. The early focus on increase of "global mean temperature" related the debate to the capabilities of the leading models, and it also cohered with the comforting assumption that change into the future would be smooth and somehow manageable. It was left to commentators to elaborate on the implications of temperature rise, with melting ice-caps, changing crop patterns, new diseases, etc. More recently, we have become more aware of instabilities and extreme phenomena, occurring on a regional or local scale; the vision is now becoming more "catastrophist." These irregular phenomena are much less amenable to scientific treatment, but they offer convenient "confirmations" of climate change whenever the weather comes up for discussion. Neither focus is "right" or "wrong" in any absolute sense; each has its function, dependent on the context of the debate at any time. Each is a metaphor for a predicament which defies control and perhaps even defies full understanding.

In analyzing these metaphors, I am suggesting a sort of "deconstruction," but not in a negatively postmodern spirit of demystification or debunking. Nor am I asserting that environmental models are simply, or nothing but, metaphors. Rather, as in the analysis of works of creative art, we can use the idea of style to illuminate what the work is about. This is expressed in the less declaratory aspects of the work, but provides a key to its context, framework of ideas, or paradigm, or perspective, or *Weltanschauung* – call it what you will. In the visual arts, the "style" relates less to the explicit theme or subject of the production, and more to silent choices made by the creator, on technical aspects of the work or on particular implicit thematic materials. In written work, style can relate to vocabulary, diction, place of the narrator with respect of story and reader, and so on. “Style” is used by scholars to place works (sometimes quite precisely) within ongoing traditions; and alternatively to tease out deeper layers of meaning.

Among computer models, stylistic differences relevant to users are most easily discerned in their outputs. Even the choice between digital and graphical displays reflects cosmological metaphors. This is expressed in Oriental philosophy between the Yang and the Yin, or in classic computer terms between the IBM of the New York corporation and the Apple of the California garage. Digits provide information that is precise (perhaps hyper-precise) on details, but they fail to convey any sense of overall shape. Graphs are more expressive, but are vague; and a collection of curves all climbing upwards at roughly the same rate does not stimulate either the eye or the mind. The representation of uncertainty is even more fraught. To accompany each principal curve with others that display “confidence limits” can give a seriously misleading impression of the precision and information content of those supplementary curves. It might be best (or rather least worst) to show curves as “caterpillars,” consisting of shaded areas with gradations from center to edges; but I have seen hardly any examples of this.

If we adopt maps for our display, we may be involved in another level of inference and interpolation (from the global to the regional for the case of IA models on climate change and its relations to social activities). We also incur a significant risk of conveying a false verisimilitude to users. The partly metaphorical character of maps has not been generally concealed (unlike in the case of numbers). For example, the use of standard colors and conventional symbols is obvious (Funtowicz and Ravetz 1990). When a map makes a patent distortion of what is on the ground, like the graph maps of the London Underground tradition, the metaphor is clear. Even there, it has been discovered that people (and not only tourists!) sometimes orient themselves solely by the Underground map, ignoring coincidences on the ground that could not be conveyed on the plan. (The most famous of these is the pair of stations, Bayswater and Queensway, within a stone’s throw of each other in reality and yet unrelated on the map.)

Indeed, we may say that the more realistic and powerful becomes the map display, the more urgent becomes the question of its epistemic character. It is all too easy for maps to become instruments of seduction, where the display is taken for the reality. This can happen even when the given output is only one among several alternatives. Somehow each alternative "vision" gets a quasi-real status: if this and that about the general picture are as we assume, then the detailed future will be just as shown on the screen. The task for users may then seem to become one of making "correct" or "the best" assumptions, to predict the "real" future state. In spite of all the variety and uncertainty that may be built into the model and clearly expressed in the instructions for its use, the combination of deductive structure and compelling display can tend to make its interpretation fatally scientistic after all. Those who use them extensively are at risk of becoming seduced by the assumptions concerning reality and value that are embedded in their structures (Dyson 1999).

There are various ways to guard against such a development. One is for the models to be able to convey the "bad" along with the "good" news. Particularly when regional models are employed, anything that shows the effects of general constraints (as in land or water supply) or contradictions between various goals, is to be welcomed. When they cause discomfort by showing unexpected or unwanted consequences of a position assumed to be good and natural, they can have real educational benefits. Better still, if they are employed within a dialogue, so that the experience of disappointment and disillusion are shared, their Socratic function is enhanced. For then it becomes a public knowledge, that just as men formerly made gods in their own images, so now they construct apparently scientific futures out of their hopes and dreams based on the past.

When embedded in a dialogue full of surprise and shock, the model can then function truly as a metaphor. It is recognized as carrying not a literal truth, but an illumination. And what the bare output (numerical, graphic or cartographical) lacks in enhancing an aesthetic imagination, it can compensate for in its development of our self-awareness. Knowledge of our ignorance is, it was said long ago, the beginning, or rather the prerequisite, of wisdom. This sort of knowledge has been systematically excluded from our intellectual culture for the past 400 years; and it could be that this ignorance of ignorance, and the scientific hubris to which it gives rise, is responsible, in no small measure, for the present perilous character of our total scientific system. While in some ways this is still plausibly in the image of the conqueror of Nature, even more does it remind us of the Sorcerer's Apprentice.

Moreover, the recognition of models as metaphors will have a profoundly subversive and liberating effect on our very conception of science itself. For a metaphor has a reflexive, even ironic character (O'Connor 1999). When I say, "My love is like a red, red rose," I know as well as the reader that this is literally false. There is a deeper truth, which may be explicated later in my story; but starting with the metaphor I draw the reader into a little conspiracy, perhaps in its way a seduction. We share the knowledge that I have said something apparently false and ridiculous, and we will now play a game where I show how this apparent non-knowledge actually becomes a better knowledge than a photographic description. Of course, she/he may not want to play; some people find metaphors peculiar, useless and distasteful.

Healing the amputation of awareness in science

There is a long history in Europe, partly cultural and partly political, of a reaction against metaphor. One can find it with the early Protestant reformers, who wanted the Bible to be understood as a plain history for plain men. This, they thought, would eliminate the corrupted spiritual expertise of the priesthood. Later the same impulse was realized in the forging of a new conception of science. The prophets of the Scientific Revolution all put literature in a separate, and usually unequal, category from the knowledge derived in the experimental-mathematical way. Subsequent spokesmen of science stressed the need for clear thinking, for a hobbling of the imagination, lest the mind be led astray.

But now we find ourselves in a peculiar situation. Beneath the hard surface of scientific discourse, metaphors abound; we have "chaos" and "catastrophe" in mathematics, and "charm" in physics. It is just possible that those who create and popularize these metaphors are unaware of their complex character. They might think of them as cute and suggestive names, rather than as conveying realms of knowledge and presuppositions, which can be all the more powerful for being unselfconscious. In this way the creative scientists are, all unawares, poets *manqués*; in their nomenclatural practice they violate the principles on which their knowledge is claimed to rest.

Were this a matter concerning only theoretical scientists ensconced in academe, it would be of purely "academic" interest. But the pretensions of science, embedded in and unselfconsciously conveyed by the apparently impersonal conceptual instruments of analysis can, in cases of environmental policy, deceive and confuse the scientists as much as their audience. The numbers, graphs, and maps announce themselves as objective, impersonal facts; they are a whole world away from the red, red rose of the poet. Appreciation of them as metaphors requires an even greater sensitivity than grasping that the red, red rose is not a photographic description. But it is all the more difficult, because of the amputation of awareness that is instilled by the standard education in science.

Students of the traditional sciences are still formed by a curriculum which teaches by example that for every problem there is just one and only one correct answer; and the teaching is reinforced by the discipline of the exam. Having been thus force-fed for a decade or more until they emerge as "Doctors of Philosophy," students or researchers generally do not know what they are missing of the total picture of scientific knowledge in its context. Those who know about this amputated awareness do not necessarily think it is a bad thing. Indeed, it was argued, by Kuhn himself, that it is integral to the process of science and essential for its success (Kuhn 1962). The deficiencies and dangers of "puzzle-solving" in "normal science" become manifest only when that process fails in its own terms, when, in Kuhn's words, there is a "crisis." This can occur in research science as a precursor to a Kuhnian "scientific revolution." More commonly, now, it occurs whenever science is in a "postnormal" situation where facts are uncertain, values in dispute, stakes high and decisions urgent. Then puzzle-solving is at best irrelevant and at worst a diversion.

The amputated awareness of science is directly challenged when models are introduced as a means of education about global environmental problems and urban lifestyles. The experience of our focus groups has repeatedly shown that the "plain man's question," namely, "are these real predictions?" will, if accepted at its own level, produce nothing but confusion (see also the discussion in Chapter 5 by Dahinden *et al.*). If the models are claimed to predict scientifically, refutation follows swiftly; but if they are not predictors, then what on earth are they? The models can be rescued only by being explained as having a metaphorical function, designed to teach us about ourselves and our perspectives under the guise of describing or predicting the future states of the planet. In that process, we all have the opportunity to learn, not merely about ourselves, but about science as well.

In all this, there is another lesson to learned about science. The triumphs of science and the technology based on it are undeniable; no one could, except provocatively or mischievously, say that science is nothing but metaphor. But that science has produced our present predicament, where our urban lifestyles are clearly unsustainable. How is that total system of knowledge and power to be transformed, so that it does not destroy us in the end? Can the understanding which has become the leading problem for civilization, simply turn around and constitute the total solution? My argument, supported by the ULYSSES experience, is that a new understanding of the science that is employed in the policy processes is necessary, and that the awareness of metaphor has its part to play.

Conclusion: ULYSSES and the future

There is a consensus among its participants that this enriched understanding has been an important achievement of the present study. Through the interaction of experts with laypersons, we have found that the question for discussion and mutual learning is not restricted to the properties of this or that particular model, in relation to its user-friendliness. In the many interactions with intelligent and thoughtful laypersons, these methodological issues have come up repeatedly. While related considerations have pervaded the whole work of the present study, the "metaphor" metaphor (so to speak) has even been introduced explicitly in one of the regional case studies. Here, the participatory process has been portrayed as a "voyage of discovery" on which one of the passengers is a somewhat odd "Mr Computer" (De Marchi *et al.* 1998). And, crucially, all participants have learned important lessons, the experts no less than the laypersons. Such an outcome is the essence of post-normal science, that in these conditions the experts also have something important to learn. They can teach the laypersons something from their expertise, but the others can teach them something about that expertise itself. When all sides are aware of their mutual learning, and all sides gain thereby in self-understanding and mutual respect, then (and only then) can there develop that element of trust among participants, which is becoming recognized as the essential element in our making progress toward a sustainable world. In this way, the experience of the study discussed in this book, where (perhaps uniquely) the products of leading-edge integrated assessments of climate issues were exposed to scrutiny and earnest criticism by the supposed beneficiaries of the research, provides lessons of the utmost importance for us all.

A general recognition of models as metaphors will not come easily. As metaphors, computer models are too subtle, both in their form and in their content, for easy detection. And those who created them may well have been prevented, by all the institutional and cultural circumstances of the work, from being aware of their essential character. Furthermore, the investments in the scientistic conception of models, in the personal, institutional and ideological dimensions, are enormous and still very powerful. But the myth of the reductionist-scientific character of our studies of the future, and indeed of all complex systems, cannot hold. Only by being aware of our metaphors, and our ignorance, can we fashion the scientific tools we need for guiding our steps into the future, now appreciated as unknown and unknowable, but where our greatest challenge lies. Real, working dialogues between the community of experts and the "extended peer community" are essential in improving this awareness on both sides. The initiative of the study discussed in this volume has illuminated the problem of the use of science for policy, and it has shown the ways toward its solution, through dialogue, learning and awareness. In this, I hope that the understanding of models as metaphors has played a part.

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