SCIENCE AND GOVERNMENT

Post-normal science: A new science for new times

Silvio Funtowicz and Jerry Ravetz

The challenges of global environmental and other complex political and technical issues present new tasks – and require a new science.

Since the Second World War, science has become increasingly capital-intensive, and intimately connected with technology and political power. But paradoxically, as science prospered materially, in the public mind it has lost its ideological function as the unique bearer of the True, and therefore of the Good. Now the challenges of global environmental and other complex political and technical issues present new tasks for science; and in future, instead of discovery and application of facts, the new most public achievements for science will be made in this work.

But we argue that for such achievements a new scientific method, neither value-free nor ethically neutral, will need to be developed. The product of such a method, applied to complex public problems, will deserve a new name: we call it: "post-normal science".

Why does science need a new method? Because it is being called upon to reach conclusions on problems before all the data are to hand. For example, data on the effect of global warming, and even baseline data for the "undisturbed" climate, are seriously inadequate. The phenomena of climate change are novel, complex and variable, and poorly understood. In such circumstances, science cannot always provide well-founded theories based on experiments for explanation and prediction; but can frequently achieve at best only mathematical models and computer simulations, which are essentially untestable. The questions of the impact of the release of genetically engineered organisms, or any of the fundamental social changes that society now faces, present similar problems.

Silvio Funtowicz (right) and Jerry Ravetz

The trouble is that on the basis of uncertain inputs, decisions must be made, under conditions of some urgency. In such conditions science cannot proceed on the basis of factual predictions, but only on forecasts influenced by values and policy. Typically, in such issues the facts are uncertain, values in dispute, stakes high and decisions urgent. In this way, it is "soft" scientific information which serves as inputs to the "hard" policy decisions on many important environmental issues.

Indeed, we may speak of a new sort of pseudo-science, depending not on magic but usually on computer modelling, which can be called GIGO ("Garbage In, Garbage Out"). This can be defined precisely in the following way: a GIGO science is one where the uncertainties in the inputs must be suppressed, lest the outputs become completely indeterminate. How much of our present social and environmental research belongs to this category, is an interesting and urgent question. Parallel to these computer-based pseudo-sciences are the computer-based pseudo-technologies. Here the excellence of the computer graphics conceal the difference between a functioning technological system and one which is not merely imaginary but also impossible.

The uncertainties in research related to policy are not restricted to the uncertainties of computational models. Even the empirical data that serve as inputs to the models may be of doubtful quality. Their uncertainties are frequently incapable of management by traditional statistical techniques. As J. C. Bailar puts it: "Random variability – the stuff of p-values and confidence limits – is simply swamped by other kinds of uncertainties in assessing the health risks of chemical exposures, or tracking the movement of an environmental contaminant, or predicting the effects of human activities on global temperature or the ozone layer." (Bailar, J. C.: 1988,"Scientific Inferences and Environmental Problems: The uses of Statistical Thinking", Institute for Envi-

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ronmental Studies, The University of North Carolina, Chapel Hill.)

In such research, inputs are frequently untestable, and methods not validated, so the scientific status of the conclusions is dubious at best. On the other hand, without them there could not even be a pretence of a role for science in the solution of these new problems.

We can compare the different sorts of scientific problems that are now being encountered. The diagram (on the right) exhibits three kinds of inquiry in terms of the two attributes of "systems uncertainty" and "decision stakes". These define two factors, ranging from low to high. What is traditionally called "applied science" is performed when both factors are low; then "puzzle-solving", as defined by the renowned US philosopher of science Thomas Kuhn is adequate (Kuhn, T.S.: 1962, "The Structure of Scientific Revolutions", University of Chicago). But when either factor is medium, something extra must be brought into the work, which we can call "consultant's skill" or "judgment". It is important to notice that even when uncertainty is low, if decision stakes are high then puzzle-solving will not be adequate for a decision. In such circumstance, either party in a disagreement can find ways to challenge results methodologically, as a defence of their interests, and so the forum for decision becomes enlarged from that of the technical experts.

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The outermost region, whether either systems uncertainty or decision stakes – or both – are high, is a more extreme case. Here traditional science is totally inadequate, and a new methodology, indeed a new conception of the appropriate sort of science, is necessary.

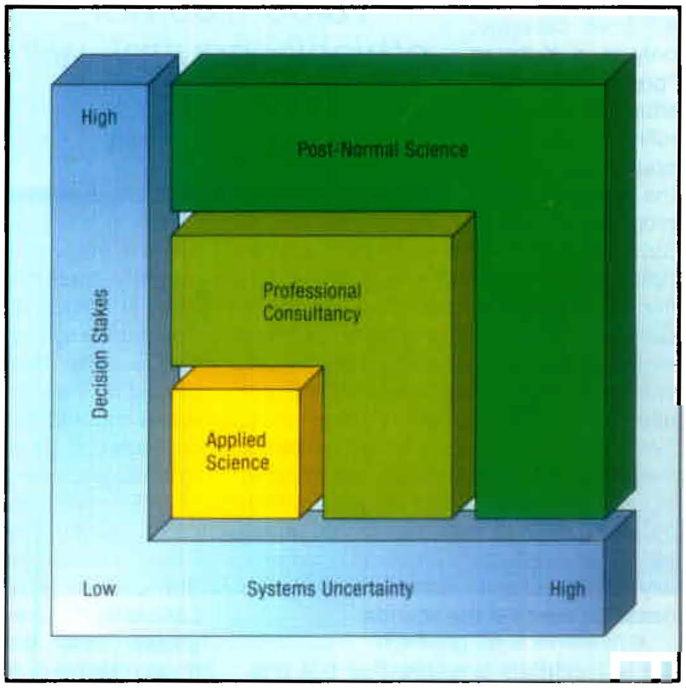
The solutions to these problems lie in quality control and assurance, which are also essential to successful practice in industrial production. Quality assurance in information is less familiar than quality assurance in production; yet it is equally fundamental.

Thomas Kuhn defined "normal" science in his classic work "The Structure of Scientific Revolutions", (op. cit.). There he described it as "puzzle-solving" within an unquestioned "paradigm", or accepted picture of the world under investigation. For Kuhn, the subject-speciality community consists of all those with the appropriate educational qualifications who also agree on what constitutes real problems and proper solutions. "Progress" takes place by means of such routine puzzle-solving; indeed this is the defining property of "normal" science, in "matured" fields. Only when this approach fails in resolving anomalies of practice, does the community lose its unanimity and undergo crisis; this leads to a "scientific revolution" and the adoption of a new paradigm. In our terms, we may say that in normal science quality-control is effected by the closed community of practitioners on a well-defined set of problems on which they have exclusive expertise.

In the case of global environmental and other complex issues, there is always a body of "normal" scientists who are involved. But frequently we find that they are creating problems for which their training does not equip them to solve. Thus nuclear physicists are not skilled in oncology or epidemiology; nor are molecular biologists familiar with microbial ecology. Even more, specialists in human reproduction engineering are not systematically educated in ethics.

Scientists who venture into the fields of political advice thus find themselves in unfamiliar territory. The relevant sciences are weaker, technically and socially. They deal with more complex systems, are less well developed theoretically, and tend to lack prestige and resources. Furthermore, their relations with the public are very different. It is no longer a case of "popularising" esoteric results to an appreciative lay audience. Rather, the sciences address the worries of people, as residents, parents and human beings, perhaps even the families of those involved in creating the problem. The criteria of quality, of judging what is good or bad science, are broader than (say) theoretical interest or industrial applicability; they include considerations of health and well-being, of the environment and of humanity. Therefore, the narrowly defined puzzle-solving community cannot maintain a monopoly on the quality-control of their work, and so "normal" science must in these fields be superseded.

In all these ways, these new sorts of science are radically different from the normal science which Kuhn took as his standard when analysing "revolutions"



Three kinds of scientific advice – applied science, professional consultancy, post-normal science – measured by the uncertainties about the system on which advice must be given, and the magnitude of the public issues at stake in the decision.

such as those which led to quantum mechanics, or a recognition of the molecular basis of life. In the present case, we have scientific disciplines which cannot be expected to attain the normal state where routine puzzle-solving is effective for progress. There are many scientists and scientific advisors who still believe that these problems can be solved through the application of more "normal science". In the terms of the diagram they cannot imagine anything other than "applied science" as being effective, for that is all that their philosophical formation and technical training allows for. For that reason it is particularly important to have a name that is easily remembered and that carries its meaning within it; and "post-normal", recalling the Kuhnian revolution in philosophy of science, is very appropriate in that regard.

In what we might now call "pre-normal" science, all the practitioners were what we might call amateurs. They could and did debate vigorously on all aspects of the work, from data to methodology, but there was no in-group of established practitioners in conflict with an out-group of critics. In "normal" science, any outsiders were effectively excluded from dialogue; only in a Kuhnian "pre-revolutionary" situation, when the ruling paradigm could not deliver the goods in steady progress, would outsiders get the chance to be heard. In post-normal science there is still a distinction between insiders and outsiders, based (on the cognitive side) on certified expertise and (on the social side) by occupation. But since the insiders are manifestly incapable of providing effective conclusive answers to the problems they confront, the outsiders are capable of forcing their way into a dialogue. When the debate is conducted before a lay public, the outsiders (including community activists and journalists) may on ocassion even set the agenda.

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It is important to realize that this phenomenon is not merely the result of the external political pressures on science that occur when the general public is concerned about some issue. Rather, in the conditions of post-normal science, the essential function of quality assurance can no longer be performed by a restricted elite of insiders. When problems do not have neat solutions, when the phenomena themselves are ambiguous, when all mathematical techniques are open to methodological criticism, then the debates on quality are not enhanced by the exclusion of all but the academic or official experts. For the knowledge of local conditions which not only shape the policy problems, but also determine which data are strong and relevant, cannot be the exclusive property of an elite whose training and employment inclines them to abstract, generalized conceptions. Those whose lives and livelihood depend on the solution of the problems will have a keen awareness of how general principles are realized in their "back yards". It may be argued that they lack theoretical knowledge and are also biased; but it can equally well be argued that the experts lack practical knowledge and have their own pressures towards a bias.

An appreciative study of local wisdom in solving scientific and technological problems is only now getting underway. Some authors have recognized this as the key to genuinely sustainable development in the Third World. The author Arnold Pacey gives examples (Pacey, A.: 1990, "Technology in World Civilization", Blackwell, Oxford and Cambridge, MA, 203) to show how a really successful technology is the outcome of a "dialogue" between what is an apparently more advanced innovative culture, and the apparently traditionalist receiving culture. Thus in African agriculture, the previous dominance of colonially-introduced temperate-zone techniques is being replaced by the integration of tree and field crops (incomprehensible to earlier Western experts), together with irrigation and minimal engineering .

In Europe, a recent survey by Brian Wynne of the University of Lancaster has shown how the sheep farmers of Cumbria in England have a better understanding of the ecology of radioactive deposition than the official scientists (Wynne, B.: 1990, Personnal Communications). The farmers would not have made the assumption that radioactive caesium would leach away through their thin cover of acid moorland soil at the same rapid rate as through lowland pastures. Also, they would have recognized that high ground lying directly downwind of a major reprocessing plant – the nearby Sellafield plant of British Nuclear Fuels – is liable to have a different deposition pattern from remote fields. Although they could not criticize the technically esoteric measurements made by the official scientists, they were fully competent to evaluate their methods and interpretations at every stage.

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Along with such enrichment of the traditional scientific peer-communities there is a parallel enrichment of the cognitive basis of post-normal science; we could speak of "extended facts". This is the material which is effectively introduced into a scientific debate on policy issues. It is becoming apparent that people's beliefs and feelings, whatever their source and validity, must be recognized and respected lest they become totally alienated and mistrustful. But extended facts go beyond that purely subjective base.

There will also be anecdotes, circulated verbally, and then the edited collections of such materials prepared for public use by citizens groups and the media. These will not usually be of traditional scientific quality, but they may be essential for establishing a *prima facie* case for the existence of a problem, and therefore the urgency of systematic research. When such testimonies are introduced into scientific debate, and subject to some degree of peer-review before reporting or acceptance, they approach the status of scientific facts.

Of similar strength are the experiences of persons with a deep knowledge of a particular environment and its problems, like the hill farmers of Cumbria reported by Wynne. We should not forget materials discovered by investigative journalism. Finally, the category of "extended facts" can also be applied to information which is quite orthodox in its production, but which for political or bureaucratic reasons is officially secret in some way or other: such facts can then function covertly, forming a background to loaded public questions.

This last sort of "fact" may seem very strange to those whose idea of science is derived from the textbook and the academic research laboratory. But for those of us who are familiar with science in the policy context, such extended facts may be quite crucial in the accomplishment of the quality assurance of results on which our health and safety depend.