Environmental problems, post-normal science, and extended peer communities

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Résumé

Problèmes d'environnement, science post-normale et communautés étendues de pairs. Les problèmes d'environnement ont des caractéristiques qui les distinguent radicalement des problèmes scientifiques traditionnels : les faits sont incertains, les valeurs en discussion, les enjeux graves et les décisions urgentes. Pour ces nouveaux problèmes la science ne peut généralement pas fournir des théories bien établies, avec une base expérimentale pour l'explication et la prédiction ; les questions d'environnement présentent donc de nouvelles tâches pour la science. Nous rangeons les stratégies scientifiques de résolution de problèmes sur un diagramme à deux axes, les "incertitudes du système" et les "enjeux de la décision" ; la situation de la science post-normale est celle dans laquelle ces deux critères sont les plus élevés; ici nous trouvons des décisions avec des enjeux graves, pour lesquelles les bases scientifiques sont décidément incertaines. Dans ces conditions les fonctions essentielles de l'assurance-qualité et de l'évaluation critique ne peuvent plus être complètement réalisées par un corps restreint d'experts. Le dialogue sur la qualité, ainsi que celui sur la politique, doit être étendu à tous ceux qui ont des enjeux dans la question et qui sont ici appelés "communauté étendue de pairs". L'objectif est de voir quel type de changements dans les pratiques et les institutions scientifiques seront entraînés par la reconnaissance de l'incertitude, de la complexité et de la qualité dans la recherche opérationnelle.

Mots-clés : incertitude, complexité, science post-normale, communautés étendues de pairs.

Abstract

The new environmental problems have common features that distinguish them from traditional scientific problems: facts are uncertain, values in dispute, stakes high and decisions urgent. For these new problems science usually cannot provide well-founded theories, based on experiments, for explanation and prediction; therefore environmental issues present new tasks for science. We range scientific problem-solving strategies on a biaxial diagram which exhibits them in terms of the two attributes of "system uncertainties" and "decision stakes"; the situation of post-normal science is one where both attributes are highest; here we find decisions with high stakes, for which the scientific inputs are irremediably uncertain. In these conditions the essential functions of quality assurance and critical assessment can no longer be completely performed by a restricted corps of insiders. The dialogue on quality, along with that on policy, must be extended to all those with a stake in an issue; these we call "the extended peer community". The task is to see what sorts of changes in the practice of science and in its institutions will be entailed by recognition of uncertainty, complexity and quality within policy-relevant research.

Keywords: *uncertainty, complexity, post-normal science, extended peer communities.*

Introduction

Few will still doubt that our modern technological culture has reached a turning point, and that it must change significantly if we are to manage our environmental problems. It may not yet be as widely appreciated that science, hitherto accepted as the mainspring of technological progress, must also change. Environmental issues present new tasks for science; along with the discovery and application of scientific facts, new fundamental achievements for science must also be concerned with remedying the pathologies of our industrial system. We no longer require the ideal of a science that is totally value-free and ethically neutral, nor do we need to believe that rational and correct policy decisions automatically follow from the facts discovered by science. A new method, based on the recognition of uncertainty, complexity and quality, will guide the new scientific enterprise, which we call "post-normal science".

Our approach is new in its emphasis on the concepts of uncertainty, complexity, and quality. All these had previously been kept at the margin of the understanding of science, among researchers, philosophers and popularisers alike. Science was traditionally imagined as steadily advancing our certain knowledge and effective control over the natural world. Now science is appreciated as confronting complexities and coping with uncertainties in urgent technological and environmental decisions on a global scale. The work of quality assurance of the results of research in this new, broader context of science can no longer be left to isolated specialist communities; it must be renewed and enriched. The dialogue on quality, along with that on policy, must be extended to all those with a stake in an issue who are committed to a genuine debate; these we call "the extended peer community". We have developed a method for assessing and expressing the quality of technical information in terms of its characteristic uncertainties (Funtowicz and Ravetz, 1990). This "NUSAP" system will facilitate the critical assessment of technical information, thereby contributing to the work of quality assurance in the extended peer communities that engage on environmental problems through post-normal science.

Post-normal Science

The new environmental problems have common features that distinguish them from traditional scientific problems. They are planetary in scale and long-term in their impact. The phenomena are novel, complex and variable, and are often not well understood. Data on their effects, and data for baselines of "undisturbed" systems, are radically inadequate. For these new problems, science cannot usually provide well-founded theories, based on experiments, for explanation and prediction. Frequently it can achieve no more than mathematical models and computer simulations, neither capable of being tested by traditional scientific methods. On the basis of such uncertain scientific inputs, policy decisions must be made, under conditions of some urgency. Therefore policies for solving the environmental problems cannot be determined on the basis of scientific predictions, but only supported by policy forecasts.

We adopt the term "post-normal" to mark the passing of an age when the norm for effective scientific practice could be a process of routine puzzle-solving (Kuhn, 1962) conducted in ignorance of the wider methodological, societal, and ethical issues raised by the activity and its products. The leading scientific problems can no longer derive solely from the curiosity of scientists or the missions of defence, industry or medicine. The community of researchers does not have the luxury of deferring investigation of problems until they are hopeful of success; in the problems related to the environment, researchers must do their best, however complex the problem and uncertain the solution. For these new problems are created by issues where, typically, facts are uncertain, values in dispute, stakes high and decisions urgent. Moreover, when research is called for, there must first be a definition of the problem to be studied, and this will depend on which aspects of the issue are most salient. Hence political considerations constrain the possibilities of the sorts of results that can be produced, and thereby the sorts of policy options for which there is scientific support. In general, the situation of post-normal science is one where the traditional opposition of "hard" facts and "soft" values is inverted; here we find decisions that are "hard" in every sense, for which the scientific inputs are irremediably "soft".

The inherent limitations of the traditional problem-solving strategies are revealed by a structural feature of the new sort of problems. For in these, decisions depend on assessments of future states of the natural environment, resources, and human society, all of which are unknown and unknowable in any detail. Further, in addition to the irremediable uncertainties in knowledge relevant to policy, the powers of science have also created moral complexities resulting from the invasion of the domains of the sacred and private. The most notable cases are reproductive technology and also scientific research that requires the inflicting of harm on aware beings. Under these new circumstances of radical uncertainties of every sort, a new type of problem-solving strategy is emerging.

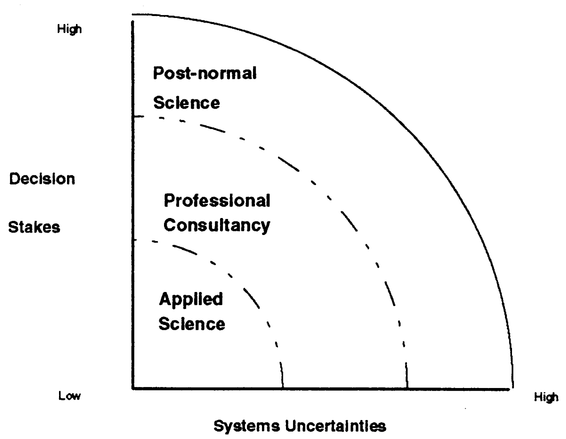

Figure 1

We can analyse the different sorts of problem-solving strategies that are now employed, through a biaxial diagram which exhibits them in terms of the two attributes of "systems uncertainties" and "decision stakes" , ranging from low to high, as on Figure 1 (Funtowicz and Ravetz, 1992). For systems uncertainties, the three intervals along the axis correspond to different sorts of uncertainty, namely technical, methodological and epistemological. The other axis of the diagram relates practice to the world of policy. For decision stakes, we understand in general the costs, benefits, and commitments of any kind, for the various stakeholders in an issue. There are three zones, corresponding to three types of problem-solving strategy: applied science, professional consultancy and post-normal science (Traditional "pure" science would, on this diagram, be located at the intersection of the axes).

There is no pretence of quantifying either of the attributes defining the problem-solving strategies. They provide a rough gauge whereby the distinctions among the three zones can be illuminated. When both attributes are minimal, then routine puzzle-solving research in the Kuhnian sense is adequate; this occurs when the research contributes a useful piece of information that is neither contested nor critical in relation to a policy issue. But when either attribute is medium, something extra must be brought into the work, which we can call the professional's skill or judgement. For professional consultancy, the attributes may range from moderate to severe; the medical doctor normally cares for the health or life of a single patient, though the task is more demanding in times of public health crises; while for the engineer there is the welfare of a client, and in connection with safety, that of a wider community. In post-normal science, when global environmental issues are involved, the stakes can become the survival of a civilisation or ecosystem, and even of present forms of life on the planet; and the systems uncertainties are correspondingly severe.

The diagram displays the feature that even when uncertainties are low, if decision stakes are high then "applied science" puzzle-solving alone will not be effective in a decision process. For no scientific argument can be logically conclusive; even the traditional positivist philosophy of science acknowledged this. In the course of a scientific debate, the arguments evolve in a continuous dialogue which is incapable of reduction to logic; what makes scientists "rationally" change their opinions is a matter of ongoing discussion among philosophers and sociologists of science. Applying this lesson to debates on particular issues (as in the regulatory system) we can appreciate that when any party finds its interests threatened it can always identify some methodological weakness by which to challenge the quality of the scientific information presented by the other side. This is particularly easy in the case of regulatory decisions on risks or the environment, where the uncertainties of evidence and argument are severe. Thus in the policy arena the forum for scientific debate becomes enlarged, from that of the technical experts alone, to include all those interests, commercial or corporate, with a strong stake in the outcome.

All these tendencies to a broadened forum of debate appear still more strongly in the case of post-normal science. Research work and the deployment of skills still have an essential role to play, but this must be done in a framework in which the narrowly defined scientific problems are integrated into larger policy issues. In this way they are provided with direction, quality assurance, and also the means for a consensual solution of policy problems in spite of their inherent complexities and uncertainties. Examples of problems with combined high decision stakes and high systems uncertainties are familiar from the current crop of environmental problems. Indeed, any of the problems of major technological hazards or large scale pollution belong here. The paradigm case for post-normal science could be the design of a repository for long-lived nuclear wastes, required to be secure for the next ten thousand years.

The usefulness of our diagrammatic scheme can be illustrated by consideration of cases located close to either of the axes. For a problem with low systems uncertainties, we have examples among the major disasters that have afflicted our modern industrial societies in recent years. Subsequent inquiries have in many cases established that the disaster had been "waiting to happen" through a combination of physical predisposing causes and management practices which had been well known in advance (e.g. Bhopal, Challenger, Exxon Valdez). Yet applied science and professional consultancy were insufficient for preventing the accidents in the first place; and the strengthening of the regulations for avoiding recurrences requires the disasters to become policy issues, eventually resolved through post-normal science.

A contrasting case is cosmology, a science which now (unlike in Galileo's time) has low decision stakes along with high uncertainty. There the data are so sparse, theories so difficult to test, and public interest so lively, that the field is as much "natural philosophy" as science; and experts must share the platform with amateurs, popularisers, philosophers and even theologians. In this latter example we see an historical continuity between the science that was practised before the establishment of the authoritarian paradigms, and the emerging post-normal science of the present. This can help us appreciate the methodological continuity between post-normal science and all the other problem-solving strategies. For post-normal science is a development of traditional forms of science, one that is appropriate to the conditions of the present age. Its essential principle is that in science-based policy decisions and even in science we can no longer expect to conquer or banish uncertainty and ignorance. Instead they must be managed, for the common good. Programmes for the reform of technology, industry or lifestyle which ignore this aspect of contemporary scientific knowledge are likely to remain part of the global problem rather than contributing to its solution.

By the use of the diagram, we can better understand the different aspects of complex projects in which all three sorts of practice may be involved. For this we may take an example of a dam, that was discussed previously (Ravetz, 1971) in connection with an analogous classification of problems as scientific, technical and practical. First, in the construction of a dam there is much basic, accepted scientific knowledge that is deployed; and there will be particular research projects of an "applied science" character to provide information on the relevant features of the local environment and details of the dam's construction. But the creation of the dam is in the first place a design exercise, where the shape and structure is not completely determined by the scientific inputs. If nothing else, there will be a design compromise among the various possible functions of the completed dam, which may include water storage, hydroelectric power, flood control, irrigation, and leisure, together with their associated costs. Achieving an optimum balance among these, given both the uncertainties in scientific inputs and the value-conflicts among the various affected interests, is a task for a "professional consultancy". But the matter does not stop there. There may be a possibility of long-term deterioration of the hydrological cycle in the district, of adverse effects downstream, and perhaps even local earthquakes. Some people may find their homes, farms and religious monuments drowned by the artificial lake; can they possibly be adequately recompensed? Dams, once seen as a completely benign instrument of human control over raw Nature, have suddenly become seen as a sort of predatory centralism, practised by vast impersonal bureaucracies against local communities and the natural environment. When such issues are in play, we are definitely beyond professional consultancy, and we are in the realm of post-normal science. Also, we observe that the "complexity" of the dam project does not lie essentially in the variety of relevant scientific disciplines, but rather that it consists of the multiplicity of legitimate perspectives on the total issue.

Extended Peer Communities

We can also use the diagram to illustrate how a problem in post-normal science can evolve so that it is tamed, and brought some way in towards manageability. For when (for example) a risks or pollution problem is first announced, it will almost always be in a condition of considerable uncertainty. Since it had not been appreciated previously, there is hardly likely to be substantial information about it. Hence the evidence will tend to be anecdotal on the experimental side and speculative on the theoretical side. But the strength of the decision stakes will ensure that all interests will offer their opinions with apparently complete certainty. The first phase of the discussion will therefore resemble ordinary political debate, but of a particularly confused kind. For each side will attempt to define the problem in the terms most favourable to its interest, typically proponents of a development presenting it as straightforward applied science and opponents stressing its uncertainties and also its ethical aspects. It is a new phenomenon for such broad debates to be effective; hitherto commercial viability or State security was the overriding consideration for industrial development, subject to some concern for health, safety and the environment. Indeed, in recent decades, traditionally trained experts have experienced bewilderment and dismay as they confronted those who try to block "progress" on the basis of apparently intangible and non-scientific arguments.

If such problems remained in the realm of pure power-politics, the outlook for our policies for science, technology and the environment would be grim. But there is a pattern of evolution of problems, with different problem-solving strategies coming to prominence. This gives hope that professional consultancy and also applied science may yet have an important role to play. For as the debate develops from its initial confused phase, positions are clarified and new research is stimulated. Although the definition of problems is (as we have seen) never free of politics, an open dialogue can ensure that such considerations are neither one-sided nor covert. In the developing discussion on the technical aspects, no advocates need admit they were wrong; it is sufficient for there to be a tacit shifting in the terms of the debate. And as new research eventually brings in new information, the problem becomes more amenable to the approach of professional consultancy, and even of applied science. Thus by means of the diagram of the three strategies for problem-solving, we can indicate a pattern for the progressive evolution of a complex and uncertain issue involving science and policy.

It is important to appreciate that post-normal science is complementary to applied science and professional consultancy. It is not a replacement to traditional forms of science, nor does it contest the claims to reliable knowledge or certified expertise that are made on behalf of science in its legitimate contexts. Recent critical philosophies of science, concentrating on scientific knowledge alienated from its social context, have led to a view that "anything goes" in science. It is as if any charlatan and crank should have equal standing with qualified scientists or professionals (see notably Feyerabend, 1975). Our critical analysis proceeds on another basis, that of quality assurance, or critical assessment. The technical expertise of qualified scientists and professionals in accepted spheres of work is not being contested; what can be questioned is the quality of that work, especially in respect of its environmental, societal and ethical aspects. Previously the ruling assumption was that these were "externalities" to the work of science itself; and that when such problems arose an appropriate response would somehow be invented by "society". Now the task is to see what sorts of changes in the practice of science, and in its institutions, will be entailed by the recognition of uncertainty, complexity and quality within policy-relevant research.

In what we might now call "pre-normal" science, nearly all the practitioners were amateurs. They could and did debate vigorously on all aspects of the work, from data to methodology, but usually there was no in-group of established experts in conflict with an out-group of critics. In normal science, any outsiders were effectively excluded from dialogue; they would get a chance to be heard only in a Kuhnian "pre-revolutionary" situation, when the ruling paradigm (cognitive and social) could not deliver the goods in the way of steady puzzle-solving progress. In post-normal science there is still a distinction between insiders and outsiders, based (on the side of knowledge) on certified expertise and (on the social side) by occupation. But since the insiders are frequently incapable of providing conclusive solutions to the complex 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 members, environmental activists, lawyers, legislators and journalists) may on occasion even influence the agenda. An example has already been shown in biomedical science, where non professional groups advise on ethical issues, and where activists have now joined the dialogue about treatment and even research in some of the more controversial diseases like AIDS.

Because of these human aspects of the issues giving rise to post-normal science, there must be an extension of all the elements of the scientific enterprise. First there must be a presence of a complementary expertise whose roots and affiliations lie outside that of those involved in creating or officially regulating the problem. These new participants, enriching the traditional peer communities and creating what might be called "extended peer communities", are necessary for the transmission of skills and for quality assurance of results. It is important to realise that this phenomenon is not merely the result of the external political pressures on science that occur when the general public is concerned about an environmental issue. Rather, in the conditions of post-normal science, the essential functions of quality assurance and critical assessment can no longer be completely performed by a restricted corps of insiders.

When problems lack neat solutions, when environmental and ethical aspects of the issues are prominent, when the phenomena themselves are ambiguous, and when all research techniques are open to methodological criticism, then the debates on quality are not enhanced by the exclusion of all but the specialist researchers and official experts. The extension of the peer community is then not merely an ethical or political act; it can positively enrich the processes of scientific investigation. Knowledge of local conditions may determine which data are strong and relevant, and can also help to define the policy problems. Such local, personal knowledge does not come naturally to the subject-specialty experts whose training and employment predispose them to adopt abstract, generalised conceptions of genuineness of problems and relevance of information. Those whose lives and livelihood depend on the solution of the problems will have a keen awareness of how the general principles are realised in their "back yards". They will also have "extended facts", including anecdotes, informal surveys, and official information published by unofficial means. It may be argued that they lack theoretical knowledge and are biased by self-interest; but it can equally well be argued that the experts lack practical knowledge and have their own unselfconscious forms of bias.

But the task is not to say whether the restricted or the extended peer community has a "better" knowledge. Rather we should see them as complementary, mutually supporting and reinforcing. Indeed, with the perspective of this new sort of practice, we can envisage a new, humanistic goal for science and technology. In post-normal science, we weaken the logical ideal of "scientific prediction", and are satisfied with the more pragmatic goal of "policy forecasting". However, in regard to the knowledge gained, we can enhance the traditional conception of "scientific explanation" to a richer "societal understanding". In this way the new challenges and the emerging practice of post-normal science can lead to new, appropriate ideals for science itself.

Conclusion

We have now reached the point where the traditional strategies of scientific problem-solving are no longer appropriate to our new needs. Unless we find a way of enriching our research endeavour to include this new sort of practice, we will fail to develop methods for meeting the new environmental challenges, with all their complexity and uncertainty. Fortunately, the conditions are ripe, in the broadening social distribution of knowledge and skills. In modern societies, including some of the poor as well as the rich, there are now large constituencies of ordinary people who can read, write, vote and debate. The democratisation of political life is now a commonplace; its hazards are accepted as a small price to pay for its benefits. Now it is becoming possible to achieve a parallel democratisation of knowledge, not merely in mass institutional education but also in enhanced participation in decision-making for the wise management of our scientific powers.

The democratisation of this aspect of science is therefore not a matter of benevolence by the established groups, but (as in the sphere of politics) the achievement of a system which in spite of its inefficiencies is the most effective means for avoiding the disasters that result from the prolonged stifling of criticism. Recent experience has shown that such a critical presence is as important for our technological and environmental issues as it is for society. Let us be quite clear on this; we are not arguing for the democratisation of science on the basis of a generalised wish for the greatest possible extension of democracy in society. The epistemological analysis of post-normal science, rooted in the practical tasks of quality assurance, shows that such an extension of peer-communities, with the corresponding extension of facts, is necessary for the effectiveness of science in meeting the new challenges presented by complex environmental problems.

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