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Interdisciplinary Science and Policy

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PREFACE

On 1 December 1980 the Austrian Federal Ministry for Science and Research and the International Institute for Applied Systems Analysis (IIASA) cosponsored a conference on "Aspects and Perspectives: Science and Research in the New Decade" at the Laxenburg Conference Center.

The meeting was opened by Minister Dr. Hertha Firnberg, who spoke on "Science Policy for Tomorrow." Dr. Sigvard Eklund, General Director of the International Atomic Energy Agency, then presented a paper on "Energy Research - Prerequisites for a Long-term Energy Policy."

This paper is the text of the third and concluding presentation of the session. It is based on the author's experience at two interdisciplinary policy research institutions: fourteen years at the Rand Corporation in the United States and seven years at the International Institute for Applied Systems Analysis.

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One of the central issues of science policy in all nations during the past three decades has been determining how to bring the findings and methods of the sciences and technology to bear on national policy making.

To this end, a great many policies have been tried. Among them have been creation of scientific advisory bodies and scientific advisors directly responsible to policymakers; the establishment of new departments, ministries, agencies, and commissions concerned with science; and the sponsoring of research directly relevant to specific policy problems. While much progress has been made, these efforts have for the most part not returned the benefit of enhanced scientific contributions to policymaking in the degree anticipated or desired by their initiators.

A principal reason for the limited results is the failure in most cases to recognize the different organizing principles of science and policy and to design new institutions that can serve as effective interfaces between them. The thesis of this paper is that most fields of policy require the support not of specific disciplinary sciences, but of truly interdisciplinary science; and to achieve that support will require new institutions and policies, which will in turn require new directions for science policy in the '80s.

I am a mathematician by education and a manager of interdisciplinary policy research by experience. In this paper, I want to use the style of my discipline to express the lessons of my profession. Through a series of propositions, corollaries, and theorems I will try to demonstrate my thesis of relationship between interdisciplinary science and policy: interdisciplinary science is a necessary aid to policy, and special policies are needed, in turn, to achieve useful interdisciplinary science. Strengthening this symbiosis should be a basic goal of science policy in the '80s.

SCIENCE AND POLICY

Let me begin with some basic propositions about the relationship between scientific knowledge and policy. (Here and throughout this paper, I include technology in the term "science" rather than use the longer phrase "science and technology." But this is done for simplicity of expression only; there should be no doubt that technological knowledge is as relevant to policy questions as scientific knowledge.) The central relationship between science and policy in our time is expressed in the first proposition.

> *Proposition 1.* Policymaking in almost every policy arena requires knowledge from science and technology.

In energy policy, for example, the applicability of this proposition is evident. National energy policymakers cannot proceed reasonably without scientific and technological knowledge about energy resources; technologies for energy production, distribution, and use; energy demand to meet social and economic requirements; environmental constraints on energy production and use;and so on. But this proposition is even true for social welfare or cultural policy, where relevant information has been provided by the social sciences about individual and group behavior, and new microprocessor and videorecording technologies are certain to affect future employment and cultural policies. And as in the case of energy, scientific knowledge is obviously needed for policymaking in the communications, transportation, health care, agriculture, environment, resources, and national defense arenas.

Despite the evident desirability of drawing upon scientific knowledge in many if not all of these fields, policy is still made in its absence. There are many reasons for this situation, some the fault of the policy makers, whose education does not always equip or induce them to seek scientific advice; and some the fault of the scientists, who generally do not determine or report the policy consequences of their work. But the purpose of this paper is not so much to explore the reasons why scientific information is not obtained when it should be, but rather to establish the conditions under which such information, if sought, can be most successfully provided.

Often, too, when scientific advice has been solicited in a field of policy, its provision has been monopolized by one group of scientific specialists. For a long time energy was the province of the physicists and engineers, health care the exclusive domain of the physicians, and environmental protection the preserve of the ecologists. However, as the policy questions in each field have become more difficult, attracted more public attention, and overlapped more with other fields, the need to draw upon the knowledge and techniques of other specialties has become more evident.

Economists, environmentalists, and geographers have been called upon to assist energy policymakers. Demographers, social psychologists, operations researchers, and economists have become engaged in health care policy analysis. And the ecologists have been joined by engineers, economists, geographers, and water resource specialists in their concern for environmental policy. These examples can be repeated often and easily enough in other policy areas to justify the second proposition.

> *Proposition 2.* No single field of science possesses all the policy-relevant knowledge in any policy arena.

The reason for this is that science and policy are organized in different ways. The decomposition of the world of action into bureaus--ministries or departments, follows a completely different taxonomy from the decomposition of the world of thought into disciplines--sciences or technologies. The concern of a single bureau then naturally encompasses the interests of many disciplines --and conversely.

While this observation may seem self-evident, it is not in accord with what actually happens. Despite the growing recognition that many fields of knowledge must be consulted in most fields of policy, it is still common practice for the old monopolies to prevail in real policymaking. It takes a long time to change long-established channels and, as we shall note below, the mechanisms for mobilizing assistance from several disciplines have not been well developed.

> Corollary: *Knowledge from several fields of science must be combined to provide proper assistance to policymakers.*

The combination of knowledge from different disciplines can take several forms. There are, for example, the new subdisciplines that are formed at the intersection of two or more traditional disciplines--biophysics, psycholinguistics, mathematical ecology, for example. Such activities might be called <u>cross-disciplinary</u>. Although they have evident importance to the evolution of science, these combinations tend to produce a more sharply focused field, rather than one able to bring the insights of both parent fields to the policy arena. Another form of junction of disciplines is the simple collection of separate contributions of knowledge from several specialities. This kind of combination might be called <u>multidisciplinary</u>, because no real integration is achieved. The third way in which knowledge from several fields of science might be combined is in the form of a single coherent investigation that integrates the insights of all the contributory disciplines. This is what I shall mean by the term <u>interdisciplinary</u>. It is this coherent combination of insights from several fields that is most likely to be responsive to the policymakers' need for information that matches the policy questions they face.

We are now in a position to state the first conclusion of this "mathematical" excercise.

THEOREM 1. *Policymaking requires interdisciplinary research.*

Two further requirements, perhaps self-evident, should nevertheless be stated: interdisciplinary research useful to policymakers will be applied in character and high in quality. The question then becomes: under what conditions can high quality, applied interdisciplinary research be produced?

THE SCIENTIFIC SYSTEM

To learn how to provide good applied interdisciplinary research to the policy community, we must turn to an examination of the characteristics of the scientific community and the scientific system that nourishes it.

Perhaps the most important observation for our purposes is that science is a social activity, which cannot be separated from the aspirations and motivations of scientists nor the incentive structures of their institutions.

Proposition 3. Science is a social activity organized into disciplinary groupings.

The division of science into disciplines is taken for granted; the recognition that the social structure of a science plays an important role in its development is relatively recent. It was given prominence, for example, in the writings of T. S. Kuhn.*

It is now recognized that associated with each established discipline is a corresponding scientific community whose agreement determines what is admitted to the science and the status of its members. The opinion of the community defines "good" science and "good" scientists in the discipline. It follows that members of the community seek, in the first instance, the approbation of their colleagues.

Proposition 4. Scientists seek the recognition of their peers in their scientific community.

The road to that recognition is first of all through publication in the journals of the discipline, entry to which is of course controlled by peer reviewers. And each discipline generally has an hierarchy of other rewards, honorific and real, whose allocation is under the control of the high-ranked members of the community. These range from medals for promising junior researchers, through membership in scientific academies, up to the ultimate achievement of the Nobel Prize.

One role that the scientific communities ordinarily do not have is providing employment for and supporting the research of

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*Kuhn, T.S. The Structure of Scientific Revolutions, 2nd edition, Chicago; University of Chicago Press, 1970.

their members. This is usually the function of the universities, research institutions, and industrial laboratories. However, it is critically important that to a large extent, especially in the leading research institutions, the rewards and advancement of a scientist within one of these institutions are highly dependent upon the recognition accorded the scientist in the disciplinary community outside of the institution. Thus, the academic code phrase "publish or perish" really means "gain the recognition of your disciplinary peers outside these walls or you will receive no recognition inside them."

The need to gain that outside recognition is reinforced by the necessity to keep open the possibility of obtaining employment or advancement at other institutions housing groups from the same disciplinary community.

Thus, the desire for approval by one's disciplinary colleagues is generally one of the strongest motivations of a scientist. On that approval rests the prospects both of scientific honors and of career advancement.

What must a scientist do to acquire that recognition?

> *Proposition 5.* Most scientific communities value fundamental research in the discipline more highly than applied research.

It seems to be generally true that most scientific disciplines place higher value on work of a fundamental, theoretical character than they do on applications of existing knowledge. There are many reasons for this: such work is for the most part more readily publishable and teachable; it is easier to carry out or comprehend by the lone scholar or small groups at the smaller disciplinary outposts; it has the quality of generality, in contrast to the specific relevance of a piece of applied work; it can be picked up, tested, and carried forward by other members of the discipline more readily than an application can. It seems that even subjects of an inherently applied character, such as engineering, often take on in an academic setting the characteristics of the fundamental sciences; the concern for theoretical elegance and publishability overwhelming the engineer's more fundamental interest in design elegance and practicality, and concern for acceptance by one's peers replacing concern for acceptance by the user.

Having explored some of the characteristics of disciplinary science and its practitioners, let us turn for the moment to interdisciplinary science.

> *Proposition 6.* Good interdisciplinary science must be built on the base of good disciplinary science and scientists.

It is worth emphasizing this apparently obvious assertion because its consequences are especially important for the design of interdisciplinary research. It is this requirement that links interdisciplinary science and scientific institutions with the disciplinary communities and that, therefore, sets up the tension with disciplinary incentives that such institutions must face and overcome. Let us, therefore, spend a moment to consider the justification for the assertion.

Imagine for the moment that an interdisciplinary study were made that did not draw only on good disciplinary science. The chances would be high, consequently, that in the fabric of the study there would be information, methods, or approaches that would not be acceptable to one or another of the incorporated scientific disciplines. And it is therefore likely that the entire study would be vulnerable to discrediting by the disciplinary specialists and, consequently, lose its value to policymakers. (Of course, even interdisciplinary studies that incorporate good disciplinary contributions are subject to attack on scientific grounds where the discipline itself still has internal differences; but good disciplinary specialists should be alert to those vulnerabilities and incorporate exploration of the alternative viewpoints in their contributions.)

Because so much of a science is embodied in the training, experience, awareness and judgment of the scientists, the most effective way to be certain that good science will be incorporated in an interdisciplinary investigation is to insure that the participants are all well-qualified representatives of their specific disciplines.

We now come to the crux of the difficulty for interdisciplinary research.

> *Proposition 7.* The normal scientific system discourages the participation of good disciplinary researchers in interdisciplinary research, especially when it is applied.

There are two reasons for this difficulty. First, the peer recognition that disciplinary specialists seek almost invariably arises from success in dealing with questions that originate within the discipline itself and not outside it, as the questions posed by interdisciplinary research do. (Of course, there is the possibility, as has happened on many occasions in the history of science, that an externally-posed question will turn out to be extraordinarily fruitful within a discipline; but without assurance that this will happen, many specialists are unwilling to divert their attention.) Second, interdisicplinary applied work does not have a high probability of leading to work publishable in the discipline's literature.

The consequence of the tension induced by the recognition that, on the one hand, good interdisciplinary research requires the participation of good disciplinary specialists and, on the other hand, that the normal scientific system sets up incentives that discourage the good disciplinary specialists from participating, is that the conduct of effective interdisciplinary research requires the establishment of special new institutions that can set up a pattern of incentives to overcome the tendency for disciplinary separation. This leads to my second conclusion:

> THEOREM 2. *Interdisciplinary research requires new institutions--interdisciplinary research institutions.*

INTERDISCIPLINARY RESEARCH INSTITUTIONS

The basic requirement of interdisciplinary research institutions (IRI) is that they somehow establish motivation and rewards that will bring good disciplinary specialists together in interdisciplinary activity.

> *Proposition 8.* Interdisciplinary research institutions must have an environment and incentive system that balances (i) attractiveness to good disciplinary specialist, and (ii) encouragement of interdisciplinary and applied research.

As a consequence of having to meet these conflicting demands, a good IRI is schizophrenic. To attract first-class specialists it must respond to the incentive structure of the disciplines and, indeed, be accepted by the disciplines as a prestigeful "home" for some of its members. But to achieve applied and interdisciplinary research it must establish a framework of "countervailing" incentives that encourage and reward them to work together in teams of mixed disciplinary composition on problems that lie outside the disciplinary domain.

Generally, this dichotomy has led successful interdisciplinary institutions to some form of two-dimensional internal structure, often called a "matrix" organization. One dimension of organization generally reflects the disciplines. These "departments" function as outposts of the IRI in the discipline and of the discipline in the IRI. Their function is to recruit good scientists from the discipline and provide a local peer group that can motivate and reward them in the light of the standards of the discipline. The second dimension of organization usually reflects a taxonomy of the fields of application--the fields of policy. These "programs" function as the linkage between the IRI and the bureaus of the policy community. Their function is to bring together good scientists from the departments in interdisciplinary teams to work on real policy problems. This two-dimensional internal structure is a concrete representation of the fact that IRI are indeed the "crossing points" between science, organized by a disciplinary taxonomy, and policy, organized by an orthogonal, problem taxonomy.

One important consequence of the necessity for IRI to maintain a delicate balance between the pulls of science and those of policy is that they cannot readily be created and sustained within either the scientific or the policy communities.

> *Proposition 9.* Successful IRI are ordinarily independent of existing research and policymaking bodies.

When an attept is made to create an IRI within a traditional academic scientific setting, as in a university, it ordinarily runs afoul of the very strong underlying disciplinary orientation, which is embedded in both the formal mechanisms for determining rewards and advancement and in the general culture that assigns status and prestige to its members. The tendency then exists for the disciplinary dimension of the IRI to become dominant, and for real interdisciplinary research to degenerate to, at best, multi-disciplinary activities from which each disciplinary specialist extracts his own separately identifiable contribution.

In a similar way, when an attempt is made to create an IRI within a traditional governmental policy setting, it is subject to all the pressures of a bureau to concentrate its attention on problems and leave the disciplinary contacts to the universities. And, of course, the rewards and advancement tend to follow the lines established within the larger governmental setting, emphasizing contribution to the bureau's immediate goals. The tendency in this instance is for the problem dimension to become dominant and for good disciplinary specialists to be driven away, leaving their contribution to be made by less-qualified individuals, not closely connected to the fields.

Thus, the greatest chance for preserving the delicate balance between a scientific and a policy orientation lies in institutions that are independent of both the scientific and the policy communities. But that does not mean that IRI can function completely alone.

> *Proposition 10.* To succeed, IRI must be part of a larger community.

Participants in interdisciplinary research include both those who retain strong ties to their disciplinary homes and those who become specialists in the integrative work needed to produce a truly interdisciplinary study. The former can continue to see their career opportunities as lying primarily in the network of institutions housing their disciplinary community; if progress within the IRI is not satisfactory, they have a broad range of other alternatives. Members of the latter group, however, become separated from their disciplinary communities and the path of advancement it provides. For most talented individuals, limitation to the prospects within a single IRI would not be sufficient to substitute for the greater opportunities in their disciplines. Thus, either sufficient numbers of scientists of talent will not be attracted to the important integrative work of an IRI or there must be enough other IRIs to offer reasonable career paths to those who have diverged from the purely disciplinary path. Since IRI can only succeed if they house talented integrators, it follows that IRIs must be part of a larger community.

What this means is that a single IRI cannot establish by itself the full system of incentives needed to encourage and reward specialists in good, applied interdisciplinary research.

We have now established the third theorem:

THEOREM 3. *Interdisciplinary research requires a new scientific subsystem--a network of independent IRIs.*

In addition to the network of IRIs that provide employment opportunities, there should also be the other kinds of scientific institutions that fulfill critical functions in the social structure of all scientific communities. For example, there should be professional associations to foster and transmit the state-of-the-art through conferences and publications, as well as to provide a formal definition of membership in the community. (In some countries, those who provide the integrative function in interdisciplinary research addressed to policy questions have formed communities under the names "systems analysis" or "policy analysis.")

Creation of the network of independent IRIs will ordinarily require governmental initiative, intervention, and financial support. In most countries this is the only possibility, although in some countries private sources could also play a role. In any event, the difficulty for science policy is posed by the necessitiy that the government support not be given at the expense of the institution's independence. For if the IRI is drawn too closely into the governmental orbit, it is likely to be unable to sustain the careful balance between its policy and disciplinary orientations, which was the original justification for setting it up independently.

Thus science policy must itself strike a critical balance between the encouragement and support of a network of independent IRIs, capable of bringing together and integrating first-class disciplinary science in investigation of policy issues, and the maintenance of their independence in the face of what can sometimes be unwelcome findings.

It should also be noted that truly successful interdisciplinary research is a rare commodity, as are the integrators required to achieve it. Thus, while there is a need to build a network of IRIs, they cannot possibly be built up quickly, nor will all of the seeds planted grow successfully to maturity. Thus, science policy will have to be unusually patient in nurturing the growth of these delicate plants.

This leads, then, to the conclusion of this line of reasoning for science policy in the '80s:

THEOREM 4. *To enable policymaking to draw upon knowledge from science and technology requires special science policies to establish the critical conditions in which good applied interdisciplinary research can be carried out.*