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Problem-oriented research: Between politics and science

1. Technology assessment as "problem-oriented research"

The classic idea that technology assessment (TA) is scientific policy advice in an instrumental sense (Pinkau 1991) has lost its plausibility, at least as far as it contains the image of giving and taking scientific information. Alvin Weinberg (1972) already pointed out that science cannot provide answers to many questions. In the meantime, descriptions of a "politicization of science" and a "scientification of politics" have also become popular, and there is ample opportunity to observe corresponding mixtures of science and politics in which an advisory influence of one side upon the other is hardly discernible. Only rarely is it possible to identify the respective scientific "message" and its political implementation, when it is being "talked to death" in expert disputes and there are no clearly attributable political actions.

Has technology assessment thus lost its guiding principle? Or even the addressee? The never-ending discussion of new TA concepts could be taken as an indication that people are still, or repeatedly, searching for the "actual" idea of TA. For example, in the Netherlands ("constructive TA") or in Denmark ("proactive TA"), new TA concepts are being propagated (Hack 1995), and traditional TA research is ironized as "reactive reporting TA," which starts too late in the development process of a technology and has overly high expectations with regard to its political impact. The "control dilemma of technology development" by Collingridge (1980) is used to locate traditional TA: Between the forecasting problem in the early stages of a technology, when it is a question of early recognition of consequences, and the power problem, when it is more a question of recognizing them at a later stage, traditional TA has located itself close to the power problem (Gloede 1994). It relies on the strength of the argument. "Constructive TA" and "proactive TA," however, would like to intervene in the social process of technology development at the earliest possible stage, and both see the possibility of exerting influence in the form of direct participation in the "seamless web" of technology (Bijker et al. 1987).

Nevertheless, in these as in most other cases of the TA discussion, the old impetus remains: One wants to achieve “better” policy using the means of science. The influence of constructive TA on the “seamless fabric” of social interactions is also politics in the name of science. Although the old formula of scientific policy advice can no longer be used as naively as it perhaps once was, the underlying conception of the problem (the insufficiently informed nature of political decisions) and the solution approach (utilization of science) still seem to be a driving force in the TA movement. The above-mentioned discussions in the Netherlands and Denmark as well as activities at European Union level (Rader et al. 1996) show that these motives have evidently not yet disappeared, despite the equally unflagging resistance and destruction (e.g., in the OTA case). In view of the urgency of old (e.g., environmental problems, North-South conflict) and new problems (e.g., climate change), it would be surprising if politicians did not make use of one of the most important, or at least most expensive, social resources.

However, if it has become evident today that TA cannot be reduced to a purely instrumental relationship to politics, then one would naturally like to know whether, in the light of over twenty years of TA experience, there are not equally evident indications of a different meaning. This essay places this question in the broader framework of the relationship between science and politics. For the practice of technology assessment shows what the theoretical discourse must first laboriously come to an agreement on: The thematic link to technologies is repeatedly abandoned, the projects often go beyond purely technology-related issues, and the approaches and problems often overlap with those of other research areas, such as risk research and environmental research.

This reveals the context of a development that has increasingly taken shape since the Second World War (1939–1945) and is now emerging as a new type of scientific research. As will be shown below, it can be distinguished from basic research and applied research as “problem-oriented research.” There is talk of a change in the function of science since 1945, which is only taking full effect today.

2. The changing relationship between science and society

Beginning with the “Manhattan Project”[1] and the construction of the atomic bomb, the increasing integration of science into the field of politics had begun. A

1 *Editors' note*: The Manhattan Project was a U.S. research and development program during World War II to produce the first nuclear weapons. It was carried out in collaboration with the United Kingdom and Canada.

scientific establishment was formed (Price 1965), which over the years played an important role in the process of policy formulation. Scientists no longer limited themselves to the communication of hard "facts," or to a certain extent to the analysis of clearly comprehensible empirical facts, but also participated in the definition, analysis, and solution of so-called "big problems," as Weinberg once called them.

"Big problems" are, for example, questions of national security, the expansion of the welfare state, and the development of technology programs (Weinberg 1972). Science thus takes on the task of providing an answer to political goals and social needs. Scientific representation of practical contexts, including prognostic services, is increasingly needed for political and social innovations, now that the secondary consequences syndrome (unintended consequences) has grown to an incalculable size. Finally, scientists have also assumed an important interpretative function where, according to current standards of scientific knowledge, only unverifiable knowledge can be obtained, be it in relation to the development conditions of society or in the analysis of possible crises or upheavals in the social process. These more or less plausible interpretations are incorporated into the background knowledge of political decision-makers and form an orientation framework for alternative political strategies. In other words, science leaves its laboratories and intervenes in the public debate.

> Effective policy making required fast what scientists believed they had to offer: objective shifting of the facts, balanced visions, thoughtful reflection and the mobilization of the best wisdom and highest competence (Wood 1964, p. 64).

The political decision-making process now presents itself as an interplay between scientists, professional interest groups, administrative experts, and politicians, whereby the final decision-making power is reserved for the politician, but the scientist increasingly has the power to define and find solutions. However, scientists not only play an influential role in the political process but also in the public sphere. In the major controversies surrounding new technologies (nuclear power, genetic engineering), some of them acted as scientific "entrepreneurs," attempting to use their scientific authority and formal methods to counter criticism of the risks and consequences of the increasing technologization of society (Nelkin 1987). Fields of problem-oriented and applied research emerge that differentiate themselves from the hard core of basic research and develop independent orientations, career patterns, and forms of organization.

This development is intensified and takes on a new quality as the environment becomes a scientific political issue and at the same time a social field of action. It is becoming clear that environmental policy cannot do without scientific analysis. Politics depends constitutively on scientific knowledge both in defining problems and in designing solution strategies. Only with the help of science can environmental changes be measured, environmental quality determined, and causes and possible solutions to environmental problems formulated. In this context, science is not only involved in diagnosis, but also assumes the role of admonisher – either voluntarily or ascribed to it by society. The warning of unintended consequences and forecasts of future dangers and risks becomes a legitimate part of its activities. It becomes an early warning authority for society (Bechmann/Gloede 1991; Bechmann 1994).

The fact that society has been addressing ecological issues for a good twenty years now means two things for science: First, new fields of activity are emerging that require interdisciplinary cooperation, new topics are being created and, last but not least, large amounts of funding are being made available. Secondly, the need for scientific advisory capacity is increasing. Not only politicians, but also companies and associations, insofar as they deal with environmental policy and ecological regulation, need to draw on scientifically-generated knowledge. The rise of the scientific community to a new elite in social decision-making processes is, as it were, an expression of the new and complex tasks facing society as a result of its own development, namely the regulation of increasingly complex social relationships and the regulation of environmental and nature-related issues.

However, as science has taken on this new role, it is confronted with two problems that call into question the traditional self-image of science as rational and value-free:

- It is advancing into areas of application in which even those interdependencies that can still be recorded or even technically generated are no longer controllable. In contrast with "normal science," where science only asks itself questions that it can answer with its own resources, it must be recognized today, particularly clearly in the field of environmental research, that science is reaching the demonstrable limits of its analytical and forecasting capabilities. Known non-knowledge is emerging in a new way.
- With its integration into the political regulatory process, science loses its innocence, which it had propagandistically defended for so long through the norm of value freedom. Value freedom also means, among other things, objectivity of knowledge. What is known scientifically is indisputable knowledge that applies to everyone until proven otherwise, i.e., until refuted. The consensus of the scientific community is the criterion here. It is precisely this that can no longer be maintained in the new areas of application. Knowledge, although produced by scientists using scientific methods, quickly turns out to

> be context-bound, unsystematically acquired, quickly in need of revision and, above all, selective. In other words: It is controversial.

These observations raise the question of how the new and expanding field of science can be understood. There are a number of important studies that attempt to define the phenomenon of "problem-oriented research" in more detail.

3. Characterization and delimitation of "problem-oriented research"

The emergence of "problem-oriented research" can be seen as the science system's response to new demands placed on science by society (Nowotny 1993). More and more problem areas are emerging that have been defined by science, or with its help. "Transdisciplinary" research teams are emerging, i.e., research teams that can no longer be described within the scientific disciplinary structure and that develop knowledge-based solution strategies in cooperation with social groups. But what are the characteristic features of this problem-oriented research, which to a certain extent represents a new type of research?

A look at the literature reveals terms such as "mandated science" (Salter 1988), "postnormal science" (Funtowicz/Ravetz 1993), "science in action" (Latour 1987), or "science for policy" (Jasanoff 1990). As different as these descriptions may be in detail, they agree on the fundamental characterization of problem-oriented research.

First of all, problem-oriented research must be distinguished from *basic research*. Problem-oriented research is centered on problems that arise in the realm of society, while basic research, whose model is knowledge about itself, responds to no other stimulus than that of research itself (de Bie 1973). This definition implies several things.

Problem-oriented research is issue-dependent. Depending on how relevant a problem is considered to be by politics, the public, or the economy, research capacities, funding, and the number of positions increase. Problem-oriented research is therefore directly dependent on social values and their transformation. It must strive to ensure that its definition of the problem is prioritized on the agenda of the major systems. This has an impact on the role and scope of action of the researcher. Not only is the scholar required, but scientists are becoming managers. They generate public attention and know how to direct it toward their field of research (Ingram et al. 1992, p. 46). In some cases, science becomes a political venture with a high risk of failure. In addition, this type of research is conducted under time pressure and in project form.

Problem-oriented research cannot wait until the fundamentals of this field have been clarified in order to collect data and give advice based on well-established theories. On the contrary, even if the theoretical basis is unclear, it must attempt to arrive at sufficiently plausible and argumentatively justifiable solutions using scientific methods. Where basic research has time, problem-oriented research is under pressure to make decisions.

Problem-oriented research is necessarily interdisciplinary or even transdisciplinary. It cannot be expected that social problems can be adapted to the scientific disciplines. This is precisely where the high selectivity of disciplinarily-organized science becomes apparent. In the individual disciplines, more and more highly specialized knowledge is being accumulated through the constant progress of "normal science," but the reaction to interdisciplinary questions is usually helpless, with problems being narrowed down. The expectation of problem-oriented research, however, is to translate social problems into scientific questions and to organize their solutions in an interdisciplinary manner.

However, problem-oriented research also differs from *applied research*. Although the differences here are not as clear at first glance as with basic research, it is evident that applied research is more strongly related to the criterion of useful application. Application means that acquired knowledge is used to solve problems that are given in practice and that can also be expected to provide solutions within the framework of proven practice. In most cases, this a simple repetition: Analytical models, conceptual schemes, techniques, and instruments are applied to a specific problem situation. Furthermore, in applied research, knowledge is prepared in a client-specific way and there is no reference to the public. Direct relationships between client and researcher still prevail here. One could almost speak of an instrumental relationship.

4. The characteristic problems of problem-oriented research

The dependence of problem-oriented research on the political-public decision-making process and its relation to the identification and penetration of social problems creates specific prerequisites that characterize this new type of research.

4.1 The inherent uncertainty

The first and perhaps most important characteristic is dealing with uncertainty. Uncertainty can relate to several dimensions in dealing with knowledge. Uncertainty can initially mean *uncertainty of the knowledge base,* and this is where the most difficult problems arise (Salter 1988, p. 199).

Phenomena such as forest dieback, climate change, but also genetic engineering or AIDS are new, complex, variable in their effects, and still poorly understood. In these cases, there are no well-founded theories or proven findings that problem-oriented science can fall back on. In this case, the basis for robust argumentation must be created with the help of our own research design and by drawing on other disciplines. The preferred means here are computer simulation or expert surveys, statistics, and ad hoc theories (Funtowicz/Ravetz 1990). Nevertheless, this uncertainty remains inherent, as problem-oriented research is not only confronted with complex and new questions, but is also involved in a consultation and decision-making process. It is therefore also under pressure of time and decision-making. It cannot wait until all questions have been scientifically clarified, but decisions must also be made in unresolved situations (Collingridge/Douglas 1984).

This compulsion to make a decision gives rise to a second uncertainty. It can be called *practical uncertainty*. In many cases, science cannot give a clear answer to practical questions. Whether a certain pesticide is causally responsible for an allergy or whether CO_2 emissions contribute significantly to forest dieback cannot be decided unequivocally. Especially when clear causalities are demanded by decision-makers or judges, research usually has to remain silent or refer to further research (Ladeur 1995).

A third uncertainty can be characterized as *methodological uncertainty*. Methodologies usually arise within disciplines in relation to the development of theories or the generation of data. In both cases, there is a chronic shortage in the field of problem-oriented research, so that it has to develop its own methodological standards (Fuller 1993).

A fourth uncertainty is *ethical or normative uncertainty*. Decisions about risks, hazards, and public problems are not only decisions about the content of knowledge but also set standards that determine how people are affected (Ungar 1992). In addition to setting levels of protection, limit values also define the burdens to be endured. If science is involved in this process of standardization at a decisive point it also determines normative patterns. However, values and preferences are controversial in society and cannot be clearly defined. Which threshold value should be followed and what implications does it have for people's lives? Who is disadvantaged, who is favored? These are both cognitive and normative questions to which there are no certain answers. Depending on the state of scientific research, different solutions are found (Beck 1986; Jamieson 1992; Jasanoff 1987).

In summary, the inherent uncertainty of problem-oriented research can be characterized, in the words of Funtowicz/Ravetz, by the fact that the facts are uncertain, the values are disputed, the dangers and risks are high, but the decision is urgent (1993, p. 744).

4.2 The hypotheticality of knowledge

Another feature that distinguishes problem-oriented research from traditional research is the role it plays in the political regulation and decision-making process. The usual understanding of the relationship between politics and science is based on a clear separation of the two areas. Science provides the factual knowledge, politics makes the value-based decisions. Science is characterized by its neutrality and freedom from values, which extends to the establishment of facts and the generation of causal or legal knowledge, while politics makes the assessments and decides on value conflicts. This cozy image of separate worlds that harmonize peacefully with each other has become obsolete, at the latest with the debate about unintended consequences of technological developments and since the controversy about ecological precaution. What is now required of science is not only specialist knowledge, but also predictions about future events that need to be prevented. Sheila Jasanoff gives a precise description of this change:

> These preventive policies placed unprecedented demands on the capacity of science to predict future harm. Fed by images of impending environmental disaster, the public turned to science for more sophisticated methods of identifying and measuring risk. Science responded with a new emphasis on toxicological testing and increased use of predictive mathematical models. But this shift of scientific attention to the unknown, and possibly unknowable, effects of technology highlighted the intuitive, subjective and uncertain underpinnings of much of the advice that scientists provide to government. Moreover, the increasingly adjudicatory style of decision-making in the United States forced scientists to articulate their reservations about their technical assessment and generated questions about the coherence or reliability of policy-relevant science (1987, p. 201).

When investigating the side effects of large-scale technologies and determining the environmental risks of major projects and long-term planning, science comes up against limits that it can prove to be insurmountable in principle. The complexity and diversity of overlapping causal relationships and circular processes cannot be dealt with analytically because the problem orientation prohibits ceteris paribus assumptions, which basic research can use if necessary. The smallest deviations in the initial data, which are unavoidable due to measurement inaccuracies, lead to completely different quantitative and qualitative forecasts in the case of non-linear relationships. This fact, which has been known for a long time, is only now being recognized in its full extent in the context of problem-oriented research, in which the scientific tradition of working with linearity assumptions is losing its value. Such evidence of the fundamental limits of analysis and prognosis means that the certain awareness of scientifically proven factuality is increasingly being replaced by an awareness of the fundamental hypotheticality of science (Häfele 1993). Although scientific methodology can limit arbitrariness, it can never really be reduced to certain statements. Neither with simulation models nor with statistical methods will it be possible to analyze all possible causal relationships.

The belief in the reliability of knowledge, which is used instrumentally for political decision-making and which relieves the burden on politics, is thus questionable in three respects:

From a factual point of view, problem-oriented knowledge is under the sword of Damocles of hypotheticality. The increasingly long decision-making horizons of today's planning and decisions as well as shorter innovation times are leading to the replacement of traditional trial-and-error procedures, which allow technical systems to be successively adapted to situational requirements. They are being replaced by scientifically elaborated long-term planning and probabilistic risk analyses that can only make hypothetical assumptions about reality.

Practical experience and empirical research are increasingly being replaced by models, scenarios, and idealizations. Empirical knowledge is being replaced by subjective assumptions of probability. Damage potentials and damage probabilities can no longer be determined through experience, trial and error, but must be anticipated mentally, as tests cannot be carried out to a sufficient extent, and observations or experiments cannot be repeated at will or may not even be carried out.

In social terms, it is clear that science is losing authority as a result of the dispute between experts. The products of high technology are increasingly giving rise to a socially relevant syndrome of mistrust and insecurity, which is a source of political conflict. With every new accident, the pent-up tensions are released and cause public opinion to explode. Over the last twenty years, technical risk has become the focal point of social insecurities and fears. Belief in progress itself has reached its limits and is turning into mistrust of the supporting institutions of the scientific world.

The delegitimization of experts is only one consequence of this development; another is the loss of legitimacy of state decision-making procedures. The credibility of state decisions is threatened by the decline in reliable knowledge based on personal experience in favor of scientifically-generated hypothetical knowledge, where one must be prepared for revisions at any time. Those who are legitimized by our constitutional norms to make decisions in the name of the common good depend on expert committees to form their opinions; those who possess decision-making knowledge are not legitimized to make such decisions. The result of this process is the loss of a clearly defined responsibility structure, which makes it impossible to clearly attribute responsibility in the event of wrong decisions.

In terms of time, scientific and technological progress creates an excess demand for knowledge compared to the actual generation of knowledge. To the extent that technical development is accelerating and constantly causing changes, every decision – due to the increased involvement of different authorities and the inclusion of ever more complex side effects – requires more and more time.

While this time elapses, the data that gave rise to the need for a decision in the first place changes. If you still want to reach the conclusion of the decision-making process, you have to largely ignore this constantly changing data. The decision is made on the basis of fictitious facts. Marquard sees this as a general feature of our technical culture: The increase of the fictitious (Marquard 1986). Where everything is in flux, any adherence to a decision forces us to flee into fiction, and the boundary between reality and fiction becomes blurred (Marquard 1986, pp. 85–86). For the observer, this leads to a loss of trust in the public decision-making systems, as he can see through the fiction from the outside and denounce it as such. The decision-maker is denied such a perspective.

Dealing with non-knowledge thus becomes a decisive variable in decision-making (Frederichs/Blume 1990). Since we cannot know the future, it is all the more important how this non-knowledge is processed in public decision-making systems; the fact that this problem is still relatively new can be recognized by the fact that there are as yet no elaborated theories for this, let alone procedures or routines that can cope with these new uncertainties.

4.3 The fusion of facts and values

The traditional fiction of a separation of facts and values is difficult to maintain in the context of problem-oriented research: Normative aspects are so obviously intermingled with factual aspects that in many cases, due to strategic argumentation fraught with uncertainties, even the most gullible can no longer adhere to the assertion that science is value-free and neutral. The close relationship between uncertainty in the field of scientific expertise and ethical implications has been mentioned above. Particularly in the case of decisions on risks or environmental problems that have to take into account the impact on third parties, the assumptions of profit or harm to others cannot be separated from the scientific factual analysis. This is especially true when no clear statements can be made about the expected extent of damage and possible opportunities. The question of social and environmental compatibility, a normative criterion, is therefore an inevitable part of the scientific investigation. Just as with limit value conditions, there are no objective markers of the necessary exposure below which it is possible to determine whether something is harmful or harmless. Risk definitions and limit values are the results of consensus/dissent processes in which cognitive arguments must be used to reconcile conflicting interests and decide uncertain facts (Colglazier 1991; Jones 1991; Funtowicz/Ravetz 1993; Jamieson 1990).

There is another factor that blurs the clear distinction between values and data: The inability to predict the effects of new technologies or human intervention in nature. The risk debate has opened up the broad field of hypothetical risks, possible damage that is not known but can nevertheless be assumed. The debate on genetic engineering is one example, the problems of the consequences of possible climate change another in a long series of examples. The discrepancy between knowledge and the consequences of action has only recently become fully apparent. Whereas in the past it was said, first knowledge, then action, today this has been reversed: Action first, and then perhaps knowledge later. This priority of action over knowledge leads to a peculiar reversal of the burden of proof in the environmental debate. It is no longer identifiable dangers and their prevention that play the central role in precautionary policy, but dangers or damage that lie in the distant future, that are unknown but cannot be theoretically and logically ruled out. These arguments are based on theoretical assumptions and possible empirical observations, which are by definition provisional and thus open to falsification by future research (Wynne 1988). Scientific expertise then becomes speculative, and under the conditions of a lack of knowledge, an uncertainty that cannot be resolved, it becomes apparent that scientific knowledge is also tainted by the flaw of being merely conjecture and ad hoc plausibility. It is not for nothing that experts appeal to the trust of their audience (Fischer 1990).

5. The political function of problem-oriented research

The characteristic problems of problem-oriented research mentioned in the previous section are not generally recognized in their fundamental nature. On the contrary, scientists and politicians involved in problem-oriented research often propagate an idealistic image of science that asserts objectivity and freedom from values (Salter 1988, p. 5). This is presumably based on the view that the scientific legitimization of risky decisions is only possible in this way. It is true that no one can deny the insight that science is burdened with the aforementioned problems of uncertainty, hypotheticality, and the normative content of its statements. However, it is assumed that these are deficits which, if not eliminated, can be marginalized by increased research efforts to such an extent that they become negligible.

However, to the extent that science tries to maintain this fiction, it loses credibility. This occurs in various forms, for example, when predictions are made that then fail to materialize. Or when there is talk of value-free research whose implicit values are then proven by lawyers in court. The error also occurs in the form of disciplinary hegemonies, when the claim to interdisciplinarity is undermined by a project organization in which the discipline of the project leader is decisive: The research results are then very quickly relativized by counter-reports in which the perspectives of other disciplines dominate. The loss of credibility is the worst prerequisite for the scientific legitimization of decisions under uncertainty.

The counterfactual idealization of science will be all the less tenable the more urgent and complex the problems that are to be decided. But what then is the point of scientific policy advice? Surprisingly, the starting points for answering this question arise from the radicalization of the previous diagnosis of the problem:

(1) To the extent that scientific statements refer to the future, they can at best only provide estimates of the certainty of their statements. This is why rhetoric, the moment of conviction, takes on an important role in scientific debate. However, this devalues scientific statements to opinions (Luhmann 1991, p. 228f.)

(2) Problem-oriented science is reflexive in a counterproductive sense, in that the conditions, contexts, and consequences of decision-making are changed by feeding scientific knowledge back into the practical process, so that new situations constantly arise to which research must refer. Therefore, one cannot expect that an increased research effort will create more certainty, but rather, on closer inspection, more uncertainty (Giddens 1990).

Scientific statements that can only be regarded as opinions and which, moreover, only increase the uncertainty of the political problem – these are findings that make the claim of scientific policy advice appear completely meaningless. The fact is, however, that scientific policy advice diagnosed in this way is an everyday practice that nobody can do without. The contradiction is resolved when the propagated expectations of scientific policy advice are distinguished from its actual functions. These, in turn, can only be understood if one grasps the full extent of the uncertainty with which political action is confronted.

It is the hallmark of modern society to become increasingly aware of this degree of uncertainty and to look for ways to make legitimate decisions nonetheless. The two deficits of problem-oriented research – the devaluation of the scientific statement to a contribution to the discussion, which could also look different, and the change in the political discussion through precisely such scientific statements, describe exactly what problem-oriented research does: It continues the political and social discourse with scientific means and thus sets up an indispensable barrier against the danger of fatalism spreading in the face of seemingly insurmountable uncertainties, either against the arbitrariness of particular interests or against lethargy and inaction (Stehr 1993, p. 15). For example, we can know almost nothing about the social effects of climate change in the second half of the next century, but we still have to deal with them and do so in a qualified and meaningful way.

The scientific discourse is not the only one that serves this function. Salter (1988), for example, describes a close interweaving of scientific and legal discourse and sees this as a characteristic of problem-oriented research ("mandated science," loc. cit., p. 6). However, the special prerequisite of problem-oriented research for social discourse lies in its scientific nature. For the fundamental lack of knowledge does not lead to arbitrariness in the spectrum of opinions, in which every horoscope maker could appear with the same legitimacy as a scientist. It is not a matter of absolute knowledge, but of provisional, revisable knowledge, which is, however, obtained according to rational methods that can be explicated and argued. Scientific knowledge is characterized by the fact that it is obtained using recognized methods and that it can in principle be understood by anyone who uses the same methods. This does not yet produce unambiguous knowledge – think of the expert disputes – but it does produce knowledge that can be communicated according to democratic rules.

6. Uncertainty and discourse: Structures of "problem-oriented research"

The development of "problem-oriented research," as described in the previous sections, is still relatively recent. Nevertheless, structures can be recognized that are an indication of the direction in which the development is heading in order to guarantee the functional requirements of a meaningful social debate on uncertainty.

In modern society, "uncertainty" is increasingly becoming a topic of new dimensions in various contexts and especially in scientific discussions. This is particularly associated with environmental problems, the coalescence of global society, the risks of technological progress, and other contemporary issues. While the traditional understanding of science saw the reduction of cognitive uncertainty as the scientific goal, this goal is increasingly losing its orientation function with the realization of the insurmountability of many uncertainties. It is being replaced by another goal, the creation of "consensus knowledge," which is not compatible with the traditional understanding of science. This term arose primarily in the context of international climate research – out of the necessity that climate researchers were unable to meet the demands of politics with unambiguous information.

The decisive point in the scientific examination of uncertainty is how the mixture of knowledge and ignorance is structured in the respective situation. This is why factual knowledge and value knowledge are intertwined, and their separation is only carried out pragmatically under the respective conditions of action, and preferably only for a limited period of time. Conversely, this also shows that value judgments cannot be made in a purely normative, so to speak decisional way, but also have cognitive components that are accessible to rational argumentation (Fuller 1993). Problem-oriented research is not merely "applied research," but always also interpretation and evaluation (Ravetz 1987).

Another aspect points to the intrinsic value of scientific expert knowledge. When analyzing complex problems, different disciplines are always involved that do not have a common research approach or a uniform view of the problem. Even the formulation of the problem depends on which scientific disciplines are considered relevant. Which questions are prioritized requires a decision, as otherwise an endless discourse would be set in motion.

Expert judgments are also necessarily based on a conclusion of the analysis in order to reach a decision in the practical problem-solving process. The results essentially depend on the time of this closure, i.e., on the stage at which the research process is then at. Facts are thus generated qua decision and can be changed by new research as soon as the discourse is reopened. Thus, what is considered a fact or recognized knowledge essentially depends on the consensus of the participants that the discourse is concluded. When new participants enter, the situation changes, new facts are discovered, and reality changes. Knowledge in the context of problem-oriented research is always constructed knowledge based on consensus and incompleteness.

The problem is therefore not only scientific uncertainty but also ethical and normative uncertainty as to the criteria according to which hazard and risk management should be carried out. Both uncertainties create a fundamental social contingency with regard to what is possible and what is necessary. As there is neither certain knowledge nor general and binding standards for making recognized and acceptable decisions, it is necessary to generate consensus knowledge. In more recent times, a proceduralization of knowledge generation is often resorted to.

Procedurality refers to the rationality of procedures in the sense that the chosen processes and procedures guarantee the rationality of their results. The connection between such procedures and the rationality of their results can be understood in different ways. The fulfillment of certain procedural conditions can be regarded as conducive to the achievement of rational results, or it can be regarded as a necessary but not sufficient condition for the acceptability of procedural results, and finally it can also be regarded as a sufficient, constitutive condition of rational decisions per se.

It would go too far here to take up the entire discussion on the procedurality of rationality, but what is important for our question is how a way out can also be sought via procedurality against the background of the debate on risk management. Discourse is highly regarded as a procedure for generating consensus knowledge. Without rashly advocating one or the other discourse theory, discourse can be understood as social processes or interactions, which in everyday language are called discussions or – somewhat more scientifically – topic-centered communication.

Central to discourse is the exchange of arguments to answer questions, to solve problems, or to clarify controversial claims. In other words, argumentation is at the center of discourse. Discourses are regulated partly by symbolic rules of operation and partly by pragmatic rules that apply to communication in general or specifically to particular forms of communication. Discourses do not create or set obligations that are relevant to action. They can serve to discover or gain insights of an empirical-cognitive or normative nature.

According to Rawls, scientific discourse can be described as a "quasi-pure" process (Rawls 1979). This means that arguments can be structured by reasons, but due to cognitive uncertainties – whether due to a lack of information or a lack of knowledge of causal processes – arguments must be made consistent by assertions, plausibility assumptions, or evaluations. Two forms of discourse can be distinguished in the context of these procedures: Truth discourses, in which it can be stated under what conditions truthful statements can be expected (Habermas 1973), and epistemic discourses. René von Schomberg has vividly explained the structure of this second type of discourse:

> The discourse around the acquisition of new knowledge can, in my opinion, be reconstructed within the framework of a specific concept of discourse in which arguments have precisely no consensus-enforcing force. I refer to this as an 'epistemic' discourse. Here, the disputing scientists can only refer to arguments that, like analogies, attestation arguments, and counterfactual arguments, articulate an uncertain and insufficient knowledge: Plausibility. Consensus in the strict sense is not reached here because the truth conditions of individual statements cannot be explicated due to the background of uncertain knowledge. In an epistemic discourse, it is not so much the truth of statements that is controversial, but rather the plausibility of theories and hypotheses with which we can assert the recognizability of certain areas of knowledge. The typical arguments of epistemic discourse do not directly serve the argumentative fulfillment of truth claims, but rather the coherent construction of theories, hypotheses, and assumptions with which we can first and foremost reliably open up areas of knowledge. In epistemic discourses, the plausibility of knowledge claims is therefore controversial (Schomberg 1992, pp. 262–63).

If it is precisely epistemic uncertainty that constitutes the actual difficulty of scientific discourse, one must first and foremost ask about the social-organizational form of knowledge-producing or knowledge-mediating discourses. One can, as Habermas does, primarily reflect on the "quasi-transcendental" preconditions of a truth discourse. According to Habermas, only communication in which a problematization of the validity claim of propositions and an argumentation with the aim of verification takes place is worthy of being called a discourse (Habermas 1971). Validity can only be determined by recourse to an "ideal speech situation," the only motive of which is the cooperative search for truth, i.e., communication that is in principle unrestricted and unconstrained, in order to reach an understanding. Understanding here is a normative concept that must be determined counterfactually (Habermas 1971, p. 201). This peculiar mixture of descriptive characterization with the normative stylization of discourses has been criticized many times (Schnädelbach 1977; Giegel 1992): From the perspective of epistemic discourses, which have to struggle with conditions of uncertainty, it becomes apparent that the dissent that occurs there cannot be explained exclusively as a violation of rules of argumentation, but that incommensurable systems of orientation clash here, whose divergence can be traced back to the logical and correct adherence to different rules and norm systems. Even concepts such as communication, understanding, and argumentation are still controversial in this context (Lueken 1992). In principle, it must be left to the participants in the discourse to decide what conditions, rules, and norms they must or want to base their argumentative actions on. Nevertheless, if we do not want to adhere solely to an ideal justification of the discourse, whose idealized conditions can only be followed with an oblique upward glance and a guilty conscience as a norm in the factual events, we must also ask about the practical conditions of the empirically perceptible discourse. There is no doubt that discourses are conducted in society, sometimes even with astonishing success and in a few cases are concluded by consensus.

A real discourse must fulfill two essential, albeit contradictory, conditions: openness and closure (cf. Bühl 1984, p. 95ff.). On the one hand, the discourse must be so open that it allows room for new ideas and the expression of different views; on the other hand, however, a certain amount of pressure must be exerted for theoretical integration and the continuous working through of shared knowledge. Based on this understanding of the problem, some organizational criteria can be specified.

Firstly, a fruitful discourse should allow for a broad diversity of topics, people, and viewpoints. This determines its adaptive capacity, namely the extent to which the discourse is able to process uncertainty and variety. At the same time, a high degree of variety requires a structured discourse community that is organized according to rules. Secondly, there must be a willingness for variable interaction; the participants must be prepared to communicate with everyone and on all topics. Interdisciplinary perspectives and interpersonal understanding are essential prerequisites. Diversity has its limits where the collective identity and constitutive factors of the members' common orientation are called into question (procedural rules). Here too, a reciprocal relationship between openness and closure is an essential prerequisite. Thirdly, knowledge discovery and knowledge verification must be separated in discourses, an old theme in the philosophy of science (Popper 1966, p. 6f.). Knowledge discovery is about discovering and constructing new elements of knowledge, regardless of the methodological level at which this occurs. Knowledge testing is about integrating the newly acquired knowledge into the existing body of knowledge, that is, about logic, consistency, generalizability, theoretical relevance, i.e., overall about cognition and acceptability.

These three organizational principles – diversity, variability, and separation – can be found in different forms and combinations in the various types of discourse – practical discourse, scientific discourse, and cultural discourse. The idea of discourse makes an essential insight of problem-oriented science its fundamental principle: That scientific knowledge is always only valid under hypothetical conditions, that it can be changed at any time, and that the mutual increase of consensus and dissent is to be regarded as an essential motor of knowledge expansion.

Discourses are aimed at the cognitive prerequisites of decisions. Here, interpretation and evaluation divergences are at the center of the process. Agreement must be reached on the validity of empirical results, the plausibility of theories and propositional systems, and on stringent argumentation and interpretations (Bora/Döbert 1993; Hennen 1994).

The difficulties in the discourse can be seen in the meaningful termination. When is a debate over? Who concludes it and with what arguments? What is characteristic, however, is the self-reference of the discourse, i.e., its capacity for self-transformation. The capacity for self-transformation consists in the fact that in the process – and nowhere else – both the learning conditions under which new assumptions of reality arise and the specification of consensus-building structures, consensus content, and problem-solving strategies are generated. In this respect, it can be said that the process is both the path and the goal.

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