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Inter-und Transdisziplinarität im Wandel?

Neue Perspektiven auf problemorientierte Forschung und Politikberatung

Expert Advice and the Vast Sea of Knowledge

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1. Introduction

Mathematician Alexander Ostrowski once observed that when he took his qualifying examination for a Ph.D. in mathematics (around 1915) that he needed to be prepared to answer any question in any branch of the study of mathematics (Davis and Hersh 1981). By the 1980 s Davis and Hersh (1981) estimated that the average Ph.D. candidate in mathematics could be expected to have acquired knowledge equivalent to about 60 to 80 volumes worth of books from what was by then an ocean of perhaps 60,000 books of mathematics knowledge available. The explosion of knowledge in mathematics is representative of a broader trend: in any area of knowledge the expert can know only a tiny fraction of the material available in his or her area. Davis and Hersh observe further that the amount of available knowledge in mathematics is small when "compared to other collections, such as physics, medicine, law, or literature."

In 2008 the accelerating production of knowledge is mind boggling. According to Thompson Scientific, a major bibliographic and citation tracking service, in 2008 the natural and social sciences together saw about 23,000 new articles published every week in more than 9,500 academic journals.[1] Traditional disciplines have repeatedly furcated and these subdisciplines have fused with other areas of knowledge to create interdisciplinary fields, multiplying the areas of study as well as the substantive content. As available knowledge grows and grows the human assimilative capacity remains roughly constant. One might be forgiven for thinking that the task of bringing knowledge to bear upon decision making is thus an impossible task. Information flows from the research community like a pouring rain filling the vast sea of knowledge, threatening to swamp both the policy analyst and the policy maker.

Yet information very often matters in decision making. And decision making has the potential to profoundly influence outcomes. So while scholars have recognized that the role of information in the process of achieving desired outcomes is quite complex, it is no understatement to observe that the production and effective use of knowledge can serve an influential, and potentially very positive role, in realizing collective human aspirations. Hence, society has not given up on producing evermore knowledge to aid policy making, far from it.

But realizing the potential value of knowledge is not the same thing as realizing that potential in practice. What knowledge? How produced? For what priorities? And crucially, how brought to bear upon specific decisions? These questions and others like them have occupied the attention of scholars who have been studying science in society for many years and decades. In this chapter I seek to explore how different answers to

1 http://images.isiknowledge.com/help/WOS/h_database.html. Less than 80 % of the articles are published in the social sciences. Articles in the arts and humanities, not included here, would add another 2,300 articles per week in 1,160 journals.

these questions imply very different approaches to the organization of knowledge production, the roles of experts and their relationship to decision makers.

Part II of the Chapter begins by introducing a simple framework of four idealized roles played by experts in an advisory process. The idealized framework is then used in Part III to illustrate how different types of knowledge take on differential importance in the far more complex context of real-world situations in which experts seek to characterize opportunities for action and to inform decision making. Part IV emphasizes the importance of problem definition as the essence of transdisciplinary knowledge that connects information with action, and thus is the key intellectual exercise for knowledge to serve practical purposes.

2. A Framework for Expert Advice

You need only glance at your computer screen and the deceptively austere internet search page of Google to understand that today we have more access, more quickly, to the vast sea of knowledge that modern technology has made available than ever before. But simply having knowledge readily available does not imply that it will also be useful or used. Scholars in science and technology studies, and in related fields, have developed a robust vocabulary for describing and characterizing efforts to make effective use of the abundant knowledge, including both the scholarly and other forms of knowledge. Thus concepts – such as Mode 2, well-ordered science, new social contract, socially robust knowledge, serviceable truth, post-normal science and others – have found their way alongside conceptions of disciplinary, multidisciplinary and transdisciplinary to create both intellectual frameworks and a vocabulary that allows for a deeper understanding of the challenges that await when dipping your toe into the vast sea of knowledge.

The valuable work that seeks to connect the burgeoning knowledge about the role of knowledge in decision making – ironically enough – represents a further contribution to this vast sea. In an effort to make that knowledge useful, I have sketched out a very simple framework for the various roles that experts might play in advising decision makers. The framework is perhaps best illustrated by an extended analogy.

When former US Vice President Al Gore testified before the United States Congress in 2007 he used an analogy to describe the challenge of climate change:

> "If your baby has a fever, you go to the doctor. If the doctor says you need to intervene here, you don't say, "Well, I read a science fiction novel that told me it's not a problem." If the crib's on fire, you don't speculate that the baby is flame retardant. You take action."

With this example Al Gore was not only advocating a particular course of action on climate change, he was also describing the relationship between science (and expertise more generally) and decision making. In Mr. Gore's analogy, the baby's parents (i. e. in his words, "you") are largely irrelevant to the process of decision making, as the doctor's recommendation will be accepted without question.

But anyone who has had to take his or her child to a doctor for a serious health problem or an injury knows that the interaction between patient, parent, and doctor can take a number of different forms. In my book The Honest Broker (Pielke 2007), I describe various ways that an expert (e. g., a doctor) might interact with a decision maker (e.g., a parent) in various ways that might all lead to desirable outcomes (e.g., a healthy child). Experts therefore have choices in how they relate to decision makers, and these choices have important effects on decisions but also on the role of experts in society.

Mr. Gore's metaphor provides a useful point of departure to illustrate the four different roles for experts in decision making that are discussed in The Honest Broker. The four categories are very much ideal types – the real world is more complicated, but nonetheless I do argue that they help to clarify roles and responsibilities that might be taken by experts seeking to inform decision making.

- The Pure Scientist – seeks to focus only on facts and has no interaction with the decision maker. The doctor might publish a study that shows that aspirin is an effective medicine to reduce fevers. That study would be available to you in the scientific literature.
- The Science Arbiter – answers specific factual questions posed by the decision maker. You might ask the doctor what the benefits and risks associated with Ibuprofen versus Acetaminophen as treatments for fever in children are.
- The Issue Advocate – seeks to reduce the scope of choice available to the decision maker. The doctor might hand you a packet of a medicine and say "give this to your child." The doctor could do this for many reasons.
- The Honest Broker of Policy Options – seeks to expand, or at least clarify, the scope of choice available to the decision maker. In this instance the doctor might explain to you that a number of different treatments is available, from wait-and-see to taking different medicines, each with a range of possible consequences.

Scholars who study science and decision making have long appreciated that efforts to focus experts only on the facts, and to keep values at bay, are highly problematic in practice. As Sheila Jasanoff wrote: "The notion that scientific advisors can or do limit themselves to addressing purely scientific issues, in particular, seems fundamentally misconceived." (Jasanoff 1990). How does the overlap of science and values occur in practice?

The answer to this question is that it depends. It depends on the context of decision making, which is located in a broader societal context of values, institutions, culture, interests, uncertainties, and many other factors.

For instance, consider the Pure Scientist or Science Arbiter as described above. How would you view your doctor's advice to take Ibuprofen if you learned that he or she had received $50,000 last year from a large company that sells Ibuprofen? Or upon hearing advice to perhaps forgo medicine for this particular ailment, what if you learned that he or she happened to be an active member of a religious organization that promoted treating sick children without medicines? Or if you learned that their compensation was a function of the amount of drugs that he or she prescribed? Or perhaps the doctor was receiving small presents from an attractive drug industry representative who stopped by the doctor's office once a week? There are countless ways in which extra-scientific factors can play a role in influencing expert advice. When such (trans-disciplinary) factors are present they can lead to "stealth issue advocacy", which I define as efforts to reduce the scope of choice under the guise of focusing only on purely scientific or technical advice. Stealth issue advocacy has great potential for eating away at the legitimacy and authority of expert advice, and might even be called a corruption of expert advice.

Then how does one decide what forms of advice make sense in what contexts? In The Honest Broker I argue that a healthy democratic system will benefit from the presence of all four types of advice (with the same actor even taking on different roles in different situations) but, depending on the particular context of a specific situation?, some forms of advice may be more effective and legitimate than others. Specifically, I suggest that the roles of Pure Scientist and Science Arbiter make the most sense when values are broadly shared and scientific uncertainty is manageable (if not reducible). An expert would act as a Science Arbiter when seeking to provide guidance to a specific decision and as a Pure Scientist if no such guidance is given. (In reality, the Pure Scientist may exist more as historical legend than anywhere else.) In situations of values conflict or when scientific certainty is contested, that is to say mostly every political issue involving scientific or technical considerations, the roles of Issue Advocate and Honest Broker of Policy Options are most appropriate. The choice between the two would depend on whether the expert wants to reduce or expand the available scope of choice. Stealth issue advocacy occurs when one seeks to reduce the scope of choice available to decision makers but couches those actions in terms of serving as a Pure Scientist or Science Arbiter (e. g., "The science tells us that we must act...").

So imagine your child is sick and you take him to the doctor. How might the doctor best serve the parents' decisions about the child? The answer depends on the context.

- If you feel that you can gain the necessary expertise to make an informed decision, you might consult peer-reviewed medical journals (or a medical web site) to understand treatment options for your child instead of directly interacting with a doctor.
- If you are well informed about your child's condition and there is time to act, you might engage in a back-and-forth exchange with the doctor, asking him or her questions about the condition and the effects of different treatments.
- If your child is deathly ill and action is needed immediately, you might ask the doctor to make whatever decisions are deemed necessary to save your child's life, without including you in the decision making process.
- If there is a range of treatments available with different possible outcomes, you might ask the doctor to spell out the entire range of treatment options and their likely consequences to inform your decision.

The interaction between expert and decision maker is complicated, and understanding the different forms of this relationship is the first step towards the effective governance of expertise. We have choices in how experts relate to decision makers. These choices shape the ability to use expert advice well in particular situations, but also shape the legitimacy, authority, and sustainability of expertise itself. Whether we are taking our

children to the doctor, or seeking to use military intelligence in a decision to go to war, or using science to inform policies, better decisions will be more likely if we pay attention to the role of expertise in decision making and the different forms that it can take. But these choices are also informed by, and subsequently shape, our thinking and action with respect to the production of knowledge, and this relationship between knowledge, advice, and action is emphasized in the remainder of this chapter.

3. Context: Disciplines, Problems, and Decisions

With the four roles for experts presented in The Honest Broker providing a simple framework for modes of interaction between experts and decision makers, we can now probe a bit deeper into the nature of decision making, in order to orient the taxonomical structure of the modern knowledge enterprise with the challenge of providing useful advice. I argue that views on expert advice are a function of the perspectives that we hold about the nature of democracy and the role of experts in a democracy. Consequently, how each of us thinks about the Pure Scientist, Science Arbiter, Issue Advocate, and Honest Broker of Policy Alternatives is likely related to our beliefs about two relationships: (a) the role of science in society, and (b) the role of the expert in a democracy.

One well-understood conception of how democracy serves common interests is that competing factions engage one another in political debate, and the resulting compromise reflects the best possible balancing of conflicting demands. Political scientists have called this notion of democracy "interest group pluralism", and it is well described in the writings of James Madison (1787), e. g., as is found in Federalist 10, which Madison wrote when arguing for adoption of the original US Constitution in the late eighteenth century. Under such a view of Madisonian democracy, experts would best serve society by simply aligning themselves with their favoured faction or interest group, and offer their special expertise as an asset in political battle. From this perspective on the role of experts in a democracy, it is a virtue for scientists to take a more proactive role as advocates in political debates seeking to use their authority and expertise as resources in political battles.

An objection to such a conception of democracy, and the role of experts it implies, was offered by political scientist E. E. Schattschneider in his book The Semi-Sovereign People (Schattschneider 1975). He argued that democracy is a competitive system in which the public is allowed to participate by voicing their views on alternatives presented to them in the political process. Such alternatives do not come up from the grassroots anymore, like you or I would not tell an auto mechanic what the options are for fixing a broken car. Policy alternatives come from experts. It is the role of experts in such a system to clarify the implications of their knowledge for action and to provide such implications in the form of policy alternatives to decision makers who can then select among different possible courses of action.

These different perspectives on democracy are to be complemented by different views of the role of science in society. In the post-World War II era many scientists and policy makers in the United States adopted a perspective on science that scholars have called the "linear model." This model takes two forms, one as a general model for how to make decisions about science, emphasizing the importance of basic research. The linear model will be familiar to most in terms of a metaphor that represents a flow of knowledge, presumably through some gravity-like attractive force, from basic research beyond applied research to development, and ultimately to societal benefits.[2] Since World War II, the linear model has been used to advocate policies for science that emphasize the importance of basic research and freedom for scientists from political accountability.

"Basic research" is a complex concept representing different ideals to different groups that use the phrase. For many scientists the phrase conjures up the notion of "pure research" which in its ideal form refers to the romantic pursuit of knowledge for knowledge's sake, unfettered by the need to prove relevance of extrinsic value. At the same time, for many policy makers the notion of "basic research" suggests that such research is "basic" to goals of economic development and growth. The concept thus captures two almost contradictory perspectives, which helps to explain its importance in maintaining the linear model as an underpinning of contemporary science policies. In recent years, phrases such as "transformational research" (in the US) and "frontier research" (in the EU) have been suggested to supplant "basic research", but it remains uncertain if these will gain standing.

"Basic research" also has implications for the provision of knowledge to decision makers. The conventional norms of science suggest that such research is best conducted by researchers whose proposed work and completed analyses are judged by a group of their intellectual peers. Thus, basic research conforms nicely to a disciplinary structure of knowledge where relevant peers are defined as members of the same disciplines. The logic of peer review has been extended to various multidisciplinary contexts, with varying degrees of success, such as when the disciplines are closely connected (e. g., ocean and atmospheric modelling), and even results in the creation of new subdisciplines (e. g., biogeochemistry). But "basic research" becomes problematic when sought to be placed into a transdisciplinary context, as the tensions between basic as "pure" and basic as "applied" cannot be avoided. Efforts to implement the so-called "second review criterion" focused on the criteria 'societal impacts', at the US NSF illustrate this tension (Holbrook 2006).

This tension is also reflected in a second, more specific form of the linear model, i. e. as guidance for the role of science in the context of specific decisions. Here the linear model is often used to suggest that achieving agreement on scientific knowledge is a prerequisite for a political consensus to be reached and then policy action to occur. For instance, this perspective is reflected on the website of the US Environmental Protection Agency in its description of the role of science in the agency: "Through research that is designed to reduce uncertainties, our understanding increases and, as a result, we change our assumptions about the impacts of environmental problems and how they should be addressed." (EPA 2006). In even stronger forms, some use the linear model to argue that specific knowledge or facts compel certain policy responses on topics as varied as the availability of genetically modified foods or over-the-counter emergency contraception.

Arguments that a particular fact or body of knowledge compels a particular decision have been generally critiqued in terms of what is called the "is-ought problem" first raised by philosopher David Hume, who argued simply that you can't get an "ought" (i. e., something which should be done, or an answer to a "normative" question) from an "is" (i. e., a statement of fact, or an answer to a "positive" question). Even so, claims that facts compel certain actions are frequently found in political debates involving scientific issues.

The linear model in both of its forms has been challenged by a range of scholars who have characterized it as descriptively inaccurate and normatively undesirable. Science policy scholar Harvey Brooks offers an alternative view to the linear model in terms of a complex pattern of feedbacks between researchers and decision makers:

> 'If the process of using science for social purposes is thought of as one of optimally matching scientific opportunity with social need, then the total evaluation process must embody both aspects in an appropriate mix. Experts are generally best qualified to assess the opportunity for scientific progress, while broadly representative laymen in close consultation with experts may be best qualified to assess societal need. The optimal balance between opportunity and need can only be arrived at through a highly interactive, mutual education process involving both dimensions' (Brooks 1995, 33).

Similar alternatives to the linear model have been offered by Donald Stokes in the notion of "use-inspired basic research" and Philip Kitcher with "well-ordered science" (Jasanoff 1990; Nowotny et al. 2001; Sarewitz 1996; Wynne et al. 2005). Each of these perspectives suggests some form of a "stakeholder model" of/as the relationship between science and decision making. A stakeholder model holds not only that the users of science should have some role in its production but that considerations of how science is used in decision making are an important aspect of understanding the effectiveness of science in decision making.

Combinations of these different conceptions of democracy and science provide a simple and straightforward theoretical basis for the four idealized roles for scientists (and experts more generally) that I discuss in The Honest Broker. But they also imply very different roles for knowledge (and thus the disciplines, subdisciplines, multidisciplinary, and interdisciplinary investigations) in the process of providing advice to decision makers, with different definitions of "advice" in each context. These different roles for knowledge and conceptions of advice, in turn, suggest a range of ways to think about disciplinary and interdisciplinary knowledge. In the sections that follow I explore the roles of the disciplines and advice in the context of the four categories of interaction between experts and decision makers.

2 Indeed, the title of this chapter can be read as a play on the "reservoir" analogy of knowledge "flowing" to inform decision makers.

3.1 Pure Science

"Pure science" may only be an abstraction. But in its ideal form it is the pursuit of knowledge for knowledge's sake, with absolutely no consideration for its use by decision makers. In practice, it is hard to identify any such situation. When patrons, including the public and their representatives, provide support for research, they do so with some expectation that those investments will lead to some benefits to the sponsor. Expectations of socially useful results from research are the case for research that is characterized as "basic," "fundamental," or "transformative", using terms that conjure up the ideal of pure research. And scholars have documented that a wide range of extra-scientific factors play a role in the conduct of research, even if it concerns a kind of research that does not explicitly focus on informing decision making (Jasanoff 1990). Such factors are important to consider when discussing the historical evolution of knowledge production, but go well beyond the scope of this discussion.

Once research is conducted with the expectation that it will be useful in decision making, then it no longer fits into the category of "pure research" and thus must be considered in one of the remaining three categories discussed below. If the research is indeed "pure", then it is not relevant to the present discussion. In either case, we can leave the notion of pure research behind at this point.

3.2 Science Arbitration

The Science Arbiter seeks to stay removed from explicit consideration of policy and politics like the Pure Scientist, but recognizes that decision makers may have specific questions that require the judgment of experts, so unlike the Pure Scientist, the Science Arbiter has direct interaction with decision makers. The Science Arbiter seeks to focus on issues that can be resolved by science, which may originate in questions raised by decision makers or debate among decision makers. In practice, such questions are sent for adjudication to the scientist(s), who may be on an assessment panel or advisory committee, which then renders a judgment and returns scientific results, assessments or findings to the policy makers. A key characteristic of the Science Arbiter is a focus on positive questions that can (ideally) be resolved through scientific inquiry. In principle, The Science Arbiter avoids normative questions and thus seeks to remain apart from the political fray, preferring to inform decision making through relevant research or assessments, but removed from a closer interaction with stakeholders. Of course, the presence of multiple disciplinary perspectives on particular questions, or fundamental irreducible uncertainties may in practice limit the role of the Science arbiter.

For instance, on many contested issues scientists rarely speak with one voice, and sometimes these voices can be differentiated politically based on disciplinary perspectives. Sarewitz (2004) observes the GMO debate as follows:

> "... scientists from disciplines involved in design and application of GMOs, such as plant geneticists and molecular biologists, would be potentially more inclined to view GMOs in terms of their planned benefits, and ecologists or population biologists would be more sensitized to the possibility of unplanned risks at a systemic level."

A diversity of perspectives on scientific questions is a form of uncertainty, or perhaps more accurately "competing certainties" (Thompson et al. 2006). It is in the presence of substantial uncertainties that science arbitration breaks down, as there is no way then to resolve fundamental uncertainties, whether they arise from the nature of the subjects being studied or the sociological context of science. Whether we like it or not, the presence of uncertainty forces expert advisors into a transdisciplinary context. Ironically, in many cases it is disciplinary diversity that makes a transdisciplinary perspective necessary.

In situations where uncertainties are manageable, or even reducible, Science Arbiters can take the form of a formal, authoritative committee or organization, such as committees under the US National Research Council or a federal agency. Individual scientists also seek to be Science Arbiters when they seek to answer questions posed by policy makers or the media. The defining characteristic of the Science Arbiter is a focus on positive scientific questions posed by decision makers. Successfully arbitrating positive scientific questions is replete with incentives to engage in issue advocacy, and thus in practice can be a difficult role to fill.

Examples of science arbitration can be found, for example, in many of the reports of the US National Research Council (NRC), which receives requests from the US Congress to answer technical or scientific questions. One recent example is a report of a NRC Committee titled "Hydrology, Ecology, and Fishes of the Klamath River Basin" (National Research Council 2008). The charge of this committee is reproduced in table 1.

Table 1: Example of the charge given to a committee reviewing stream flow and fish biology of the Klamath River Basin.

A multidisciplinary committee will be established to evaluate new scientific information that has become available since the National Research Council issued its 2004 report "Endangered and Threatened Fishes in the Klamath River Basin" (National Research Council 2004). The new information to be evaluated by the committee will include two new reports on (1) the hydrology of the Klamath basin and (2) habitat needs for anadromous fish in the Klamath River, including Coho salmon. The committee will also identify additional information needed to better understand the basin ecosystem.

To complete its charge, the committee will

- review and evaluate the methods and approach used in the Natural Flow Study to create a representative estimate of historical flows and the Hardy Phase II studies, to predict flow needs for Coho and other anadromous fishes.
- review and evaluate the implications of those studies' conclusions within the historical and current hydrology of the upper basin; for the biology of the listed species; and separately for other anadromous fishes.
- identify gaps in the knowledge and in the available scientific information.

Table 1 shows that the committee is narrowly focused on very technical questions involving the historical stream flow of the basin, the relationship between stream flow and fish biology, and the limits and uncertainties on what is known about these factors. In this case, answering these questions requires the input of a range of expertise from across traditional disciplines. But science arbitration does not need to be interdisciplinary, if the questions being posed by decision makers to experts are sufficiently narrow and covered by the expertise in a single discipline.

The NRC Klamath report is quite explicit that the knowledge that it presents does not compel particular decision outcomes, and suggests a stakeholder-based approach to the actual process of decision making:

> "The committee does not presume to know the exact contours of a mechanism for dealing with the intersection of science and policy for the Klamath River basin, because these arrangements are best designed by the people who live there and who participate in the agency frameworks already in place." (National Research Council 2004, 197)[3]

Recognizing a distinction between advice and decision making does not always occur in the advisory process. For instance in 2007, a member of the California legislature proposed that all young girls in California be immunized against cervical cancer with a specific vaccine called Gardisil (Walters 2007). The proposal proved controversial, and so the proposed legislation was changed to say that whatever advice was proffered by the federal Advisory Committee on Immunization Practices would become the basis for California law. But this step would have erased any distinction between advisor and decision maker, meaning that the recommendation of the advisory committee would have in fact been a decision on vaccination. The stealth issue advocacy in this case was not really stealth, leading to controversy over authority for decision making in this case, and the bill was ultimately revised to place the burden of decision making upon the California State Public Health Officer.

Walters (2007) cites another case from California, in which legislators have proposed that all buildings built or leased by the state must meet the environmental standards of an organization called the US Green Building Council. Walters explains why such a conflation of advice and decision making is problematic:

> "By all accounts, USGBC is a legitimate organization that acts as a forum for agreements on environmentally friendly building standards. But it's not the only organization doing that work. At any rate, the standards it decrees and the methods that it uses to drat those decrees are matters of its internal politics – including influence from those who support it financially – and are shielded from input by the outside world."

Thus, the primary challenge of effective science arbitration lies not in simply securing the proper disciplinary or interdisciplinary knowledge (which is challenging enough in itself in some cases), but in asking questions that can be answered by the expert community while maintaining a functional distinction between advice and decision making. In other words, effective science arbitration means avoiding issues of transdisciplinarity.

3 http://books.nap.edu/openbook.php?record_id=12072&page=197.

3.3 Issue Advocacy

The Issue Advocate focuses on the implications of research for a particular political agenda. Unlike the Pure Scientist, the Issue Advocate aligns him- or herself with a group (a faction) seeking to advance their interests through policy and politics. The Issue Advocate accepts the notion that science must be engaged with decision makers and seeks to participate in the decision making process.

Issue Advocates are found everywhere, and science is no exception. Whether the issue is a presidential election, the Nuclear Test Ban Treaty, or the Kyoto Protocol, many scientists are willing to take sides in a contested political issue, and are using their status as scientists, or invoking their specialized expertise, to argue for their cause. For some scientists advocacy poses difficult questions. For instance, the 2006 meeting of the Society for Conservation Biology held a debate on whether conservation biologists should engage in overt advocacy or instead should strive to stay away from politics and focus only on science (Marris 2006).

Advocacy also requires the integration of knowledge, and particularly knowledge of valued outcomes, but it does not necessarily require multi- or interdisciplinary expertise. Society values experts to the degree that simply having an advanced degree (usually in a mathematical or natural science-based discipline) is sufficient to wield considerable authority in policy debates, representing the personification of the linear model. Politicians and other advocates for particular causes often explain that "experts tell us that we must..." is a construction that reinforces the authority of experts, but at the same time shifts accountability for action from the politician to the advisor.

Advocacy always involves a normative dimension. In situations where values are broadly shared and desired outcomes are not in dispute, knowledge may appear as if compelling a particular outcome. In the Honest Broker I suggest that knowledge of an approaching tornado will typically be sufficient to compel a group of people to act alike based on the information, since all of them share a desire to stay alive and out of harm's way.

There is a tendency for advocates to present an agenda grounded in advocacy in the cloth of science, either as a Science Arbitrator or even as a Pure Scientist, above the fray. For example, consider a press release issued by the UK Royal Society in 2004, which asserted that science compelled implementation of the Kyoto Protocol approach to climate change:

> "The news that the Kyoto protocol is set to become international law is a victory for the climate. The protocol is an essential first step towards stabilising atmospheric concentrations of greenhouse gases. We must now see concerted action by all signatories of the treaty to meet their targets to reduce greenhouse gas emissions in the international effort to fight climate change. And there is no room for complacency. (…) In addition it is sobering to remember that, if the world really is serious about avoiding the worst effects of climate change, the science tells us we need to see major greenhouse gas emission reductions in developed countries – which will dwarf the approximately five per cent which Kyoto accounts for. Therefore, the Royal Society urges

Tony Blair to use the UKs presidency of the G8 to drive forward the global climate agenda and maintain the momentum that Kyoto has begun."[4]

The endorsement of the Kyoto process by a national science academy raises broader questions of the roles that national science academies play in policy and politics. For instance, in 2005 eleven national science academies sent a letter to "world leaders, including those meeting at the Gleneagles G8 Summit in July 2005", advocating a number of specific policy actions on climate change. The letter – from science academies in Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, the United Kingdom, and the United States – was released to increase pressure for action among members of the G8.

Upon release of the statement, the head of the UK Royal Society, Lord Robert May, said that the US National Academy of Sciences had made specific policy recommendations in an earlier report on climate change, and these recommendations had been rejected by President Bush:

"The current US policy on climate change is misguided. The Bush Administration has consistently refused to accept the advice of the US National Academy of Sciences."[5]

In a letter, the president of the US National Academy of Sciences responded strongly to the suggestion:

"Your statement is quite misleading... [and] considerably changed our report's meaning and intent. As you must appreciate having your own misinterpretation of the US Academy work widely quoted in our press has caused considerable confusion, both at my Academy and in our government. By advertising our work in this way, you have in fact vitiated much of the careful work that went into preparing the actual G8 statement."

Lord May responded brusquely:

"I can understand that the Academy may have received criticism for re-stating its position so clearly and so appropriately now. It is clear not a politically convenient message for the US Government."

It is unlikely that the public spat between the science academies added to the influence of the 11-academies letter to the G8. But it did reflect the challenges of public advocacy among science academies that have historically taken on a role more accurately characterized as science arbiters. In this case the transition from multidisciplinarity to transdisciplinarity was not so smooth.

There are at least three reasons why political advocacy by science academies should be greeted with caution: As the public disagreement between the US National Academy of Sciences and the UK Royal Society suggests, one reason is simply practical – science academies have much to lose (including stature, legitimacy, public funding, etc.) if they take on the characteristics of an advocacy-oriented interest group. Regardless of the merits of the actions on climate change called for by the 11 academies, by endorsing a particular political agenda the academies may compromise their future ability to serve as resources for policy makers on scientific issues. After all, one reason that policy makers look at science academies to provide reports on science rather than at, say, pharmaceutical companies or environmental groups, is because policy makers believe that science academies will not shape science to fit a pre-existing political agenda. By endorsing a political agenda, science academies begin to resemble these other groups.

The second reason has to do with the needs of policy making – sometimes all of the available options on a particular issue are bad ones. Climate change provides a clear example, as the options currently being debated and implemented, both on mitigation and adaptation, are not proving particularly effective. Yet, in their letter, the science academies are, in effect, calling for renewed support of the current approach to emissions-reduction under the Climate Convention that has proven woefully inadequate over more than a decade. Sometimes effective policy making requires more than just picking sides in a two-sided debate – specifically, the introduction of new and innovative possibilities for action. One of the most important, but often overlooked lessons of national and international responses on ozone depletion and acid rain is that new options can break a stalemate (e. g., substitutes for chlorofluorocarbons in the case of ozone depletion, or tradable permits in the case of acid rain). When science academies engage in political advocacy by taking a side in an existing debate, they miss their opportunity to suggest options previously unseen or underappreciated that might break a gridlock or prove more effective.

In a public series on science advice to the president that we held in 2005 and 2006, former president of the US National Academy of Sciences during the 1980 s and prior to that President Jimmy Carter's science advisor, Frank Press, explained that during his tenure the US NRC never conducted a study on the subject of "nuclear winter" which occupied considerable policy debate at the time. The main reason for this, he explained, was that a large number of members of the NAS had signed on to an advocacy statement on the subject, and he felt that the objectivity of the Academy had been compromised, thus robbing the nation of expert advice on this important subject.

The third reason why Science Arbiters should exercise caution in making the leap to advocacy has to do with democratic accountability. For example, in the United States the National Academy of Sciences is supported in large part with public funds. But when taking advocacy positions, who are they accountable to? Also, where does advocacy stop? Should science academies endorse specific candidates running for election or issue position papers on pending legislation? This is, of course, what special interest advocacy groups do, and do very well. Democracy is strengthened by political advocacy. But national science academies, especially those supported by public funds, are supposed to work in support of common interests, not particular special interests. If national academies continue down the path of issue advocacy, they should not be surprised if they are soon viewed by the public and their representatives as just another special interest group. The risk for science is not only the loss of particular political battles, but a potential diminution of the public support that has led to considerable, sustained investments in research over many decades.

4 http://royalsociety.org/news.asp?id=2738..
5 http://business.timesonline.co.uk/tol/business/markets/united_states/article540543.ece. The following two quotes are also taken from this source.

Thus, the Issue Advocate cannot escape transdisciplinary questions. What happens when certain schools of knowledge associate themselves with particular agendas (e. g., ecologists vs. genetic engineers)? Whose values do they represent? What is the basis for the authority granted to experts? Where does accountability lie for decisions justified on expert claims in advocacy? What happens when relevant, qualified experts appear on different sides of policy debates? Such questions appear to be rarely engaged by scientists who take on an advocacy role in political debates.

3.4 Honest Brokering

Some might suggest that national academies and other prestigious advisory bodies should stick to science and not engage in issues of policy or politics. But as scholars of science, technology, and society have taught us, considering science as if it existed in a vacuum is only possible in highly idealized circumstances, usually those that are not politically controversial or scientifically complex. If we want science academies to be relevant to policy, science needs to consider social and political issues. So, if overt political advocacy is fraught with risk, and consideration of science alone is impossible, is there another option? One way for science advisors to closely engage with the needs of policy makers, but avoid recreating themselves as special interest groups, is to work to clarify and, if possible, expand the scope of choice available in decision making. Unlike the Science Arbiter, the Honest Broker of Policy Options seeks explicitly to integrate scientific knowledge with stakeholder concerns in the form of alternative possible courses of action. As such, honest brokering is inherently transdisciplinary and multidisciplinary, because it must focus not simply on creating relevant knowledge (a product), but also on making knowledge relevant (a process).

Like the Science Arbiter, the Honest Broker of Policy Alternatives is likely to take the form of a formal, authoritative committee or assessment. There are several reasons why this is so. First, it can be difficult, and in some cases impossible, for an individual scientist to represent all of the areas of expertise required to recommend a range of action alternatives. Further, a diversity of perspectives can help to militate against issue advocacy (stealth or otherwise). The defining difference between the two, Issue Advocate and the Honest Broker of Policy Alternatives, is that the latter seeks to place scientific understandings into the context of a smorgasbord of policy options. Such options may appeal to a wide range of interests. For example, in the United States the congressional Office of Technology Assessment (which was terminated in the 1990 s) often produced reports with a wide set of policy options contingent on ends to be achieved. A simple way to think about the key difference between the Honest Broker of Policy Options and the Issue Advocate is that the latter seeks to reduce the scope of available choice, while the former seeks to expand (or at least clarify) the scope of choice.

4. Transdisciplinarity and the Importance of Problem Definition

As we have seen in the situations of science arbitration, issue advocacy, and honest brokering, connecting science with policy alternatives is fraught with challenges of democracy and participation. The main reason for these challenges lies in the fact that, on the one hand, policy making is problem-oriented; that is, focused on the achieving valued outcomes where the values are prioritized via a political process. On the other hand, knowledge production is typically problem-oriented in a far different way, where the problems are not often subject to the legitimization of democratic processes. Helga Nowotny (2008, 3) observes:

> "… it has become obvious that most of the problems that arise cannot be approached in a mono-disciplinary way. The desperate cry "The world has problems, the university has departments" points to a real dilemma that even the most well-intentioned and well-equipped scientific adviser faces: how to integrate scientific and technical expertise that comes from different disciplines but is based on different assumptions and expressed in different languages."

Thus, the key challenge in the integration of knowledge for purposes of informing decision making is thus not only how to bring scholars of different disciplines together (as important and difficult as this may be), but once such collaboration has been undertaken, how to make knowledge relevant to specific decisions, which is unavoidably a political act. Such relevant knowledge may be disciplinary or inter-/multidisciplinary, but it will inevitably be transdisciplinary in the sense that it becomes connected with societal values via some political process. Such problem-oriented knowledge, as used here, is the essence of transdisciplinarity. This section discusses the implications of conducting such transdisciplinary problem-oriented research for the four idealized roles of the expert advisor.

An effective way to make knowledge relevant is to create it from a problem-oriented standpoint.[6] For the Science Arbiter, this task can be fairly straight-forward, since it is the decision maker who brings the relevant questions to the expert. But for the Issue Advocate and the Honest Broker of Policy Alternatives, the characterization of a particular set of circumstances as a "problem" requires paying attention to the people who are claiming that a problem exists, their perspectives, and their ability to act (Lasswell 1971). The process of problem definition will be very different for the Issue Advocate, who seeks to advance a narrow interest by pressing for a limited set of actions, from that of the Honest Broker, who seeks to advance broader interests by presenting a wide range of policy options. There are many examples of modern-day Cassandras who identify important problems that fail to either reach or be understood by decision makers. Hence, the existence of information related to a potential problem is not a sufficient condition for action; attention to a healthy process that actively links that information with a decision maker's needs is also necessary. Specifically, issue advocacy may mean advancing a particular perspective on a problem, whereas an Honest Broker may present multiple ways to frame issues as problems.

6 The following section updates and extends a discussion first presented in Pielke (1997).

Problems can be defined in multiple ways because they have their origin in the universe of "issues," which have been defined as "patterns of events with significance for human values" (Rein and White 1977). For instance, global climate change went from an "esoteric" scientific issue to an international problem when temperature trend data was associated with societal impacts of climate. The issue of global climate change did not emerge as a policy problem overnight; observers will point out that climate change has been an issue of discussion in scientific circles for more than a century, perhaps exemplifying inter- and multidisciplinary research. Key to an issue being defined as a problem is a determination that some valued outcomes are at stake. For instance, global climate change can be viewed as a humanitarian problem, an ecological problem, and an economic problem.

Why does a particular problem definition emerge from the "policy primeval soup" in order to occupy a place on the public agenda (Kingdon 1984)? Why do problems emerge when they do? What role should the social and physical science communities play in shaping and responding to policy problems? Answers to questions like these lie in a deeper understanding of the role of problems and problem definitions in the policy process.

The first step on the path from issue to problem, and thus from disciplinarity/inter- or multidisciplinarity to transdisciplinarity, is a sense of dissonance. John Dewey, the American pragmatist, observed early in the 20th century that conscious human action is motivated by a "felt difficulty", that is, "a situation that is ambiguous, that presents a dilemma that proposes alternatives. As long as our activity glides smoothly along from one thing to another (...) there is no need for reflection." (Dewey 1933). The step from issue to difficulty is an interpretive one. It is the perception of people that define which issues are considered important and which are not (Kingdon 1984). A perceived difficulty is not necessarily a problem; "a difficulty is only a problem if something can be done about it." (Wildavsky 1979). Thus, implicit in the assertion that a problem exists is an assumption that action alternatives are available to the decision maker.

To understand or assess whether a particular difficulty is amenable to a solution, reflection, otherwise known as thinking, research, or inquiry is required. Through conscious thought, a person or a group is able to choose a course of action that they expect will improve their condition (this is one definition, of many, of what is called "rational" behaviour, Forester 1984). But before an action can be chosen in a political process, alternatives must be available. In most cases, the scope of alternative courses of action depends on how a problem is framed or defined.

People usually view the world through simplified "maps" or "models" that they create in their minds. Lippmann (1916) referred to this as "the world outside and the pictures in our heads", and cognitive psychologists have explored the phenomena in great detail. Definitions of problems are examples of such maps of the world. Such problem definitions allow for conscious reflection on ends to be sought (e. g., goals) and the means to achieve the desired ends. A problem is thus a difference between the way things are or seem to be and the way that we would like them to be (Lasswell 1971). Logically, a problem definition contains (explicitly or implicitly) some sense of goals or objectives and some measure of (non-)attainment with respect to those goals. A problem definition is therefore a frame of reference that shapes how people gather, process, and disseminate information about the world outside. As such it is obviously shaped by the culture and practices of those defining the problem, which helps to explain why different experts come to define common situations in very different ways.

The existence of different, often conflicting, problem definitions has political consequences. Even with the same information, value differences between individuals or groups often result in different conceptions of the existence, severity, or type of problem (Rein and White 1977). With regard to the public arena, such differences are worked out through a process of bargaining, negotiation, and compromise under the provisions of laws and custom. Often issues evolve through compromise as competing problem definitions move closer together through politics (Schattschneider 1975). Problem definition is further complicated with the existence of uncertain, imperfect, or partial information (Etzioni 1985). Hence, various participants in a decision-making process will appeal to (and often selectively ignore) different scientific data for a host of reasons, for example, to justify the primacy of their problem definition over others (Sarewitz 2001). Great battles are fought over the meaning and validity of pieces of information central to a problem's definition, which is the essence of a distinction between "normal" and "post-normal" science (Funtowicz and Ravetz 1992).

The act of problem definition is integrative and interpretive. Problem definition integrates knowledge with values in the sense that it relates goals (i. e., valued outcomes) to scientific data on trends, conditions, and projections with respect to those goals (Clark 2002). And here a challenge exists for experts seeking to connect their knowledge with the needs of decisions makers. Unless the decision maker comes to them with a well-defined technical question (i. e., science arbitration), some consideration must be given to the nature of the problem faced by the decision maker. Because political issues are contested, this means that there are different legitimate conceptions of goals to be sought and means to achieve them. Should the expert pick sides in such a contest? Seek to advance his or her personal values? Partner with other experts to provide a range of options contingent upon goals for means and ends? The integration of knowledge and action via advice can take many forms.

For Science Arbiters, problems may have been defined for them, and their task is thus simply to weigh in on empirical questions having to do with trends, cause and effect, or projections of the future. Hence, Science Arbiters may find that disciplinary or interdisciplinary knowledge is perfectly useful and relevant in their decision context. However, for the Issue Advocate and the Honest Broker, the question of problem definition is unavoidable, as both activities require the act of problem definition in conjunction with the provision of expert advice.

5. Concluding Comments

To summarize, conditions in society become important from the standpoint of demands for action because/as people decide that those conditions have an impact on what they value. Politics becomes necessary because people and groups define problems differently, and constraints on resources mean that decisions must be made about which problems to address with what level of resources. Consequently, human action is often shaped by how problems are defined and what issues are on the agenda. Issues generally have a finite lifetime of public or political attention. A significant challenge for the expert seeking to contribute knowledge to decision making is to orient him- or herself towards the context of societal problems, determining what role to play in the process. Such orientation is inherently a transdisciplinary project.

The process of making knowledge relevant raises many challenging questions about the roles of expertise and the creation of knowledge. Disciplinary, multidisciplinary, and interdisciplinary perspectives can help to inform these questions, but in the end, one feature of advice is unavoidable, and that is politics, which is a defining feature of transdisciplinary knowledge. As the amount of knowledge continues to grow, and as decision makers continue to demand expert advice, the challenges of expert advice and the disciplines will not go away. Creating useful knowledge is not a problem to be solved but a condition to be managed – and it can be managed in better or worse fashion. This chapter has argued that a first step in meeting the challenge of expert advice in the context of a vast sea of knowledge is to understand the options available to the advisor, and the criteria that might be applied in deciding what sort of role to play, in service of both science and decision making.

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