# Science-Policy Interface Needs Knowledge Quality Assessment

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Scientific assessments of complex risks such as climate change, biodiversity loss, natural resource depletion, nanotechnology, or endocrine disruptors (*1–6*) involve uncertainties of many sorts, not all of which can be effectively controlled in practice (*7–9*). Decisions need to be made before conclusive supporting evidence is available, while at the same time the potential impacts of wrong decisions can be huge. Questions that cannot be answered due to inconclusive evidence include: How likely are human-caused abrupt climate changes? What effects will endocrine disruptors have on reproduction, among non-human species and humans? What will be the future impact of climate change on biodiversity? What are the possible hazards of nanosized particles? What is the impact of fisheries on marine ecosystems? Governmental and intergovernmental agencies that inform the policy and the public about such risks increasingly recognize that uncertainty can no longer be suppressed or denied, but needs to be dealt with in a transparent and effective manner. Several institutions that interface science and policy have adopted knowledge quality assessment approaches in response to emerging needs (*10–14*). One of these is the Netherlands Environmental Assessment Agency (MNP in Dutch), a governmental agency that performs independent scientific assessments and policy evaluations and is associated with the National Institute for Public Health and the Environment (RIVM). MNP has recently implemented a comprehensive and innovative approach to knowledge quality assessment, which we discuss here as a key example.

According to the classic conception of scientific policy advice, certainty is necessary for the management of complex problems. However, uncertainty is a fact of life. Scientific assessments have to integrate information covering the entire spectrum from well-established scientific knowledge to educated guesses, preliminary models, and tentative assumptions. In such contexts, uncertainty can mostly not be remedied through additional research or comparative evaluations of evidence by expert panels searching for a consensus interpretation of the risks (*1*, *3*, *6*).

Social studies of scientific advice (*15–19*) show that for many complex problems, the processes within the scientific community as well as between this community and the "external" world—policy makers, stakeholders and civil society—determine the acceptability of a scientific assessment as a shared basis for action. These processes concern, among others, the framing of the problem, the choice of methods, the strategy to gather the data, the review and interpretation of results, the distribution of roles in knowledge production and assessment, and the function of the results in the policy arena. Although assumptions underlying the design of these processes are rarely discussed openly, they are important for the knowledge becoming either "contested" or "robust." More research on complex issues sometimes reveals more uncertainties (*18*) and can even lead to more intense controversy and weaker evidence if these implicit assumptions are not adequately dealt with (*20*).

Thus, it is not enough to analyze uncertainty as a "technical" problem or merely seek for consensus interpretations of inconclusive evidence. In addition, the production of knowledge and the assessment of uncertainty have to address deeper uncertainties that reside in problem framings, expert judgments, assumed model structures, et cetera. Especially in studies of the future, for which computer models are often used, we must recognize our ignorance about the complex systems under study. Verification and validation of these computer models is impossible, and confirmation is inherently partial (*21*). Furthermore, since models are products made by scientists, we must always be aware of the possible presence of personal, institutional or ideological dimensions, and their "metaphorical" nature (*22*).

The challenge to scientific advisers is to be as transparent and clear as possible in their treatment of uncertainties (*23*). Recognizing this challenge, MNP commissioned Utrecht University to develop, together with MNP, the *RIVM/MNP Guidance for Uncertainty Assessment and Communication* (*14*). The authors formed the core team and worked in close consultation with an international team of uncertainty experts. This Guidance aims to facilitate the process of dealing with uncertainties throughout the whole scientific assessment process (see figure). It explicitly addresses institutional aspects of knowledge development, openly deals with indeterminacy, ignorance, assumptions and value loadings. It thereby facilitates a profound societal debate and a negotiated management of risks. The Guidance is not set up as a protocol. Instead, it provides a heuristic that encourages self-evaluative systematization and reflexivity on pitfalls in knowledge production and use. It also provides diagnostic help as to where uncertainty may occur and why. This can contribute to more conscious, explicit, argued, and well-documented choices.

Following a checklist approach (*24*), the Guidance consists of a layered set of instruments (Mini-Checklist, Quickscan, and Detailed Guidance) with increasing level of detail and sophistication. It can be used by practitioners as a (self-)elicitation instrument or by project managers as a guiding instrument in problem framing and project design. Using the Mini-Checklist and Quickscan Questionnaire, the analyst can flag key issues that need further consideration. Depending on what is flagged as salient, the analyst is referred to specific sections in a separate Hints & Actions document and in the Detailed Guidance. Since the number of cross-references between the documents comprising the Guidance is quite large, a publicly available interactive web application has been implemented (*14*). This web application also offers a prioritized to-do list of uncertainty assessment actions, and generates reports of sessions (traceability and documentation), which enables internal and external review.

In order to facilitate communication about the different types of uncertainty that arise in scientific assessments, an uncertainty typology is part of the Guidance (*25*). The typology is based on a conceptual framework that resulted from a process involving an international group of uncertainty experts most of whom participated in developing or reviewing the Guidance (*26*). Uncertainty can be classified along the following dimensions: its "location" (where it occurs), its "level" (whether it can best be characterized as statistical uncertainty, scenario uncertainty or recognized ignorance) and its "nature" (whether uncertainty primarily stems from knowledge imperfection or is a direct consequence of inherent variability). In addition, the typology distinguishes the dimensions "qualification of knowledge base" (what are weak and strong parts in the assessment) and "value-ladenness of choices" (what biases may shape the assessment). The typology is presented as a matrix. This uncertainty matrix is used as an instrument for generating an overview of where one expects the most important (policy-relevant) uncertainties to be located (the first dimension), and how these can be further characterized in terms of the other uncertainty dimensions mentioned. The matrix can be used as a scanning tool to identify areas where a more elaborate uncertainty assessment is required. The different cells in the matrix are linked to available uncertainty assessment tools suitable for tackling that particular uncertainty type. These tools are described in a Tool Catalogue that aims to assist the analyst in choosing appropriate methods.

The Tool Catalogue provides practical ("how to") information on state-of-the-art quantitative and qualitative uncertainty assessment techniques, including sensitivity analysis (*27*, *28*), NUSAP (*23*, *8*), expert elicitation, scenario analysis, and model quality assessment (*24*). A brief description of each tool is given along with its goals, strengths and limitations, required resources, as well as guidelines for its use and warnings for typical pitfalls. It is supplemented by references to handbooks, software, example case studies, web resources, and experts. The tool catalogue is a "living document," available on the web, to which new tools can be added.

The institutional challenges of implementing this new approach should not be underestimated. It entails much more than disseminating the documents through an organization. For example, MNP's top management has ordered and subsequently endorsed the Guidance; MNP's methodology group led the development of the Mini-Checklist and Quickscan; the use of the Guidance is now mandatory as part of the agency's quality assurance procedures; and the staff is actively trained to acquire the necessary skills. In addition, a methodological support unit is available in the agency to assist and advise in assessment projects. The required process of cultural change within the institute was consciously managed over the period 2003–2005. Although the guidance is not fully used within all projects yet, it is increasingly used, the attitude has changed, and communication on uncertainty in MNP reports has improved over this period.

Knowledge quality assessment approaches such as the one exemplified here can enhance societies' capacity to deal with uncertainties surrounding knowledge production and knowledge use in the management of complex risks.

| Foci | Key Issues |
|---|---|
| **Problem Framing** | Other problem views; interwovenness with other problems; system boundaries; role of results in policy process; relation to previous assessments |
| **Involvement of Stakeholders** | Identifying stakeholders; their views and roles; controversies; mode of involvement |
| **Selection of Indicators** | Adequate backing for selection; alternative indicators; support for selection in science, society, and politics |
| **Appraisal of Knowledge Base** | Quality required; bottlenecks in available knowledge and methods; impact of bottlenecks on quality of results |
| **Mapping and Assessing Relevant Uncertainties** | Identification and prioritization of key uncertainties; choice of methods to assess these; assessing robustness of conclusions |
| **Reporting Uncertainty Information** | Context of reporting; robustness and clarity of main messages; policy implications of uncertainty; balanced and consistent representation in progressive disclosure of uncertainty information; traceability and adequate backing |

**Foci and key issues in knowledge quality assessment.** Transparent and effective uncertainty management in science-for-policy asks for systematic reflection and argued choice.

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