The role of expert knowledge in collaborative water management

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Abstract

This paper presents a conceptual framework for understanding the role of expert knowledge in collaborative water management and illustrates it with a case study. It is found that the production and utilization of expert knowledge are influenced by researchers' and policymakers' perspectives on the nature of knowledge and by characteristics of the policy process. Expert knowledge can be used to support water management decisions, directly or on the longer term, or to support preconceived positions. By identifying the role of frames and perspectives in learning, insight is developed in factors that promote knowledge utilization. Then, collaboration between researchers, policymakers and other stakeholders is proposed as a strategy to deal with complex problems. Central in this strategy is the development of a shared knowledge base through intensive interaction. The paper concludes by summarizing literature into seven lessons for the role of expert knowledge in collaborative water management: 1) Determine research needs together; 2) Focus on appropriate knowledge; 3) Produce knowledge iteratively; 4) Present results in an attractive and clear way; 5) Reflect on knowledge critically; 6) Use appropriate tools and methods; and 7) Use intermediates in case of large differences in perspective.

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1. Introduction

The relation between 'policy' and 'research' is a topic that is discussed in many fora in different ways. 'Policy' and 'research' could be seen as two different worlds with different goals, languages and reward systems. Whereas policymakers are mainly concerned with legitimating choices, researchers or technical experts are mainly concerned with discovering the 'truth'. Because of their different values and backgrounds, actors from each world often have trouble understanding each other (e.g. Weiss 1977; Caplan 1979; Raad voor het Milieu- en Natuuronderzoek 2000; Borowski and Hare 2006).

However, the two worlds can and often need to benefit from each other. When policymakers are confronted with limited expertise, researchers can help with filling the knowledge gaps. For researchers this is interesting as well, because at current there are many direct and explicit expectations and incentives (funding) for policy relevant research (Neilson 2001; Martin 2003). After 1980, the two communities have become closer to each other, as science 'democratized' and politics 'scientificated', and new institutional linkages (such as research institutes) developed (Jasanoff 1990; Maasen and Weingart 2005).

One way to deal with increasing interdependencies between research and policy is by including researchers in collaborative or participatory policymaking (e.g. Gray 1989; Busenberg 1999). In collaborative policymaking, representatives of all groups that can influence or are influenced by a policy issue collaborate intensively. This allows for exchanging different types of knowledge and a broad range of values and interest, and can help to develop mutual understanding and consensus.

In this paper a conceptual framework is developed for understanding the role of expert knowledge in collaborative policymaking. Section two introduces a case study about groundwater management in the Netherlands, which is used to illustrate the theories and concepts that are presented in the paper. Section three introduces knowledge as a subjective representation of reality and explains the relation between perspectives and expert knowledge. Section four provides a conceptual framework for the production and utilization of knowledge in different contexts. Section five links knowledge use to learning and explains how perspectives and frames influence these processes. Section six introduces collaborative water management as a promising approach for dealing with complex water management problems. Section seven summarizes literature about collaborative management in seven lessons – for researchers and policymakers – for improving the role of expert knowledge in water management. The paper concludes with a discussion of the conceptual framework and the presented lessons.

2. Case 'Groundwater management Delft'

In this section a groundwater management case from the Netherland is introduced. This practical case will be used throughout the paper to illustrate and concretize the concepts and theories discussed.

The issue at stake is that a large industrial company has – after many decades – decided in 2004 to end its extraction of deep groundwater in the city of Delft, in the low-lying western part of the Netherlands. This is expected to have impacts in an area of about 50 km^2, which had become adjusted to the situation with the extraction. Expected negative effects are hindrance and damage due to higher ground water tables, reduced water quality due to the increased transport of salt and nutrients to the surface, and damage to constructions by an increase in deep groundwater pressure and soil deformations (Gehrels et al. 2005). Ending the extraction may also have positive effects, such as restoring a more natural behavior of the water system. Many stakeholders may be confronted with the effects and their stakes are high. Alternative management solutions are to use the extracted water for other purposes, to reduce the extraction partially as to limit negative effects or to fully shut down the extraction while mitigating or compensating for the effects. The estimated societal costs (minus benefits) of ending the extraction can amount up to ca. 100 million Euros, depending on the strategy that is chosen (Gehrels et al. 2005). However, knowledge about the effects of reducing the extraction and the appropriateness of different management alternatives is lacking.

After the announcement of the termination of the extraction, the city of Delft, the Province of Zuid-Holland and the Water Board of Delfland (further referred to as the Steering Group) joined their forces to deal with this issue. They hired a group of researchers (the Project Group) from well-known research institutes and consultants in the Netherlands to develop the required knowledge. The Steering Group and Project Group formulated the research questions and methods together, and the research institutes and the Delft Cluster research program co-financed the study.

There are regular meetings concerning the progress of the research between representatives of the Steering Group and the Project Group. The municipalities surrounding Delft (the Interest Group) and other governmental and non-governmental stakeholders (the Sounding Board) are informed through newsletters and involved in workshops, including a broad start-up workshop and workshops at which results are presented and discussed.

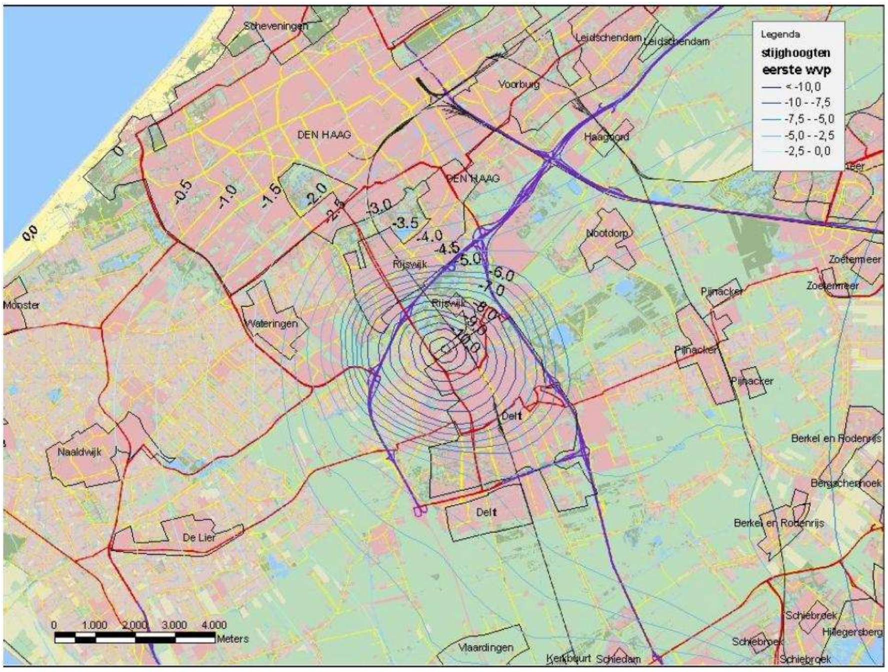

Fig. 1. Effect of the groundwater extraction on the hydraulic head in the upper aquifer (in m) (Gehrels et al. 2005)

In the first phase of the study, a qualitative Quickscan of potential problems, solutions and costs was executed. The knowledge of a broad range of stakeholders was gathered using a questionnaire and the results of the Quickscan were disseminated in September 2005. In the second phase, which started in 2006 and still continues at the moment of writing, the Quickscan results are quantified further. Detailed knowledge of the influence of the extraction on the hydraulic heads in the aquifer (See Fig. 1) and the groundwater level at different locations is required. Therefore, a detailed geological model of the upper soil is developed, which serves as a basis for a coupled ground water and surface water model, a salt transport model and a soil movement model (Gehrels et al. 2006). Furthermore, an interactive model (iMOD) is developed, to enable direct visualization of the spatially distributed effects of installing new drainage and smaller local extractions on ground water tables.

The results of the study will serve as a basis for further discussion about alternative solutions. While searching for appropriate solutions, the extraction is continued in order to prevent unexpected negative effects from occurring. Because this is very costly, there is a lot of pressure to find a solution fast.

3. The nature of knowledge

The nature of knowledge has been a topic of discussion for ages. For the discussions in this paper, it is necessary to make a distinction between two perspectives on knowledge: positivism and constructivism. Positivism assumes that is possible to obtain objective knowledge about reality, whereas constructivism considers all knowledge to be subjective constructions of reality. This paper adopts the constructivist view that all knowledge is a subjective representation of an objective, external reality. The subjectivity is caused by the selective and interpretive character of knowledge production and utilization, by individuals functioning in a social context (cf. Hisschemöller 2005; Monnikhof 2006; Beratan 2007).

Knowledge can be analyzed in terms of more or less consistent and enduring ‘perspectives’, ‘mental models’ (Doyle and Ford 1998; Kolkman et al. 2005) or ‘issue frames’ (Dewulf, Gray et al. 2005). A perspective is a cognitive representation of the external reality and the position of the individual in this reality, as seen by the individual. This means that a perspective is influenced by the background, values and interests of its owner. Because most cognitive processes happen on an intuitive level (Beratan 2007), individuals are usually only partly aware of their perspective. Although there are limits to rationality, people tend to structure their perspectives in a logical way (cf. Jaynes 2003). Consequently, perspectives can be described as argumentative structures (cf. Fischer 1995; Hoppe and Peterse 1998, see Fig. 2).

In a policy debate, the claim that a certain set of policy instruments should be implemented is supported by data, through warrants that logically link the data to the claim (Toulmin 1958). The argumentation consists of first order, case-specific grounds (concerning the problems and goals and the effectiveness and efficiency of the policy instruments), and second order, general political-ideological grounds (concerning interests and values) (Fischer 1995; Hoppe and Peterse 1998). The assumptions in the argumentation can be made explicit by formulating qualifiers (how certain is it that the claim is true?) and conditions of exception (Toulmin 1958).

Whereas policymakers generally have an integrated perspective on the problems perceived in society and possible management solutions, a researcher's perspective may include only one aspect of an issue (e.g. the technical feasibility of a certain water management solution). Expert knowledge about complex physical system behavior (e.g. hydrology and hydraulics) concerns mainly first order argumentation and underlying data. However, the selective process in which it is produced and used necessarily reflects second order arguments. Consequently, the subjective nature of knowledge also applies to expert knowledge (cf. Raad voor het Milieu- en Natuuronderzoek 2000). Still, expert knowledge can be distinguished from other types of knowledge on the basis of three criteria. First of all, it typically has a specialized and abstract character. Secondly, it is often produced using formal, scientific methods that can be characterized by the aim for inter-subjective reproducibility in the use of evidence (Weale 2001). And thirdly, expert knowledge often has a high social status and can thus be used well for legitimizing decision-making.

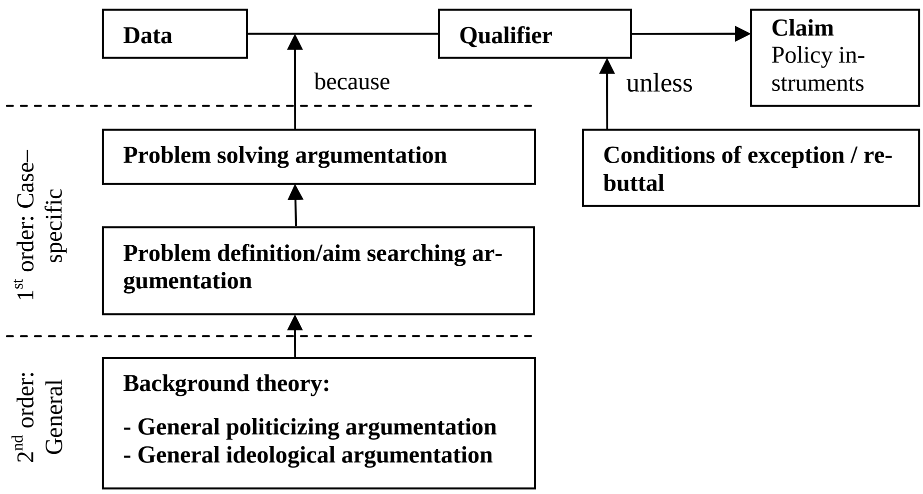

Fig. 2. The argumentative structure of a policy perspective (Adapted from Toulmin 1958; Fischer 1995; Hoppe and Peterse 1998)

Expert knowledge and perspectives in the case study

Within the case study different perspectives could be identified, using interviews and questionnaires (Raadgever et al. 2007). The perspectives reflect that the policymakers and other stakeholders involved have different problems perceptions, different goals and values, and different preferred strategies (covering all alternatives studied in the Quickscan). An example of the argumentative structure of a perspective that was shared by a group of involved actors is provided in Fig. 3. Limitations to the logic within the elicited argumentation structures indicate that the perspectives have not fully 'crystallized' yet. This may be caused by the fact that some stakeholders have only recently been confronted with the problem and that there are still large knowledge gaps. These knowledge gaps can be filled to a large extent by expert knowledge about the physical effects of ending (or reducing) the extraction. The Project Group produces such knowledge. In addition, the Group integrates knowledge from different disciplines (e.g. surface water, ground water and soil) and makes a translation to societal costs and benefits. Some researchers stated that they do not have a comprehensive perspective about problems and solutions or that it is not relevant, as they try to be neutral providers of expert knowledge.

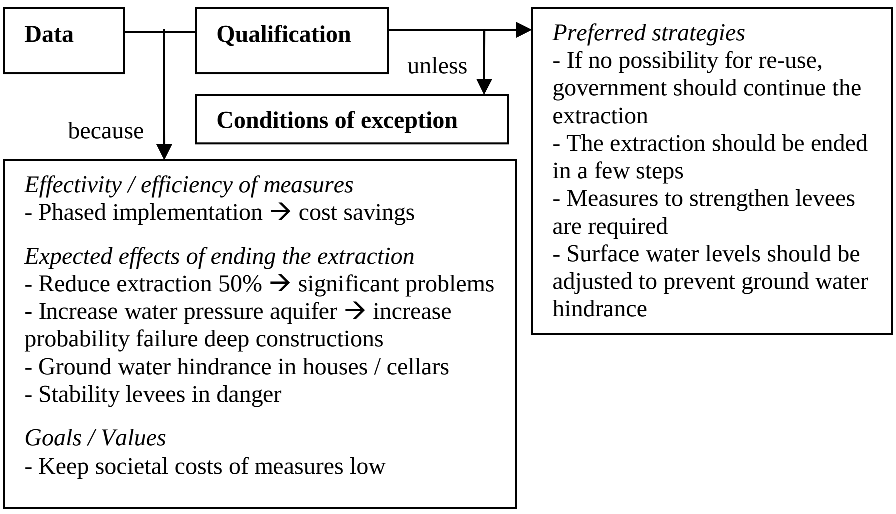

Fig. 3. Argumentative structure summarizing one of the four shared perspectives in the case study, named 'Cost limitation' (statements about what goals are not important, what effects will not occur and what strategies should not be taken have been left out)

4. Production and utilization of expert knowledge

Expert knowledge can support water management policymaking by contributing to better insight in problems and solutions, but its role is strongly influenced by the goals and perspectives of the producers and users of knowledge. Understanding the different actor constellations, activities and types of knowledge use that can occur in a policy process, can help researchers who want to influence policy to tailor their knowledge production and communication to a specific context (Neilson 2001). Similarly, understanding different types of knowledge production may be beneficial for policymakers who want to improve their interaction with researchers. This section provides a framework for analyzing the ways in which knowledge can be produced and used.

Characteristics of the knowledge producers are central in analyzing different types of knowledge production. Four different types can be distinguished based on their goals and their perspective on the nature of knowledge. The goal can be to obtain fundamental insights or to apply these insights, for example to support policymaking (cf. Jasanoff 1990). The aim to apply knowledge is sometimes accompanied by the need to obtain fundamental insights. In fact, many important scientific insights have been obtained by research that was both fundamental and applied at the same time (Stokes 1997 in Martin 2003). In the first type of knowledge production (or 'Mode 1' knowledge production, Gibbons et al. 1994), a positivist epistemology is combined with the goal of obtaining fundamental knowledge. This type of knowledge production is typically executed by university researchers operating within specialized disciplines. Peer review by experienced scientists from the same discipline guarantees the quality of knowledge.

Whereas since the second world war Mode 1 knowledge production has been dominant, a new way of knowledge production, ‘Mode 2’, is gaining importance since the 1980s (Martin 2003). In Mode 2, knowledge is produced in the context of its application and a constructivist epistemology is adopted. Application of knowledge to support policymaking often requires integration of knowledge from different disciplines. Furthermore, as scientific knowledge is not considered an objective truth, it has to compete with other types of knowledge (Gibbons et al. 1994; Heinrichs 2005), such as local and experiential knowledge, and often an integration of different types of knowledge is required. Mode 2 knowledge production can therefore be characterized by heterogeneity of knowledge producers (including consultants, government experts, NGOs and local citizens and businesses), heterogeneity of skills and experiences and organizational diversity. This requires new standards of quality control and new 'watchdogs' (e.g. media and politics) (Jasanoff 1990; Gibbons et al. 1994; Raad voor het Milieu- en Natuuronderzoek 2000; Martin 2003).

In theory, two other forms of knowledge production can be distinguished. However, knowledge production solely aimed at obtaining fundamental insights, whether this could be accompanied by a constructivist epistemology or not, is of limited relevance for this paper. Thus, the need for discussing applied knowledge production in combination with a positivist view on knowledge remains. Because it is assumed that reality can be objectively known, experts and expert knowledge dominate knowledge production. In contrast with fundamental knowledge production, the application of knowledge often requires the integration of knowledge from different disciplines. To achieve this, disciplinary fields of science (and peer review) may be complemented by interdisciplinary fields of science (with their own peers) or by institutions that are specialized in applying and integrating knowledge (such as consultant and research institutes, whose reputation is considered as the main indicator for the quality of their work).

Irrespective of the aim and epistemology of knowledge producers, knowledge may be used in different ways, which can be analyzed based on the number of knowledge users, their perspectives on the nature of knowledge and their interaction strategies. These characteristics influence whether and how knowledge is reflected in the minds of the knowledge users (e.g. policymakers, politicians, water managers, NGOs, citizens and businesses), in informal or formal policy documents, and/or in the results of policy implementation (cf. Innes and Booher 1999).

First we describe the situation in which there is only one knowledge user. In this situation, a competent government body takes care of the interests of all citizens, which are not involved in the policymaking (cf. the 'paternalistic model', Bear 1994 in Glicken 2000). It defines the problem, identifies lacking knowledge and asks researchers to generate solutions or knowledge that supports the choice among alternative solutions. Of central importance in the case of one knowledge user is therefore instrumental knowledge use (Pelz 1978; Caplan 1979; Beyer 1997), in which knowledge has a direct and concrete impact on policymaking. In addition, knowledge can have an indirect and abstract impact on a single knowledge user. This is referred to as conceptual knowledge (Weiss 1977; Pelz 1978; Caplan 1979; Beyer 1997). The importance of conceptual use in comparison to instrumental use is emphasized by the finding that university research is most likely to be used conceptually (Weiss 1977; Amara et al. 2004). Typically, the single knowledge user assumes that the world is knowable and rational and objective decisions can be taken, but a constructivist perspective on the nature of knowledge is also possible.

Another situation occurs when multiple knowledge users are involved in the policy process. Sometimes a knowledge user assumes to be the only one, when in fact other stakeholders are or will become involved in the policy process as well. Two alternative interaction strategies that each knowledge user may have are the political or conflict strategy and the collaborative or consensus-building strategy (Busenberg 1999; Glicken 2000). In the political model 'public policy results from conflict, bargaining and coalition formation among a potentially large number of societal groups organized to protect or advance particular interests common to their members' (Grindle and Thomas 1991, pp. 22-23). In this model, knowledge is mainly produced and used strategically by multiple opposing groups (cf. 'adversarial analysis' in Busenberg 1999). Strategic (or symbolic) knowledge use occurs when a certain group of policy actors uses knowledge only to confirm the programs or position that they wish to promote (Pelz 1978; Beyer 1997). It is most probable that knowledge users in the political model are aware of the strategic character of the knowledge use and have a constructivist epistemology. On the other hand, knowledge users may truly belief that the knowledge they use is fully objective (a positivist view) and that they use it in instrumental or conceptual ways.

When multiple knowledge users aim to create consensus through a process of cooperation rather than conflict, collaborative policymaking occurs. In this model, knowledge users may have a positivist or a constructivist epistemology. Creating a shared knowledge base can mean either to (jointly) discover the objective truth or to negotiate which knowledge – although to some extent subjective and selective – is accepted by all as appropriate for supporting decision-making. Knowledge users may also consider expert knowledge about the physical system as objective facts and other knowledge, for example about the social system, as socially constructed. The stakeholders involved in collaborative management aim to use expert knowledge instrumentally or conceptually, but not strategically, in order to build consensus on the shorter or longer term. The collaborative policymaking model is further elaborated in section 6.

When considering the different types of knowledge production and knowledge utilization, it can be hypothesized that some match well and other less. For example, a mismatch occurs when a producer of applied knowledge with a positivist epistemology is confronted with a discordant policy process, in which the produced knowledge is used strategically, instead of the expected instrumental knowledge use. To make sure knowledge production and use match well, we suggest that knowledge producers and users analyze whether their ideas match. In case of a mismatch they can actively try to change the situation. For example, knowledge producers could try to prevent strategic use by disseminating their knowledge to multiple stakeholders and facilitating technical collaboration. Another option is to find another knowledge producer or user.

Intermediates, boundary organizations and boundary objects

Researchers and policymakers often do not communicate directly, but through intermediates that operate on the boundaries between research and science, such as policy analysts and consultants (cf. ‘knowledge brokers’ (Jasanoff 1990) or ‘policy entrepreneurs’(Stone et al. 2001)). Intermediates have to be able to take the double role of users in communication with knowledge producers, and producers in communication with knowledge users. Exchange between producers, intermediates and users can take place through one-way communication or in interactive settings (e.g. through workshops, visits, discussions or cross-disciplinary projects) (Wenger 2000). Intermediates can play an important role in the synthesis of knowledge, and in prediction and prescription based on expert knowledge (Jasanoff 1990). This may be supported by intermediate or boundary organizations (e.g. applied research institutes) and intermediate or boundary objects (e.g. reports, websites and participatory models), which on the one hand maintain the boundary between science and policy and on the other hand integrate them (Guston 2001; Miller 2001).

Production and use of expert knowledge in the case study

The Project Group in the case study consists of researchers from research institutes, universities and consultants. They develop new model concepts to simulate physical processes in an abstract and detailed way, and they directly apply it to the issue at stake, in order to support the policy process. The researchers that translate fundamental insights into relevant knowledge for policymakers and other actors involved can be seen as intermediates from boundary organizations (research institutes). The knowledge production does not seem to be ‘Mode 2’ production, because most researchers involved seem to consider the knowledge they produce to be objective.

The intended users of the produced knowledge are policymakers from various governmental and other organizations, who require the expert knowledge to make an informed decision about which strategy to take. The interaction between these stakeholders reflects elements of political as well as collaborative strategies. The Project Group and the Steering Group decided that the produced knowledge should be presented and discussed at interactive workshops with multiple stakeholders, reflecting a collaborative strategy. Because there is so much pressure to take a decision fast, the knowledge is expected to be used instrumentally rather than conceptually. On the other hand, the stakes are high and there is disagreement about which strategies to take and about who is responsible for financing and implementation. Because expert knowledge is also developed in other studies (e.g. by the surrounding municipalities), a basis for strategic knowledge use may develop. The future will learn whether the stakeholders will continue to collaborate or will form strategic coalitions that select knowledge from the available sources to support their own position.

An important boundary object may be the iMOD model that will be developed to evaluate management strategies at the negotiation table. Other boundary objects are the result maps that are discussed during the workshops and the management summaries that describe the results of (elements of) the study. From each government organization, multiple levels – technical experts, policymakers, their directors and formal decision-makers – are involved, which require different types of information and act as intermediates for each other. For example, the policymakers in the Steering Group read entire technical reports and discuss it with the Project Group, whereas their directors and the decision-makers are informed trough management summaries.

5. Learning

In this section the concept of learning is elaborated, in order to develop better understanding of the process of knowledge utilization and factors that may promote or hinder it. Learning is the process in which individuals relate and adapt to the social and physical environment. It involves thinking, feeling, perceiving and behaving (Kolb 1984). Individuals can learn from observing the 'world out there' (e.g. the behavior of a river) or from interaction with others. The results of a learning process can be changed perspectives, new skills or new actions (Craps 2003). For a better understanding of knowledge utilization, we focus on the change of perspectives through interaction. There is evidence for the occurrence of learning through interaction in multiple case studies (Pelletier et al. 1999; Weale 2001; Beers 2005; Mostert et al. 2007).

When multiple individuals discuss a certain issue, they exchange their perspectives. This includes externalisation of the perspective of one individual (through speech), and internalisation of this knowledge by the other individual(s) (Nonaka et al. 1995). From a constructivist viewpoint, it is impossible to objectively and comprehensively represent a perspective in explicit form or to objectively and comprehensively internalise explicit knowledge into a perspective. Individuals use processing rules or 'frames' to express their perspective and to interpret explicit knowledge (See Fig. 4). Frames function as a selective and interpretative filter or lens (Gray 2003; Dewulf et al. 2004; Dewulf, Craps et al. 2005; Beratan 2007; Carton 2007). They are an abstraction of the perspectives of an individual on different topics and are strongly related to the general politicizing and ideological values of an individual. Internalisation frames may refer to first order aspects of an existing perspective in relation to the explicit knowledge that is to be internalised as well. Frames develop as a consequence of experiences (e.g. through education and work). Because of their abstract character they are expected to change slower than perspectives.

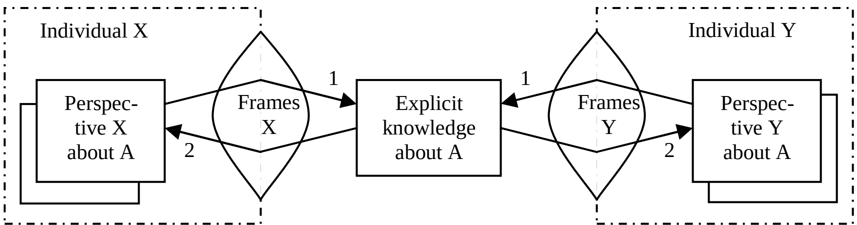

Fig. 4. Processes of externalization (1) and internalization (2) of knowledge on issue A between two communicating individuals (X and Y)

Frames determine how knowledge about a certain issue, with a certain representation, from a certain source, and in a certain context is presented and used. Because their frames and perspectives may form barriers to mutual understanding and learning, it is important that knowledge producers and knowledge users reflect on each others' frames and perspectives and base their (inter)action on it. We hypothesise that the probability of learning is large when:

- there is a difference between the explicit knowledge and the perspective of the receiver. Instrumental knowledge utilization is most probable when the explicit knowledge fills a gap, adds detail or concerns small alterations to the existing perspective of the user. When the provided knowledge differs a lot from the user's perspective, it is more likely to be used conceptually;
- the explicit knowledge does not conflict with the values and interests of the user (Fischer 1995; Sabatier 1998; Olsson and Andersson 2007). Because first order grounds can be expected to change more easily than second order grounds (cf. Sabatier 1998), knowledge with strong consequences for interest and values may evoke barriers to learning, and lead to strategic knowledge use;
- knowledge is presented clearly and is understood by the user. The most appropriate presentation of knowledge depends on the preferences and references (prior knowledge) of individual users (Lavis et al. 2003), which are reflected in their frames;
- users are willing to learn something new and perceive the knowledge as relevant, e.g. applicable to their daily practice;
- users trust the knowledge producer (Olsson and Andersson 2007) and the knowledge production process. Knowledge is tended to be perceived as trustworthy when it is produced using tried and tested methods, by experts and institutes with a good reputation and a lot of experience, and is accepted by other experts.

Learning in the case study

In the case study, frames were not directly elicited. However, differences in the second order argumentation (values) in the elicited perspectives indicate the existence of different frames. Furthermore, processes of framing and learning can be observed in the interaction during the workshops. The first two observed workshops have been dominated by the provision of expert knowledge by the Project Group. In evaluation forms, the participants indicated that the presented expert knowledge was understandable, and the quality of the information and the methods used to obtain it were very convincing. On average, the participants considered Powerpoint presentations and maps with model results to be useful tools to support the knowledge exchange. However, differences in the participants' appreciation of tools and activities indicate frame differences.

As a result of the workshops, the participants indicated to have learned about the functioning of the natural system, to have shared their perspectives on problems and solutions with other participants and to have learned about others' perspectives. The extent to which consensus was achieved – in particular about management strategies – was considered low. Some participants stated that there was not enough space to exchange perspectives, which can be backed up by the fact that many participants spoke very little during the workshops. By disseminating the results of the interviews and questionnaires to the stakeholders, it is aimed to make a step towards the mutual recognition of perspectives. After the interactive process, it will be measured whether the perspectives of the participants changed. An attempt will be made to explain why certain changes did or did not occur, based on the characteristics of the interaction process.

6. Collaborative water management

Collaborative or participatory water management (e.g. Gray 1989; Busenberg 1999; Innes and Booher 1999; Glicken 2000; Bouwen and Taillieu 2004; Monnikhof 2006) is useful in situations in which policymakers are confronted with 1) complex problems, which are characterized by little consensus about the goals that should be achieved and lacking technical knowledge, 2) the need to develop and implement solutions, and 3) the inability to implement solutions without cooperation of others or the aim not to force implementation upon them. In these situations, a certain degree of consensus, or overlap in perspectives, between the involved stakeholders is required. Collaborative policymaking aims to facilitate the development of such a shared knowledge base and to support informed, legitimate and supported decision-making (cf. Busenberg 1999; Raad voor het Milieu- en Natuuronderzoek 2000; Beers 2005; Monnikhof 2006). Sometimes consensus is intended to spontaneously result in correlated actions, and sometimes the aim is to produce agreements, such as policy recommendations (Gray 1989). Formal agreements that are not backed up by consensus between the relevant actors can experience difficulties in the implementation (cf. Pelletier et al. 1999).

To develop consensus, a broad range of stakeholders with different perspectives is involved. If there are multiple stakeholders (or groups) with large differences in perspectives (cf. Haas 1992; Sabatier 1998), there is a need for deliberation and convergence of perspectives (cf. Schön and Rein 1994). Expert knowledge can be used to fill in gaps in the individual or collective knowledge, and to identify and reduce relevant uncertainties. In technically complex issues, expert knowledge is essential for grounding policy claims in the first order argumentation. However, deliberations about perceived problems, goals, interests and general values are needed as well for consensus-building. Since the participants in a collaborative process interact in a transparent way, and reflect on the perspectives of the other participants, they are confronted with the same explicit knowledge. This promotes instrumental or conceptual knowledge use and leaves little room for strategic knowledge use. When the participants internalize the discussed knowledge in a similar way, their perspectives converge and a shared or negotiated knowledge base is developed (cf. Koppenjan and Klijn 2004; van Buuren and Edelenbos 2005). Thus, the relation between collaboration and learning is dual: collaboration increases the probability of learning and learning is required for achieving the goals of collaboration.

Although there are large differences between collaborative processes, a fundamental set of issues need to be considered, which can be allocated to the following phases (Gray 1989):

1. **Problem setting**. The problem setting phase is concerned with identification of stakeholders (e.g. governments, citizens, NGOs, researchers) and resources, finding overlap in perceptions of the major issues of concern, convening and committing the stakeholders to the collaboration;
2. **Direction setting.** During this phase ground rules are established, the agenda is set, the participants form subgroups and jointly search for (exchange and produce) information, explore management options, reach agreement on the preferred strategy and close the deal;
3. **Implementation.** In this phase the consensus has to spread to a wider audience. The participants have to gain the support of their constituencies and others involved in the implementation, develop organizational structures required for implementation, and continuously monitor whether there is still agreement among the involved parties.

Recognising that power relations can influence the collaboration, the ground rules should express which parties will have which tasks and rights (Ridder et al. 2005; Monnikhof 2006). Because fairness, reason and transparency are essential, every participant should have sufficient opportunities to express and protect their individual interests, to contribute to the development of the collective will and to use procedural tools and knowledge required to make good decisions (cf. Habermas 1984; Schön and Rein 1994; Renn et al. 1995). 'Weaker' parties could be offered resources to make sure they can fully participate (Hoppe et al. 2003). An atmosphere of mutual respect can ensure the quality of the dialogue (Olsson and Andersson 2007).

Collaborative water management in the case study

In the case study, many aspects of collaborative water management can be recognized. Multiple governmental and non-governmental organizations are involved in many interactions, such as regular meetings between the Project Group and the Steering Group and workshops with the Interest Group and Sounding Board as well. The aim is to create an understanding of the functioning of the physical system and others' perspectives, to identify an appropriate solution and to create commitment for it. The collaborative problem setting phase occurred between the announcement of the desire to end the extraction and the end of the Quickscan study. At the time of writing, the search for information and exploration of management options (in the direction setting phase) are central activities. Aspects that are less conform collaborative water management are the fact that not all stakeholders are actively involved and that the (transparency of the) exchange of perspectives is still limited.

7. Lessons for the role of expert knowledge in collaborative water management

Collaborative water management offers good opportunities for producing expert knowledge that is used instrumentally or conceptually by many stakeholders. However, it requires changes in the current state of mind: experts get a more supportive role, expert knowledge has to compete with other forms of knowledge, and policymakers have to be willing to learn and be transparent about which knowledge they will use and how they will use it (cf. Fearon 2003; van Buuren and Edelenbos 2005; Monnikhof 2006; Olsson and Andersson 2007).

In this section we synthesize the findings from literature into seven lessons for researchers and policymakers about the production and use of expert knowledge in collaborative water management. It should be acknowledged that all water management processes are different and so is the role of expert knowledge. The general guidelines need to be tailored to specific situations. In the case study, it is tried to bring the lessons into practice, by advising the Project Group on how to organize the workshops.

1. **Determine research needs together.** In order to produce appropriate knowledge, policymakers, researchers and other stakeholders should exchange their perspectives, identify relevant knowledge gaps and jointly formulate (and execute) the research that is needed (Busenberg 1999; Raad voor het Milieu- en Natuuronderzoek 2000; Hoppe et al. 2003; van Buuren and Edelenbos 2005; Olsson and Andersson 2007). Researchers should provide an overview of the existing expert knowledge and its limitations (Olsson and Andersson 2007), suggest alternative research and focus on pragmatic aspects (Monnikhof 2006);
2. **Focus on appropriate knowledge.** Expert knowledge can support water management by generating insight in problems, generating alternative strategies or distinguishing between alternatives using jointly developed criteria (Monnikhof 2006). The assumptions in the argumentation for each policy alternative should be made explicit, in order to allow for a careful tradeoff (Olsson and Andersson 2007). In order to generate comprehensive knowledge, expert knowledge should be combined with existing and new knowledge from various sources (Lavis et al. 2003; Olsson and Andersson 2007);
3. **Produce knowledge iteratively.** In an ongoing dialogue knowledge producers can present and get feedback on (intermediate) results and knowledge users can learn and indicate changes in their knowledge needs (cf. Lavis et al. 2003; Olsson and Andersson 2007). Research should be flexible to adapt to these changes (Monnikhof 2006). In addition, policy experiments may be executed, the effects may be monitored and considered in ongoing analysis and management (cf. adaptive management (Holling 1978));
4. **Present results in an attractive and clear way.** Because learning is a selective and subjective process, knowledge is more likely to be used when it is carefully tailor-made for the intended users (e.g. using visualizations such as maps) (Lavis et al. 2003). Appealing metaphors, management summaries and visualization in pictures, graphs, maps and tables are more likely to be used by a broad public than lengthy reports (Dahinden et al. 2000; Neilson 2001; Stone et al. 2001). Different users may prefer different levels of detail, but also when detailed quantifications are left out, the most important assumptions and uncertainties should still be made explicit (Alkan Olsson and Andersson 2007). Misinterpretations by knowledge users can be prevented by reflection on their interpretation;
5. **Reflect on knowledge critically.** By critical reflection on the methods, assumptions and uncertainties in the knowledge production, knowledge users can develop a sense of the reliability of the knowl-

edge and required improvements (Lavis et al. 2003). The use of knowledge can be improved when users consider in advance how they will act upon the knowledge, including uncertainties and qualitative information (Raad voor het Milieu- en Natuuronderzoek 2000; Hoppe et al. 2003; Monnikhof 2006).

6. **Use appropriate tools and methods.** Computer models can be used to develop expert knowledge. Because models are laden with assumptions, one should use multiple models that are grounded in multiple disciplines (Hoppe et al. 2003). In order to facilitate learning of different stakeholders, simple and transparent communication tools that integrate relevant knowledge from multiple sources can be used (cf. Ubbels and Verhallen 2000; Borowski and Hare 2006; Olsson and Andersson 2007). When the stakeholders have different areas of interest, tools should be applied at different spatial scales (Olsson and Andersson 2007);
7. **Use intermediates in case of large differences in perspective**. In order to facilitate direct discussion and prevent misinterpretation, knowledge exchange lines should be as short as possible. However, when knowledge users and producers do not understand or trust each other, intermediates can play an important role in the interpretation, integration and communication of expert knowledge. This may remove pressure from researchers, increase the credibility of the knowledge (Lavis et al. 2003) and speed up the process. In very complex cases, the validity of the contributed knowledge could be checked by an external 'watchdog' (e.g. an independent expert committee) (Hoppe et al. 2003).

8. Discussion

We used existing literature and case study material to develop better insight in the production and use of expert knowledge in different situations. These insights can be used by researchers and policymakers to better understand their own and others' roles in the production and use of expert knowledge. Many theoretical insights were reflected in a water management case study, and many still require (further) testing in empirical research.

In addition, we argued that collaborative water management is useful to solve complex water management problems. Other types of policy processes may be more effective and efficient in case of well-structured problems. Moreover, although the substantive, instrumental and normative benefits of collaborative water management are promising (Pelletier et al. 1999), there are still many barriers to its practical implementation (Mostert et al. 2007). If the institutional and cultural settings are not ready for it, collaborative management is difficult to execute. Problems may arise if not all stakeholders are willing or able to collaborate and to explicitly reflect on their own and others perspectives. Although this paper focuses on the role of researchers and policymakers, collaborative water management requires cooperation of citizens and NGOs as well (e.g. Fischer 1993; Weale 2001; Bäckstrand 2004; Douglas 2005; van de Kerkhof and Wieczorek 2005).

Subsequently, we derived lessons from literature for the role of expert knowledge in collaborative water management. These lessons can be used by policymakers and researchers to guide their interactions. Knowledge producers can use the paper to better understand the decision-making process and policymakers can use it to better understand the research process. Both groups can use it to influence interaction between them and at the same time test the lessons in practice and refine them.

We will apply and test some of the lessons from literature in two water management case studies, by evaluating whether perspectives change, and to what extent these changes can be attributed to expert knowledge. In addition, we support the organization of workshops, e.g. by identifying critical knowledge gaps and advising on knowledge exchange activities.

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